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CIRCUIT PROTECTION

Circuit Protection Databook

2004

PolySwitch Resettable Devices, Telecom Fuses, SiBar Thyristor Surge Protectors & ROV Metal Oxide Varistors

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- PolySwitch Resettable Devices
- Telecom Fuses
- SiBar Thyristor Surge Protectors
- ROV Metal Oxide Varistors

ISO9001
QS-9000
ISO14001

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How to Use This Databook

This databook contains application, product, and technical data on Tyco's portfolio of Raychem Circuit Protection devices. It is designed to help you select PolySwitch, SiBar, and ROV devices for overcurrent and overvoltage circuit protection needs.

There are five sections to this databook, each identified by a blue divider page so you can quickly locate the data you need. Each divider page contains information on how to use that particular section.

Databook Sections:

1. Overview—Brief descriptions of Raychem Circuit Protection, division of Tyco Electronics Corporation, PolySwitch resettable devices, SiBar thyristor surge protectors, and ROV devices.

2. Fundamentals—General explanations of PolySwitch Polymeric Positive Temperature Coefficient (PPTC) overcurrent protection, SiBar thyristor surge protection, and ROV technologies.

3. Applications—A summary of applications where PolySwitch resettable devices, SiBar thyristor surge protectors, and ROV devices are used, with detailed information on each application, either in the form of an application note or an application overview.

   Each application note or overview describes a particular circuit protection problem and Raychem Circuit Protection's recommended power management solution. These may include a circuit diagram, technology comparison, and device selection information.

4. Products—An overview of PolySwitch, SiBar, and ROV product families, and a comparison chart showing the features of each family.

   For each family of products, a step-by-step selection guide walks you through the process of selecting the right device for your application. Detailed product data helps you verify that the device will perform as required.

5. Glossary

Overview

1

This section provides an overview of Tyco Electronics, Raychem Circuit Protection, and Raychem Circuit Protection products (PolySwitch resettable devices, SiBar thyristor surge protectors, and ROV devices).

1

Tyco Electronics – The Industry Leader

1

There is no industry that evolves as rapidly as electronics.

Technologies, processes, products and companies all move from dynamic new development to industry standard to historical footnote in the blink of an eye.

The knowledge that constant evolution is not only inevitable, but also desirable, is a key aspect of the companies that continue to succeed in our industry. Recognizing this, we combined the historical leadership in the interconnect industry of AMP with forward-looking companies like ASG, Elcon, Elo TouchSystems, HTS, M/A-COM and Raychem to form Tyco Electronics, which has grown to become the largest passive components supplier in the world.

Tyco Electronics, one of the largest units of Tyco International, Ltd., was established in September 1999 with the acquisitions of Raychem and AMP. Tyco Electronics is now a global leader in cutting-edge wireless technologies, fiber optic active components, and complete power systems. We have facilities located in 54 countries serving customers in the aerospace, automotive, computer, communications, consumer electronics, industrial, and power industries. We provide advanced technology products from over forty well-known and respected product brands, including Agastat, Alcoswitch, AMP, AMP Netconnect, Buchanan, CoEv Magnetics, Critchley, Madison Cable, OEG, Potter & Brumfield, Raychem Circuit Protection, Schrack, and Simel.

A significant result of our continued growth, and a real benefit to our customers, is that Tyco Electronics' technology leadership position has become even stronger. Our expertise in materials science, product design, and process engineering allows us to develop, manufacture and sell high performance, first-to-market products which assist you in making your next generation of products successful.

Our global network of technical sales representatives provides expert application and engineering assistance, hands-on field training and superior customer service around the world. Coupled with consolidated resources such as Research, Development and Engineering, corporate infrastructure, and integrated manufacturing and delivery, Tyco Electronics is ready to bring you the advantages of shorter lead times, reduced time to market, greater economy of scale and a broader product line.

As a company that embraces the most valued brand names, we look forward to becoming your preferred supplier, as we help you shape the twenty-first century.

Overview of Raychem Circuit Protection

1

For over 20 years, Raychem Circuit Protection, a unit of Tyco Electronics, has pioneered the technology behind PolySwitch PPTC (Polymeric Positive Temperature Coefficient) devices. The use of a PPTC device as a variable resistor in circuit protection applications was first pioneered by Raychem several decades ago. They were first used to protect nickel-cadmium battery packs against excessive discharge and are still being used in that application today.

The first high-volume order for PolySwitch devices was placed shortly thereafter to protect lithium batteries in cameras. Since this first order, Raychem Circuit Protection has continued to expand its family of PolySwitch devices to include wider voltage, current, and temperature ranges in a variety of form factors.

The first miniSMD surface-mount devices were introduced in 1995. Continuing this innovation in size reduction, in May of 1999 the microSMD product line was launched. This further reduced the size of the surface-mount products by almost half to a 1210 mil footprint, and in 2000 Tyco Electronics introduced the smallest 1206 surface-mount packaging available in a resettable device. This nanoSMD device helps OEMs meet regulatory, reliability, and functionality requirements while using less board space than ever before.

Established as a leader in resettable circuit protection solutions, Tyco Electronics' Raychem Circuit Protection strengthened its product portfolio to include SiBar thyristor surge protector silicon-based devices and ROV metal oxide varistors, that provide transient overvoltage protection for sensitive telecommunications equipment. When used along with PolySwitch devices, SiBar and ROV devices provide a coordinated and resettable solution to assist OEMs in meeting stringent regulatory requirements and improving equipment reliability.

To date, billions of PolySwitch products are used to help protect a wide range of electronic products in the computer, battery and portable electronics, consumer, automotive, industrial, and telecommunication markets. In addition, Raychem Circuit Protection's leading-edge solutions continue to add value in transient overvoltage protection for telecommunications applications.

The Raychem Circuit Protection unit of Tyco Electronics is recognized as a leader for operational excellence and customer service. A dedicated direct engineering sales force, world-wide manufacturing and design centers, and local engineering support help us to think, manage, and share globally, yet act locally, to meet customer needs. We are in compliance with globally recognized ISO9000 standards and certified to QS9000 standards. This division is headquartered in Menlo Park, CA, with manufacturing facilities in California (USA), China, and Japan, with sales offices worldwide.

PolySwitch Resettable Devices

Raychem Circuit Protection PolySwitch devices are commonly called resettable devices to distinguish them from traditional one-shot fuses that work only once and then must be replaced—an expensive and inconvenient proposition. While the generic term for these devices is sometimes called "resettable fuses", technically these are not fuses but actually non-linear thermistors.

Designed for use in a wide range of electronic devices, these thermistor-type devices limit the flow of dangerously high current during fault conditions. But unlike traditional fuses that work one time and must be replaced, Tyco's PPTC devices reset after the fault is cleared and power to the circuit is removed, thereby reducing warranty, service, and repair costs.

PolySwitch resettable devices are able to withstand mechanical shock and vibration, and provide reliable protection in a wide variety of applications and are available in leaded, axial, chip, disc, and surface-mount configurations. Most have been awarded UL component recognition and meet the requirements of other agencies, including Telcordia, CSA, TÜV, and ITU-T.

Overview of Circuit Protection Products

1

Typical Applications

- Rechargeable battery packs used in cellular telephones, notebook computers, and other portable electronics applications, protecting equipment and users from the hazards of overcharging and short-circuit conditions.

- Computers, peripherals, and other compact electronics applications to protect against internal and external overcurrent conditions.

- Automotive and transformer applications, alarm systems, instrumentation and controls, audio speakers, satellite receivers, and other electronic equipment.

- Telecommunications applications, automated building sensors and controls, network and customer premise equipment can be protected from the hazards of overcurrent surges.

Telecom Surface-mount Fuses

Our telecom surface-mount fuses are slow blow non-resettable devices designed to protect sensitive electronic equipment from power contact and power induction hazards. These devices are designed to remain transparent to lightning surges.

When an overcurrent fault occurs, the surface-mount fuses will open the circuit and provide non-resettable over-current protection.

The fuses may be used in conjunction with SiBar devices to offer a comprehensive overcurrent and overvoltage protection solution for telecom equipment. Further information on implementing such circuit protection solution and description of this application can be found in Sections 329.

Typical Applications

- Designed to assist network equipment manufacturers in meeting the Telcordia GR-1089 and TIA-968-A (formerly FCC Part 68) requirements. Target applications include: analog and digital linecards, base stations and remote terminal.

- Also designed to assist CPE (Customer Premise Equipment) manufacturers meet the UL60950 and TIA-968-A (formerly FCC Part 68) requirements. Target applications include: modems, phone sets, PBX systems, point-of-sale equipment, set-top-boxes and others.

SiBar Thyristor Surge Protectors

SiBar thyristor surge protectors are bidirectional silicon devices designed to protect sensitive electronic equipment from overvoltage hazards caused by lightning, power contact, and power induction. These devices have high-surge capability to protect against transient fault and high off-state impedance to keep the devices transparent during normal system operation.

When breakover voltage of a SiBar device is exceeded, the device switches from high- to low-impedance to redirect harmful surges away from the load. The device remains latched in a low-impedance state until the current flowing through the device decreases below its rated hold current, at which point the device resets to its high-impedance state.

SiBar devices may be used in conjunction with PolySwitch devices in telecommunications applications, including customer premise equipment and network equipment. Proper selection of both devices can provide resettable overvoltage and overcurrent protection, helping designers to meet worldwide telecommunication standards while lowering equipment service and warranty costs.

Typical Applications

- Designed to assist customer premise equipment (CPE) manufacturers meet the stringent requirements of UL1950, TIA-968-A, (formerly FCC Part 68), and ITU Recommendation K.21. on equipment including modems, phone sets, PBX systems, and point-of-sale equipment.

- Also designed to assist network equipment manufacturers in meeting the Telcordia GR-1089, ITU Recommendation K.17, and ITU Recommendation K.20 requirements for secondary protection of network equipment, including analog and digital linecards, base stations, and remote terminal units.

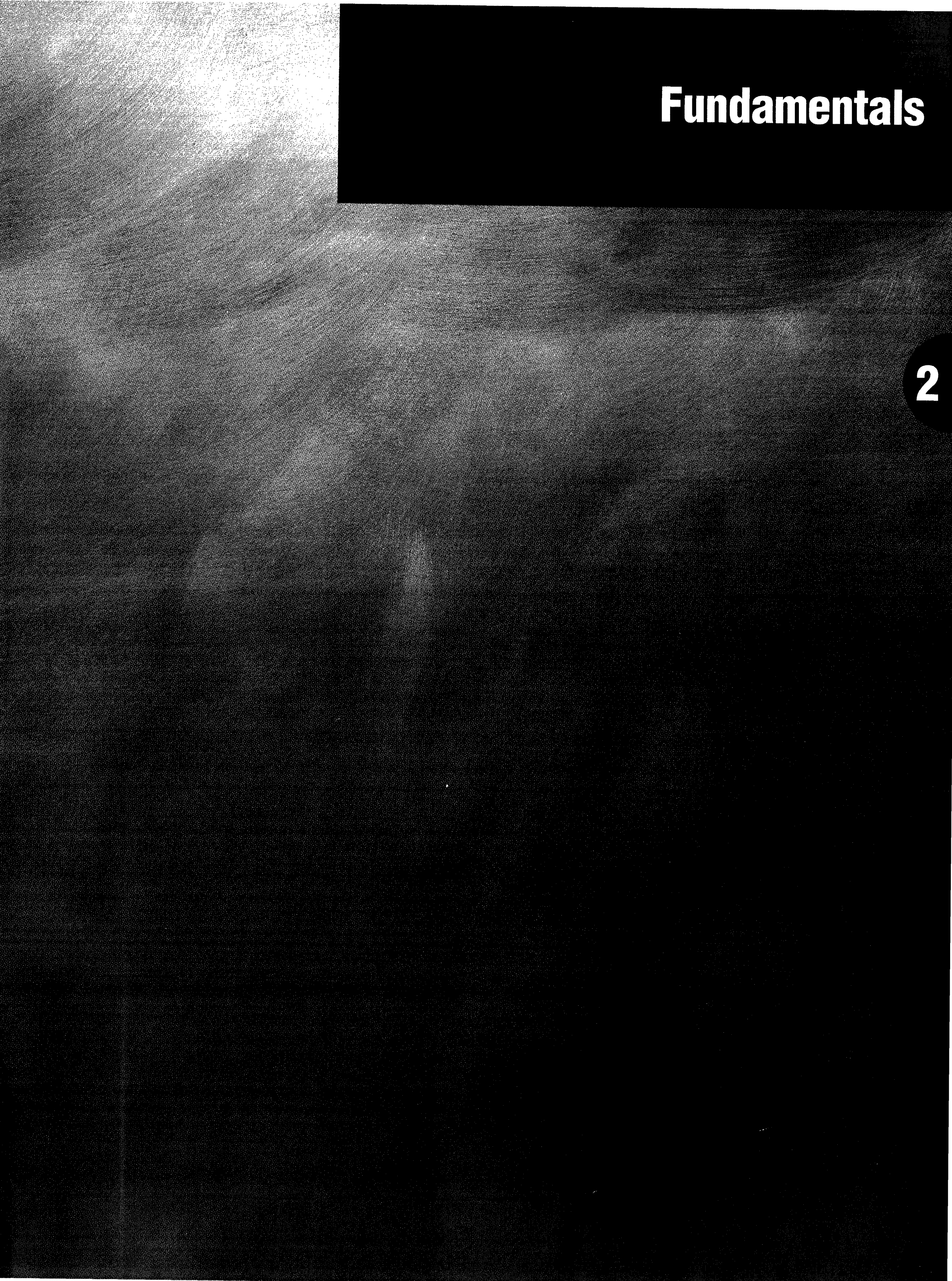
ROV

Raychem Circuit Protection's ROV (Radial-leaded Metal Oxide Varistor) products help to provide protection from overvoltage faults such as lightning, power contact and power induction, for a wide variety of power systems. Suitable for a broad range of applications including, but not limited to, security systems, power supplies, surge strips, motors and telecommunications equipment, the ROV devices help to protect valuable equipment from potential power surge damage by clamping high-energy, short-duration impulses. The ROV devices have high current handling and energy absorption capability and fast response times to help protect against transient faults.

The ROV overvoltage protection devices expand Raychem Circuit Protection's portfolio and can offer the circuit board designer a complete overcurrent/overvoltage solution. For example, pairing an ROV device with Raychem Circuit Protection's PolySwitch™ LVR overcurrent protection devices can help provide a completely resettable circuit protection solution for power supplies, surge strips and control board transformers. In addition, ROV devices can be combined with PolySwitch devices to help provide protection for electric motors, telecom equipment and various other systems.

Fundamentals

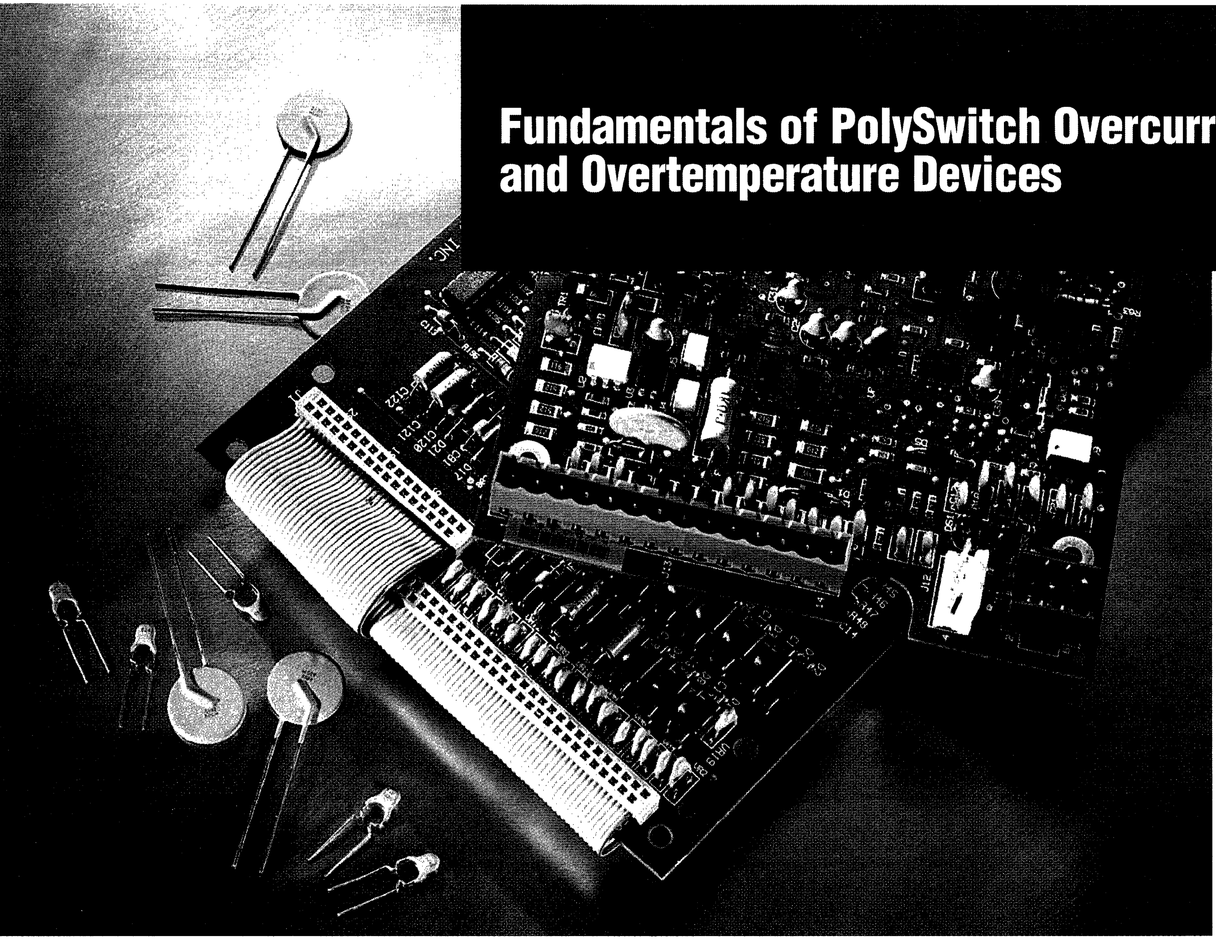
2



This section provides a general discussion of the use of polymeric PTC (positive temperature co-efficient), Surface-mount Telecom fuses, thyristor surge protection and ROV technologies.

2

Fundamentals of PolySwitch Overcurrent and Overtemperature Devices



2

Polymeric PTC Technology

The Problem of Overcurrents

An overcurrent is an abnormally high current that has the potential to cause failure in an electrical circuit. An out-of-range condition in the power source or a decrease in load impedance can cause an overcurrent.

Source-generated overcurrents usually arise from overvoltages caused by the abnormal operation of a power supply, or as a consequence of overvoltages on a power line. Source-generated overcurrents may also arise from voltage sags.

Power line overvoltages may arise from power crosses, surges, transients, or swells.[1]

A *power cross* occurs when a high-voltage circuit is inadvertently connected to a low-voltage circuit, for example, when a power line falls onto a telephone line during a storm.

Surges are short-duration increases in system voltage due to external events, such as lightning.

Transients are short-duration increases in system voltage due to the emptying of a circuit energy-storage element, such as an inductor or capacitor.

Swells are relatively long-duration increases in system voltage, generally caused by a failure in the system, for example, loss of the neutral connection at the transformer supplying a house.

Higher than normal voltages result in higher than normal currents in linear circuits. In nonlinear circuits, lower than normal voltages may lead to higher than normal currents, which is why voltage sags can cause an overcurrent problem. A common light bulb is an example of a nonlinear device that draws more current as the voltage is lowered.

[1]An excellent discussion of these effects can be found in IEEE C62 publications (C62: Complete [current year] Edition, IEEE, Piscataway, N.J.).

A partial or total failure of a circuit load can cause load-generated overcurrents. The failure lowers the total resistance in the circuit, allowing more current to flow. An example is a stalled motor, which gets hot because of excessive power draw, resulting in the insulation on the motor windings being destroyed, thus allowing adjacent windings to touch (short-circuit).

Overcurrent Protection using a Polymeric PTC Device

A polymeric positive temperature coefficient (PPTC) overcurrent protection device is a series element in a circuit. The PPTC device protects the circuit by going from a low-resistance to a high-resistance state in response to an overcurrent. This is called "tripping" the device. Figure 1 shows a typical application.

Figure 1. Typical PTC Application

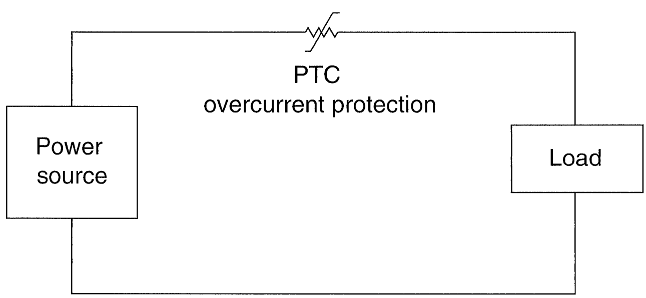
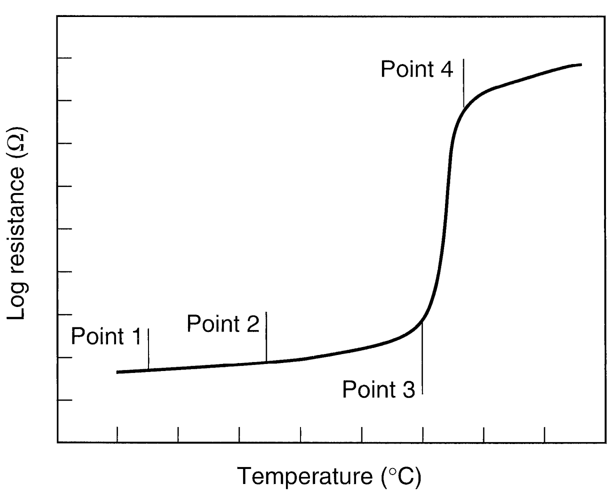


Figure 2. Example of Operating Curve for Polymeric PTC Device



Generally the device has a resistance that is much less than the remainder of the circuit and has little or no influence on the normal performance of the circuit. But in response to an overcurrent condition, the device increases in resistance (trips), reducing the current in the circuit to a value that can be safely carried by any of the circuit elements. This change is the result of a rapid increase in the temperature of the device, caused by the generation of heat within the device by I^2R heating.

The PTC effect

Describing a material as having a PTC effect simply means that the resistance of the material increases as temperature increases. All materials having metal-like conduction[2] have a positive temperature coefficient of resistance. In these materials the PTC effect is characterized by a gradual increase in resistance that is linearly proportional to temperature. This is the usual, or linear, PTC effect.

The nonlinear PTC effect

Materials undergoing a phase change may exhibit a resistance that increases very sharply over a narrow temperature range as shown in Figure 2. Certain types of conductive polymers exhibit this effect. These conductive polymers are useful for making overcurrent protection devices, generally called polymeric PTC overcurrent limiters, circuit protection devices, or resettable thermistor type devices.

[2] Materials that conduct like metals have the lowest resistivity of all non-superconducting materials. (The resistivity of metals generally falls in the range of 1–100 microhm-cm.)

2

Principles of operation

The operation of polymeric PTC devices is based on an overall energy balance described by the following equation:

$$mC_P(\Delta T/\Delta t) = I^2R - U(T - T_A) \quad \textbf{[1]}$$

- I = Current flowing through the device.
- R = Resistance of the device.
- Δt = Change in time.
- m = Mass of the device.
- C_P = Heat capacity of the device.
- ΔT = Change in device temperature.
- T = Temperature of the device.
- T_A = Ambient temperature.
- U = Overall heat-transfer coefficient.

In this equation, the current flowing through the device generates heat at a rate equal to I^2R. All or some of this heat is lost to the environment, at a rate described by the term $U(T - T_A)$. Any heat not lost to the environment goes to raising the temperature of the device at a rate described by the term: $mC_P(\Delta T/\Delta t)$.

In order to keep equation **[1]** as simple as possible, a uniform temperature within the device has been assumed.

If the heat generated by the device and the heat lost to its environment balance, $(\Delta T/\Delta t)$ goes to zero and equation **[1]** can be rewritten as:

$$I^2R = U(T - T_A) \quad \textbf{[2]}$$

Under normal operating conditions, the heat generated by the device and the heat lost by the device to the environment are in balance at a relatively low temperature, for example, Point 1 in Figure 2.

If the current through the device is increased while the ambient temperature is kept constant, the heat generated by the device increases and the temperature of the device also increases. However, if the increase in current is not too large, all the generated heat can be lost to the environment and the device will stabilize according to equation **[2]** at a higher temperature, such as Point 2 in Figure 2.

If instead of the current being increased the ambient temperature is raised, the device will stabilize according to equation **[2]** at a higher temperature, possibly again at Point 2 in Figure 2. Point 2 in Figure 2 could also be reached by a combination or a current increase *and* an ambient temperature increase.

Further increases in either current, ambient temperature, or both will cause the device to reach a temperature where the resistance rapidly increases, such as Point 3 in Figure 2.

Any further increase in current or ambient temperature will cause the device to generate heat at a rate greater than the rate at which heat can be lost to the environment, thus causing the device to heat up rapidly. At this stage, a very large increase in resistance occurs for a very small change in temperature (see "The Physics of Polymeric PTC," which follows). In Figure 2, this region of large change in resistance for a small change in temperature occurs between points 3 and 4, and is the normal operating region for a device in the tripped state. This large change in resistance causes a corresponding decrease in the current flowing in the circuit. The reduced current protects the circuit from damage. Since the temperature change between Points 3 and 4 is small, the term $(T-T_A)$ in equation **[2]** can be replaced by the constant $(T_O - T_A)$, where T_O is the operating temperature of the device. Then equation **[1]** can be rewritten as:

$$I^2R = V^2/R = U(T_O - T_A) \quad \textbf{[3]}$$

Since both U and $(T_O - T_A)$ are now constants, equation **[3]** reduces to I^2R = constant; that is, the device now operates in a constant power state. Expressing this constant power as V^2/R emphasizes that, in the tripped state, the device resistance is proportional to the square of the applied voltage. This relation holds until the device resistance reaches the upper knee of the curve (Point 4 in Figure 2).

For a device that has tripped, as long as the applied voltage is high enough for the resulting V^2/R power to supply the $U(T_O - T_A)$ loss, the device will remain in the tripped state (that is, the device will remain latched in its protective state). When the voltage is decreased to the point where the $U(T_O - T_A)$ loss can no longer be supplied, the device will reset.

The physics of polymeric PTC

A polymeric PTC material is a matrix of a crystalline organic polymer containing dispersed conductive particles, usually carbon black. The sharp increase in resistance, as shown in Figure 2, is due to a phase change in the material. In its cool state the material is mostly crystalline, with the conductive particles being forced into the amorphous regions between the crystallites.

If the percentage of conductive particles in the polymer is low, the resulting material will not conduct current. If the percentage of conductive particles is increased to (or beyond) a level called the percolation threshold, the conductive particles touch, or nearly touch, forming a three-dimensional conductive network.[3]

When the device is heated to the melting point of the polymer, the crystallites melt and become amorphous. This increases the volume of the amorphous phase, disrupting the network of conductive paths. As the network is disrupted, the resistance of the device increases. Since melting occurs over a relatively narrow temperature range, the change in resistance also occurs over a relatively narrow temperature range. When the temperature of the device has reached Point 4 in Figure 2, the connections in the conductive network are minimal and the conductive network is complete.

Design Considerations

Besides hold and trip current, the factors to consider when designing PolySwitch devices into a circuit include the effect of mechanical constraints and ambient conditions on performance, reflow and trip jump, device reset time, the resistance-temperature behavior prior to tripping, the application of devices in parallel combinations, and the effect of inductive spikes.

Device Selection: Hold and Trip Current

Figure 3 illustrates the hold- and trip-current behavior of PolySwitch devices as a function of temperature. One such curve can be defined for each available device.

Figure 3. Example of Hold and Trip Current as a Function of Temperature

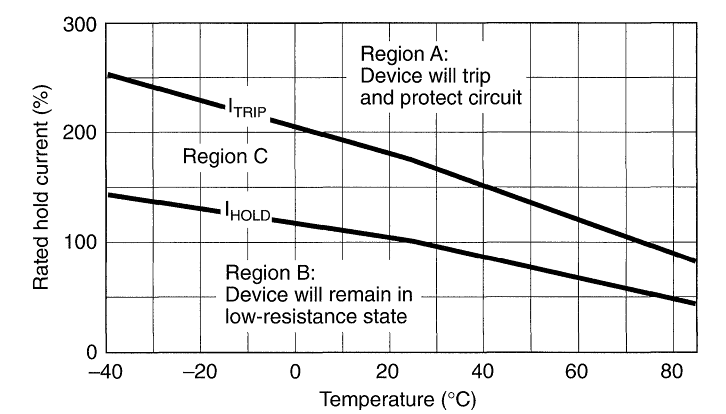


Table 1. I_{HOLD} vs. temperature (RXE devices)

Part Number	Maximum ambient operating temperatures (°C) 0°	20°	40°	50°	60°
RXE050	0.60	0.50	0.41	0.36	0.32
RXE065	0.77	0.65	0.53	0.47	0.41
RXE075	0.89	0.75	0.61	0.54	0.47

Region A describes the combinations of current and temperature at which the PolySwitch device will trip (go into the high-resistance state) and protect the circuit. Region B describes the combinations of current and temperature at which the PolySwitch device will allow for normal operation of the circuit. In Region C, it is possible for the device to either trip or remain in the low-resistance state (this will depend on the individual device resistance).

Since PolySwitch devices are thermally activated, any change in the temperature around the device will impact the performance of the device. As the temperature around the device increases, less energy is required to trip the device and thus the hold current decreases. This is why the I_{TRIP} curve and I_{HOLD} curve have negative slopes in Figure 3. Thermal derating curves and I_{HOLD} versus temperature tables are provided with each product family to help design the parts into applications over a wide range of temperatures. Table 1 is an excerpt of the derating table for RXE devices.

To use Table 1, the maximum operating temperature needed and hold current of the intended application must be known. If, for example, the application requires an operating current of 500mA at 60°C, an RXE090 or an RXE075 would be the proper choice (an RXE050 would only hold 320mA at 60°C).

Mechanical Constraints

Polymeric PTC devices operate by thermal expansion of the conductive polymer. If devices are

[3]A chain of particles that nearly touch conducts via the tunneling effect. For more details, see "Electron Transport Processes in Conductor-Filled Polymers," by R. D. Sherman, L. M. Middleman, and S. M. Jacobs, in *Polymer Engineering and Science*, Vol. 23, No. 1, 36–46, January 1983.

placed under pressure or installed in spaces that would prevent thermal expansion, they may not properly protect against fault conditions. Designs must be selected in such a manner that adequate space is maintained over the lie of the product.

Effect of Ambient Conditions on Performance Parameters

As noted under "principles of operation," the heat transfer environment of the device can greatly impact the performance of the device. In general, by increasing the heat transfer of the device the following will also increase:

- The device's power dissipation. (This reflects the change in the heat transfer coefficient.)
- The device's time-to-trip. The impact will be greater at long trip times where the effect of heat transfer is more significant.
- The device's hold current.

The opposite will occur if the heat transfer from the device is decreased. Furthermore, the time-to-trip can be modified by changing the thermal mass around the device. Again, changing the thermal mass around a device has a greater impact on slow trip events.

Power Dissipation

Power dissipation (P_D) is (to a first order) a good way to measure the change in the heat-transfer environment of a device. In other words, if a change is made that might impact the heat transfer, power dissipation measurements taken before and after the change will provide information on the significance of the change. Power dissipation is relatively easy to determine since it can be computed from a measured leakage current and a measured voltage drop across the device ($P_D = VI$). From equation **[3]**, $P_D = I^2R = U(T_O - T_A)$, we note that P_D is equal to an overall heat transfer coefficient, U, multiplied by a temperature differential (the difference between the PolySwitch device temperature and ambient temperature). In the tripped state, the temperature of most PolySwitch devices is approximately 125°C.[4] If we assume that U does not vary substantially with temperature, then by measuring the power dissipation in the tripped state, we can compute the overall heat transfer coefficient for any ambient temperature.

Time-to-trip

As noted in the Performance Testing section, the time-to-trip of a device is defined as the time it takes for the voltage drop across the device to rise to greater than 80 percent of the voltage of the power source, or when the resistance of the device increases substantially relative to the load resistance. Furthermore, a trip event is caused when the rate of heat lost to the environment is less than the rate of heat generated. If the heat generated is greater than the heat lost, the device will increase in temperature. The rate of temperature rise and the total energy required to make the device trip depend upon the fault current and the heat transfer environment.

For low-fault currents—for example two-to-three times the hold current—most devices will trip slowly since there is significant loss of heat to the environment. This is due to the fact that a substantial proportion of the I^2R energy generated in the device is not retained in the device and does not increase the device temperature. A trip event of this kind can be viewed as a nonadiabatic trip event. Under these conditions, the heat transfer to the environment will play a significant role in determining the time-to-trip of the device. The greater the heat transfer, the slower the time-to-trip.

At high-fault currents—for example 10 times the hold current—the time-to-trip of a device is much less because most of the I^2R energy generated in the device is retained in the device and thus increases the device temperature. A trip event of this kind can be regarded as an adiabatic trip event.[5] Under these conditions, the heat transfer to the environment is less important since the heat loss to the environment is less significant in determining the time-to-trip of the device.

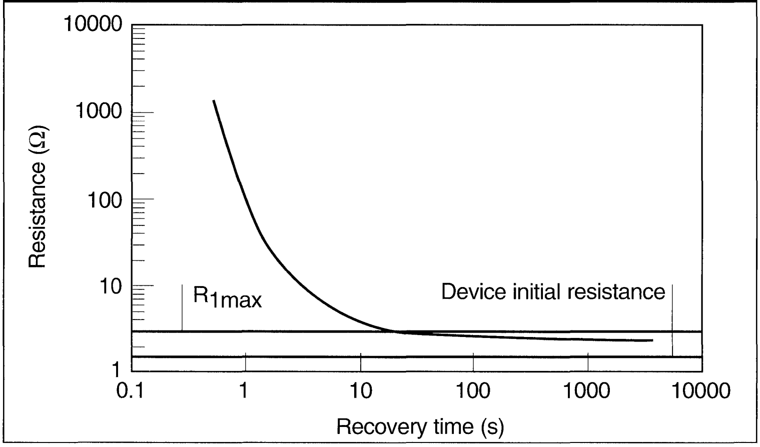
As tripping is a dynamic event, it is difficult to precisely anticipate the change in the time-to-trip since a change in the heat transfer coefficient is often accompanied by a change in the thermal mass around the device. If for example a large block of metal is placed in contact with the device, not only will the heat transfer increase, but the device will also need to heat some fraction of the metal (due to the intimate contact) before the device will trip. Therefore, not only is the thermal conductivity of the metal important, but the heat

2

[4] Most PolySwitch devices transition from a low to high impedance state at 125°C, although devices are available with both lower and higher transition temperatures.

[5] Typical time-to-trip curves for Raychem Circuit Protection devices can be found in Section 4. For most devices there is a break in the time-to-trip vs. resistance curve, which denotes the transition from an adiabatic to a non-adiabatic trip event.

Figure 4. Typical RXE025 Resistance Recovery after a Trip Event



capacity of the metal plays a role in determining the time-to-trip.

Hold current

The hold current (I_H) is the highest steady-state current that a device will hold for an indefinite period of time without transitioning from the low- to the high-resistance state. Unlike time-to-trip, the hold current of a device is a steady-state condition that can be fairly accurately defined by the heat transfer environment. Under a steady-state condition, equation **[3]** holds true and the heat-generated I^2R equals the heat lost to the environment. Therefore, if U increases, the hold current will increase, with the approximate relationship:

$$I_H \propto \sqrt{U} \quad \textbf{[4]}$$

The heat transfer for the devices can be impacted by a multitude of design choices. Some examples include the following:

- The ambient temperature around the device increases, resulting in a reduction in the heat transfer. This can be caused by an overall increase in the ambient temperature, or by placing the device in proximity to a heat-generating source such as a power FET, resistor, or transformer. As a consequence, the hold current, power dissipation and time-to-trip of the device are all reduced.
- The designer changes the size of the traces or the leads which are in electrical contact with the device. For example, a surface-mount device originally placed on a 0.030 inch-wide, 1 ounce copper trace is instead connected to a 0.060 inch, 1 ounce copper trace, resulting in an increase in the heat transfer. This results in larger hold current, slower time-to-trips and higher power dissipations.
- An RUE device is attached to a long pair of 24-gauge wires before being connected to the circuit board. This effectively increases the lead length of the device and results in a reduction of the heat transfer. As a consequence, the device's hold current, power dissipation, and time-to-trip are all reduced.
- The air flow around the device is increased. For example, a surface-mount device is mounted beneath a fan, which creates air flow around the device; the fan suddenly speeds up. This results in an increase in the heat transfer.

Reflow and Trip Jump (R_{1MAX})

PolySwitch devices exhibit some resistance hysteresis when tripped, either through an electrical trip event or through a thermal event such as reflow. This hysteresis is observed as a resistance increase over the as-delivered resistance of the PolySwitch device.

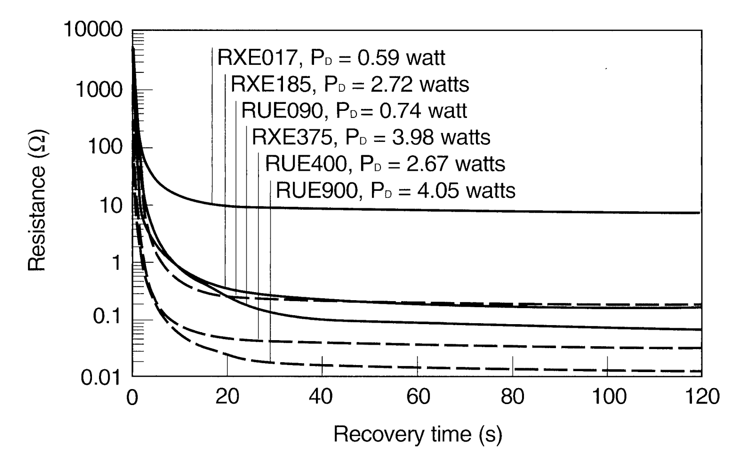
Figure 4 shows typical behavior for a PolySwitch device that is tripped and then allowed to cool. In this figure, we can clearly see that even after a number of hours the device resistance is still greater than the initial resistance. Over an extended period of time, the resistance will continue to fall and will eventually approach the initial resistance.

However, since this time can be days, months, or years, it is not practical to expect that the device resistance will reach the original value for operational purposes. Therefore, when PolySwitch devices are being developed, this “trip jump” or “reflow jump” is taken into consideration when determining the hold current. This increase in resistance is defined as R_{1MAX} and is measured one hour after the thermal event. It should be noted that these trip jumps are non-cumulative over sequential trip events.

Device Reset Time

Returning to Figure 4, we note that after a trip event, the resistance recovery to a quasi-stable value is very rapid, with most of the recovery occurring within the first one-to-two minutes. Figure 5 shows the resistance recovery curve for a number of other leaded PolySwitch devices. The power dissipation values were also measured to provide the

Figure 5. Typical Resistance Recovery after a Trip Event



user with a sense of the thermal environment the device was placed in for the measurement. As with other electrical properties, the resistance recovery time will depend upon both the design of the device and the thermal environment. Since resistance recovery is related to the cooling of the device, the greater the heat transfer, the more rapid the recovery (see Figure 6 for miniSMD075 devices on boards with traces of 0.010 inch and 0.060 inch).

Devices in Parallel

When two identical PolySwitch devices are placed in parallel, the hold current of the devices will increase and the combined resistance should be half the resistance of one of the devices. The magnitude of the hold current increase is dependent on the configuration of the devices and the consequent impact on the power dissipation. If the power dissipation doubles, the hold current will roughly double as well. If the power dissipation increases by less than a factor of two, then the hold current for the two devices will be less than twice that of a single component. Two examples illustrate this:

1. Two devices are placed in parallel and are soldered to individual traces that are thermally isolated from each other (this can be done by placing the traces far away from each other). By doing this, the power dissipation will be double that of a single part. The resistance will decrease by half and the hold current will double.
2. Two devices are placed in parallel and are soldered within close proximity, perhaps on a single trace. In this case, depending on the trace width, the power dissipation ranges from that of a single device to double that of a single device. If the power dissipation is the same as a single device, then the hold current will increase by roughly 40%. If the power dissipation is somewhere in between, then the hold current can be approximated using the following equation:

$$I_{Hp} = \sqrt{2}\; I_{Hs} \times \left(\frac{\sqrt{P_{DP}}}{\sqrt{P_{DS}}} \right) \qquad \textbf{[5]}$$

I_{HP} = Hold current for parallel devices.

I_{HS} = Hold current for a single device.

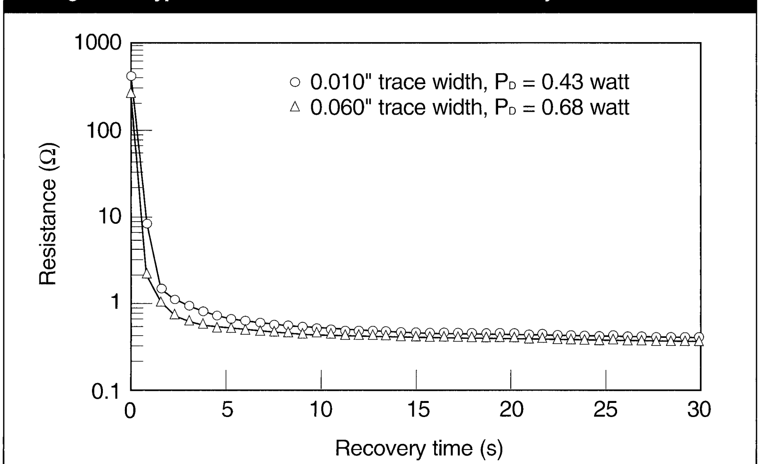
P_{DP} = Power dissipation for a parallel device.

P_{DS} = Power dissipation for a single device.

Resistance Prior to Tripping

While a significant increase in the resistance of the device occurs when the device trips, a much smaller change in the resistance is also noted at temperatures below the transition temperature.

Figure 6. Typical miniSMD075 Resistance Recovery vs. Trace Width



For example, in Figure 7, we see that for an RUE device, over a temperature range of 20°C to 75°C, the resistance increases by approximately 40 percent.[6]

Inductive Spikes

The normal time-to-trip for a PolySwitch device can range from milliseconds to many seconds. However, the actual transition from low-impedance state to high-impedance can be much faster, potentially less than one millisecond, depending on the trip current and the size of the device. This is important since the change in current over time (di/dt) can be quite large. This di/dt, in combination with a significant circuit inductance (L), can result in a large inductive voltage spike.

$$V = -L \frac{di}{dt} \qquad [6]$$

If this spike is large enough, it can potentially damage the PolySwitch device.

Design Calculations

This section includes calculations for voltage drop, resistance in a tripped state, leakage current in the tripped state, and automatic reset conditions.

Maximum Voltage Drop

Use the circuit's operating current and the PolySwitch device's R_{1MAX} resistance (from the product data for that device in Section 4 of this databook) to calculate the maximum voltage drop across the device, expressed as:

Maximum voltage drop = (Operating current) X (R_{1MAX} resistance).

R_{1MAX} resistance = Maximum resistance that can be expected in an application when the device is not in a tripped state and is measured at least one hour after reset or reflow of the device.

Resistance in the tripped state

The device's large change in resistance can be calculated by using the following equation:

$$R = V_{PS}^2/P_D \qquad [7]$$

R = Resistance in ohms of the PolySwitch device in the tripped state.

V_{PS} = Voltage across the PolySwitch device.

P_D = Power dissipated by the PolySwitch device from the product data for that device in Section 4 of this databook.

Leakage Current in the Tripped State

When the PolySwitch device is latched in its high-resistance state, the amount of current allowed to pass through the device is just a fraction of the fault current. The current can be calculated by using the following equation:

$$I = P_D/V_{PS} \qquad [8]$$

I = Self-heating current of a PolySwitch device in the tripped state.

P_D = Power dissipated by the PolySwitch device (from the product data in Section 4).

V_{PS} = Voltage across the PolySwitch device.

Automatic reset conditions

Under certain conditions a PolySwitch device will automatically reset and return to normal operation. Automatic resetting can be very useful for applications where the voltage can be varied during operation.

When the following condition is met, the device will automatically reset:

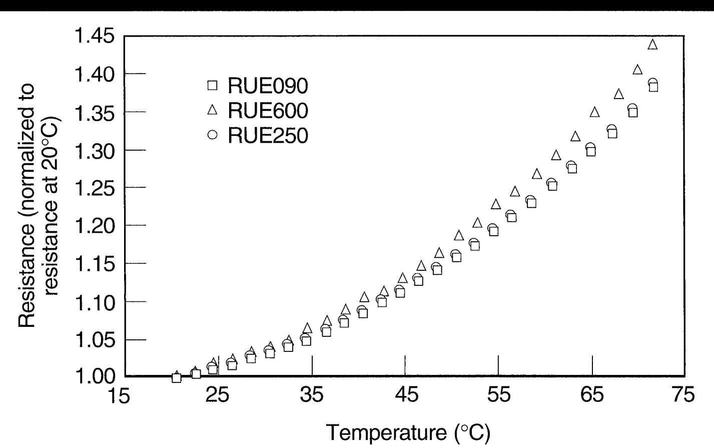
$$\frac{V^2}{4R_L} < P_D \qquad [9]$$

V = Operating voltage of the circuit.

R_L = Load resistance.

P_D = Power dissipated by the PolySwitch device.

Figure 7. Typical Resistance vs. Temperature Behavior for RUE Devices



[6]This increase is dependent upon the material used to construct the device and will vary from product family to product family.

Performance Testing

Performance Tests

The tests described in this section are commonly done to evaluate the performance of polymeric PTC devices. The descriptions are excerpted from a document that specifies how to test PolySwitch polymeric PTC devices.[7]

Resistance

The DC resistance of a PolySwitch device is a relatively sensitive measure of the condition of the device under test and is a key parameter for the use of a PTC device in an application. As such, it needs to be measured accurately.

Equipment

To obtain adequate accuracy for resistance less than 10 ohms, the 4-wire method must be used. The current for this measurement is subject to two conflicting requirements: it should be as large as possible to maximize the signal-to-noise ratio, but as small as possible to minimize device heating. Pulsing the current, using signal-processing techniques to reduce noise, or both, are effective techniques for improving the signal-to-noise ratio while minimizing device heating.

Procedure

The resistance of a PolySwitch device is sensitive to temperature, and to the time interval between stopping a given test or conditioning and measuring the resistance. To obtain accurate resistance readings, the device temperature must be accurately known. In addition, the time interval between the end of a conditioning program, process, or power removal in a test cycle and the measurement of the device resistance must be controlled. This period should be a minimum of one hour. Note that if the test calls for repeated resistance readings, they should all be made at the same time interval after stopping the test or conditioning.

Resistance vs. temperature

This test is used to generate a profile of the resistance of a device as it changes with ambient temperature. A typical result is shown in Figure 2, page 18.

Equipment

This measurement requires an environmental chamber capable of maintaining any temperature up to at least 20°C above the nominal melting temperature of the material used to make the device. The general considerations for measuring resistance discussed at the beginning of this section apply here also.

Procedure

The sample temperature is controlled with the environmental chamber. Temperature increments can be of any suitable size, but must be of sufficient duration to ensure that the device temperature has equilibrated to that of the chamber. Generally the resistance of the device will be measured using the 4-wire method. However, if the resistance of the device exceeds 10 ohms, a 2-wire resistance-measuring method may be substituted for the 4-wire method.

Operating Characteristics of Polymeric PTC

Figure 8, on page 24, shows a typical pair of operating curves for a polymeric PTC device in still air at 0°C and 75°C. The 0°C and the 75°C curves are different because the heat required to trip the device comes both from electrical I^2R heating and from the device environment. At 75°C the heat input from the environment is substantially greater than it is at 0°C, so the additional I^2R needed to trip the device is correspondingly less, resulting in a lower trip current at a given trip time (or a faster trip at given trip current).

Hold current

A hold current test is done by powering the test device at constant current. The maximum output voltage of the power supply should be set to the maximum rated voltage for the device. A device fails the hold current test if the voltage across the device rises to less than 20 percent of the voltage set on the power source.

Equipment

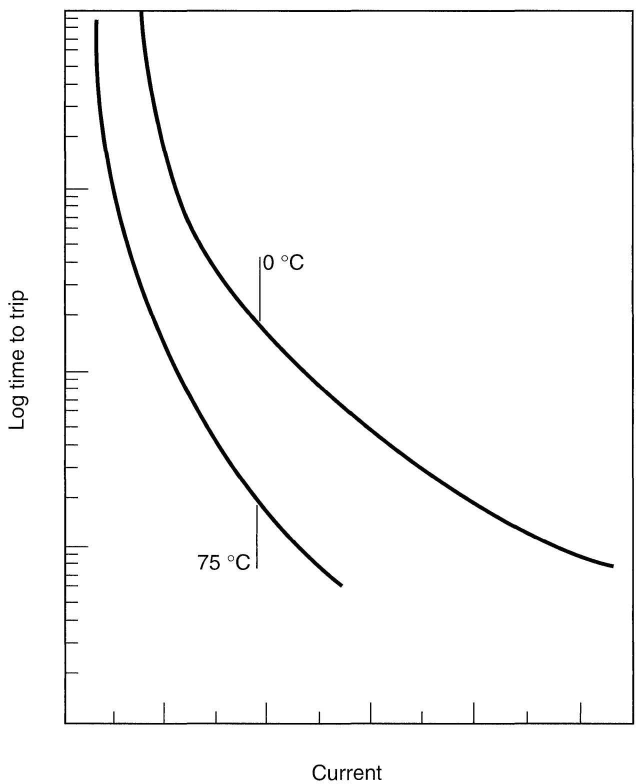
The test requires a power source that allows both a voltage and a current limit to be set. Generally this type of source is direct current (DC), but an alternating current (AC) source could be used. A system is needed for measuring either the voltage across the test specimen, or the current through it (or both), as a function of time. Suitable systems include (digital) oscilloscopes, A/D converters, and computer-controlled multimeters.

Procedure

The hold current of a PolySwitch device is very sensitive to device resistance, temperature, and heat transfer conditions.

7 "PS300 Specification: Test Methods and Requirements for PolySwitch Devices," latest revision (Tyco Electronics/Raychem Circuit Protection).

Figure 8. Example of Polymeric PTC Operating Characteristics



Resistance
The resistance of a PolySwitch device at room temperature is increased by its first trip. Therefore, a PolySwitch device should be tripped and cooled before measuring its hold current.

Temperature
Because the hold current can be changed substantially by flowing air, no air circulation around the test specimen is allowed during the test, including air flow due to body motion. The test specimens should be allowed to equilibrate to the test temperature for at least 5 minutes. During the test, the temperature rise of the surrounding air should be monitored.

Heat transfer
In addition to controlling air flow, it is generally necessary to control the heat flow out through the leads of the device. Because of this effect, the method of mounting the device needs to be described when reporting test results.

Time-to-trip
A time-to-trip test is conducted by powering the test device from a constant-voltage power supply with a series current-limiting resistor. The maximum output voltage of the power supply should be set to the maximum-rated voltage for the device. A device fails the time-to-trip test if the voltage across the device fails to rise to more than 80 percent of the voltage set on the power source in the time allotted for the device to trip.

Equipment
The test requires a power source with a regulated output voltage and a series resistor for adjusting the current to be applied to the test device. The source may be either DC or AC.

A system is needed for measuring either the voltage across the test specimen, or the current through it (or both), as a function of time. Suitable systems include (digital) oscilloscopes, A/D converters, and computer-controlled multimeters.

Procedure
The trip time of a PolySwitch device may be sensitive to temperature, heat-transfer conditions, and device resistance. If the standard trip current of five times the hold current is used to establish trip time, the device may trip fast enough that heat transfer and reasonable excursions around the specified test temperature will not affect results.

Resistance
Trip time is inversely proportional to resistance. To make sure that a device will trip in the required time under worst-case conditions, the device is tested at its lowest resistance. Generally a device that has been through the manufacturing process, but has not yet undergone testing or conditioning, is in its lowest resistance state.

Temperature
Because the trip time can be changed substantially by flowing air, no air circulation around the test specimen is allowed during the test, including air flow due to

body motion. The test specimens should be allowed to equilibrate at the test temperature for at least 5 minutes.

Heat transfer

In addition to controlling air flow, it is generally necessary to control the heat flow out through the leads of the device. Because of this effect, the method of mounting the device needs to be described when reporting test results.

Trip cycle life

A trip cycle life test consists of repeated tripping of a PolySwitch device by electrical surges.

Equipment

The test requires a power source (either AC or DC) capable of supplying the maximum rms (root mean square) interrupt current specified for the device, at the maximum rms operating voltage specified for the test. The source voltage is controlled by the power supply; the source current is controlled by a load resistor.

The test also requires equipment for turning the power on for a specified period of time, and then off for a specified period of time. A cycle timer would work, as would various computer-programmable devices, including the power source itself (if it is programmable).

Procedure

The cycle life of a device may be sensitive to temperature and heat-transfer conditions. Generally cycle life testing is done at extreme electrical conditions, which greatly diminish the influence of heat-transfer conditions and temperature.

Test cycle

A test cycle consists of applying to a device the voltage and current specified for the device for the specified ON time, and then removing power from the device for the specified OFF period. After the required number of cycles are complete, the device is evaluated according to the test criteria previously selected.

Temperature

The air temperature next to the device under test should be controlled to 20°±10°C, unless otherwise specified.

Trip endurance

Trip endurance consists of tripping a PolySwitch device and holding it in the tripped state for a specified amount of time.

A single source may be used both to trip the device and to hold it in the tripped state. Alternatively, one source may be used to trip the device, and a second source to hold the device in the tripped state. In either case, the source may be AC or DC.

Power dissipation

This test is used to determine the amount of power dissipated by a device after it has stabilized in the tripped state. Generally it is done during a trip endurance test, by measuring the voltage across the test device, and the current through it, and then multiplying the two to get power.

Because the power dissipation can be changed substantially by flowing air, no air circulation around the test specimen is allowed during the test, including air flow due to body motion. In addition to controlling air flow, it may be necessary to control the heat flow out through the leads of the device. If so, the method of mounting the device must be described when reporting the data.

Surge withstand

In many applications, polymeric PTC devices must withstand surges specified by agencies or telecommunications organizations. The appropriate agencies or organizations should be contacted for details on how the surge tests are to be conducted.

2

Reliability

Reliability is defined as the probability of a part performing its purpose for a given period of time under stated operating conditions. A part that doesn't meet this performance criterion is considered a failure. A failure-rate model that is frequently used is the "bathtub curve" shown in Figure 9. In this model, early-life failures are usually due to manufacturing defects; end-of-life failures are caused more by design limitations.

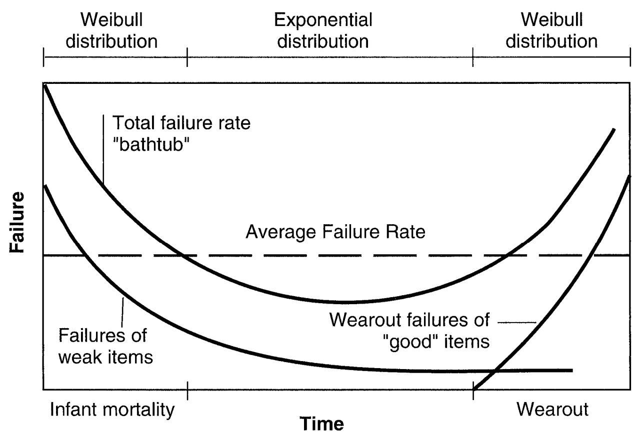
A constant failure rate, computed as an average failure rate over the life of the product, is often quoted for component relability. Standard references for failure rates of electronic components are *MIL-HDBK-217*[8] and the *AT&T Reliability Manual.*[9] Failure rates in these specifications are usually based on pooled field data. Some examples are shown in Table 2.

Polymeric PTC devices are not included in *MIL-HDBK-217* because these devices have not been widely used in military applications. Using generally accepted methods, the average

[8] *MIL-HDBK-217, Reliability Prediction of Electronic Equipment.*

[9] Klinger, D. J., Y. Nakada, and M. Menendez, eds., *AT&T Reliability Manual* (Van Nostrand Reinhold), 1990.

Figure 9. "Bathtub Curve" Failure-Rate Model



failure rate for PolySwitch devices, shown in Table 3, has been estimated as ≤ 10 FIT, using pooled field and test data for all PolySwitch devices.

Agency Approvals for PolySwitch Devices

PolySwitch devices, in many cases, have been tested and have gained the following safety agency approvals:

- UL Component Recognition in Category XGPU2, Thermistor–Type Devices.
- CSA Component Acceptance in Class 9073 32, Thermistors—PTC Type.
- TÜV Rheinland Certification, PTC Resistors.

Conditions of UL approval

UL's "Conditions of Acceptability" for PolySwitch devices include the following statements:

"These devices provide over-current protection and have been evaluated for use in safety applications where a device is needed to limit current that may result in a risk of fire, electric shock, or injury to persons . . . These devices have undergone 6000-cycle endurance testing (appropriate for manual reset devices, since de-energizing is required to reset the PTC). However, they are not designed for applications where they are routinely caused to trip."

Tests conducted for agency approvals

Typically, to qualify PolySwitch devices for safety agency approvals, a variety of tests are performed on samples to see what effect they have on properties, such as time-to-trip and resistance-versus-temperature characteristics. Examples of these are:

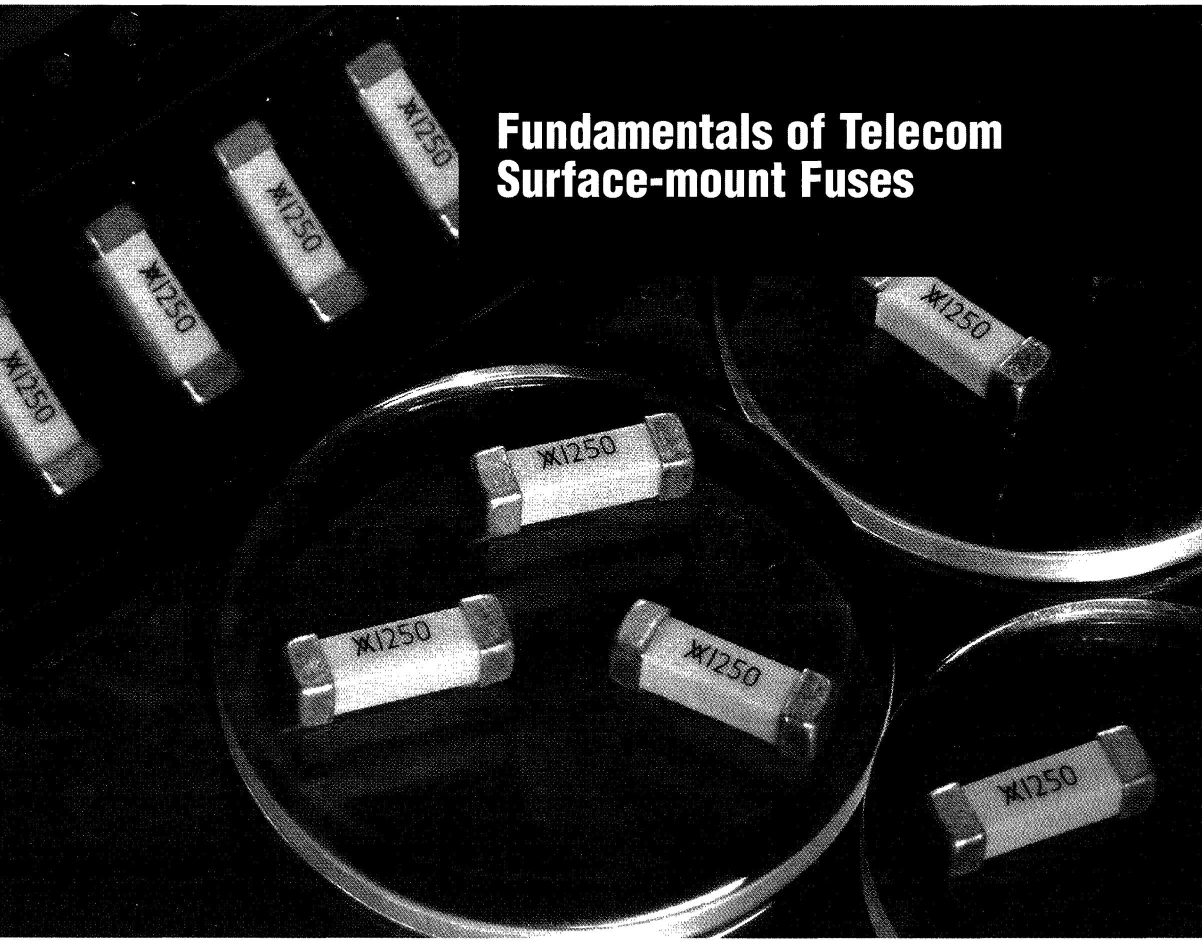
- Electrical cycles at 23°C, using maximum operating voltage and maximum interrupting current.
- Electrical cycles at 0°C, using maximum operating voltage and maximum interrupting current.
- Trip endurance at maximum operating voltage.
- Heat aging at 70°C and 135°C.
- Humidity conditioning at 40°C and 95% relative humidity.

Table 2. Baseline failure rates of typical electronic components

Component	Failures per billion device-hours (FIT)	Source
Disk thermistors	65	*MIL-HDBK-217F* and *AT&T Relia. Manual*
Thermal circuit breakers	38	*MIL-HDBK-217F* and *AT&T Relia. Manual*
Fuses	10	*MIL-HDBK-217F*
	25	*AT&T Relia. Manual*

Table 3. Baseline failure rate of PolySwitch polymeric PTC devices

Component	Failures per billion device-hours (FIT)	Source
PolySwitch polymeric PTC devices	≤ 10	Reliability reports are available with FIT calculations for the different product lines.



Fundamentals of Telecom Surface-mount Fuses

Fundamentals of Telecom Surface-mount Fuses

The Problem of Overcurrents

An overcurrent is an abnormally high current that has the potential to cause failure in an electrical circuit. Overcurrent events can be caused by various events such as fluctuations in the power source or a decrease in load impedance.

Power-line overvoltages may arise from power crosses, surges, transients or swells, and can result in overcurrent events.

A power-cross is an instance where a high-voltage circuit is inadvertently connected to a low-voltage circuit; for example, a power line can fall onto a telephone line during a storm initiating a power-cross event.

Surges are short-duration increases in system voltage due to external events, such as lightning.

Transients are short-duration increases in system voltage due to the emptying of a circuit energy-storage element, such as a capacitor.

Swells are relatively long-duration increases in system voltage, generally caused by a failure in the system, such as the loss of the neutral connection at the grid transformer.

Overcurrent Protection Using a Telecom Surface-mount Fuse

As opposed to resettable PTC devices, the telecom surface-mount fuses are devices that are no longer operational after activation. The fuses are placed in series in the circuit and protect it by going from a low resistance link to an open circuit in response to an overcurrent. When used in networking equipment operator intervention will be required after a fault occurs.

Device Construction

Raychem Circuit Protection telecom surface-mount fuse devices are built as described in Figure 1. A metallic filament is placed inside a ceramic body ended with two metallic caps. The filament and the end caps are soldered together.

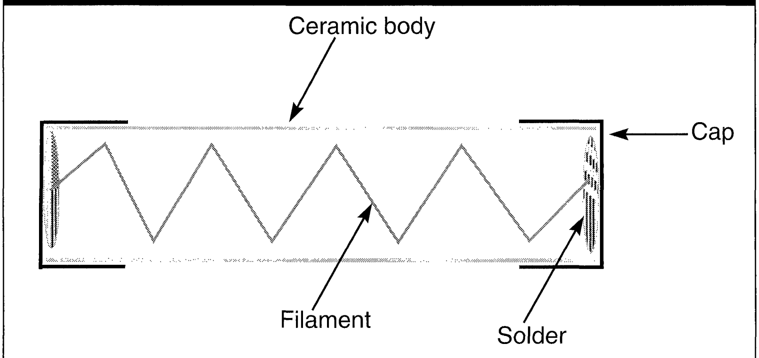
Device Design Parameters

Fuses, in general, are characterized by a nominal current below which they do not interrupt the circuit operation. In telecom applications, since the fuses are non-resettable devices, it is critical that they remain transparent during short pulses such as lightning surges. Fuse devices designed around these requirements are commonly referred to as "slow blow" fuses. Raychem Circuit Protection telecom surface-mount fuses are designed with high enough I^2t ratings to meet, or exceed, applicable lightning surge standards (GR-1089 and TIA-968-A) for telecommunications equipment in North America.

Agency Requirements

Raychem Circuit Protection telecom surface-mount fuses are designed to help telecom network and CPE equipment manufacturers meet stringent requirements of Telcordia GR-1089, UL60950 and TIA-968-A. These fuses are designed to remain transparent (not activated) to lightning surges as described in Telcordia GR-1089 and TIA-968, (formerly FCC Part 68). They are designed to open under AC power cross faults which reach high enough I^2t levels.

Figure 1. Telecom Surface-mount Fuse Construction



Fundamentals of SiBar Thyristor Overvoltage Devices

2

Thyristor Surge Protection Technology

The Problem of Overvoltages

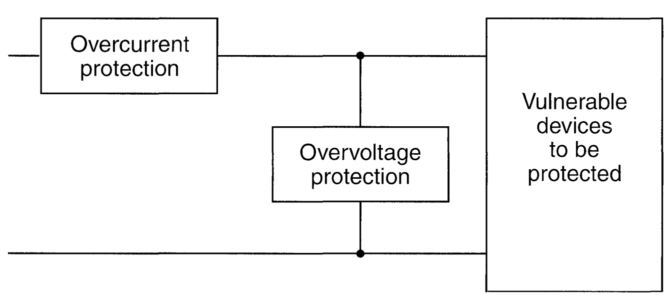
Electronic components have been designed to function properly when used within their specified current and voltage ratings. When these ratings are exceeded during operation, the component may sustain permanent damage and the equipment may cease to operate. In response to overcurrent conditions, polymeric PTC resettable devices installed in series with these components have proven to be a reliable method of interrupting the current flow by going from a low to a high impedance state. Conversely, solid-state thyristor overvoltage protection devices may be installed in parallel with these components to switch rapidly from a high to a low impedance state in response to an overvoltage surge.

In telecommunication applications, the major sources of overvoltage conditions are lightning, AC power lines, and ground shifts. Lightning surges may directly contact a telecom line or induce a rise in voltage potential when they strike adjacent equipment. Similar to lightning surges, AC power lines may cause a power contact or power induction condition. In addition, telecom equipment and its components may be prone to shifts in system ground potential, increasing the need for overvoltage protection.

Overvoltage Protection

Overvoltage devices are placed in parallel with a load to limit the amount of voltage that can appear across the input to a telecommunications circuit, as shown in Figure 1. The overvoltage device appears as a very-high-impedance (virtually an open

Figure 1. Typical Overcurrent and Overvoltage Protection Location



circuit) under normal operating conditions. When an overvoltage event occurs, however, the overvoltage device changes its impedance to divert current around the protected circuit to ground.

Overvoltage devices are designed to protect not only telecommunications circuits but also maintenance personnel and subscribers. In addition, they must:

- Not interfere with the normal operation of the telephone service.
- Provide maintenance-free operation.
- Reduce long-term cost of the installation by minimizing maintenance time and system downtime.
- Allow the designer to easily meet industry standards.

2

Overvoltage Protection Devices

There are two categories of overvoltage protection devices: clamping and foldback (or "crowbar") devices. Clamping devices, such as metal oxide varistors and diodes, allow voltages up to their designed clamping levels to pass through to the load during operation. Foldback devices, such as gas discharge tubes and thyristor surge suppressors, operate as shunt devices in response to surges which exceed their breakover voltage. Foldback devices have a current-voltage (IV) curve similar to that shown in Figure 6.

A foldback device is normally in a high-resistance state for voltages below the breakover voltage. In this state very little current flows through the device. When the voltage exceeds the breakover voltage, the device "folds back" or goes into a low-impedance state, allowing the device to conduct large currents away from sensitive telecom electronics. The device will continue to remain in this low-impedance state until the current through the device is de-creased below its holding current.

Foldback devices have an advantage over clamping devices because in the foldback state very little voltage appears across the load while the device conducts harmful surges away from the load, whereas clamping devices remain at the clamping voltage. The power dissipated in the foldback device is therefore much lower than in a clamping device, allowing a much smaller device to be used to conduct the same amount of surge current.

In addition to its smaller size and lower power dissipation, a foldback device offers lower capacitance and cost for a given silicon die size. Raychem's SiBar thyristor surge protector (TSP) devices are foldback devices.

Table 1. Agency standards for telecommunications equipment

Requirement	Application	Overvoltage Protector	Market Segment	Region
Telcordia GR-974	Line protectors for telco equipment	Primary	Primary	US
Telcordia GR-1089	Telco-owned network equipment	Secondary	Network	US
TIA-968-A, (formerly FCC Part 68)	Subscriber-owned equipment	Secondary	CPE	US
UL 497	Line primary protectors for subscriber-owned equipment	Primary	Primary	US
UL 497A	Line secondary protectors for subscriber-owned equipment	Secondary	CPE	US
UL 497B	Protectors for data comm and fire alarm circuits	Secondary	CPE	US
UL 1459	Subscriber-owned equipment connected to telco lines	Secondary	CPE	US
ITU K.11	Principles of protection	Primary/ Secondary	All	ROW
ITU K.20	Telecommunications switching equipment	Secondary	Network	ROW
ITU K.21	Subscriber terminal equipment	Secondary	CPE	ROW
ITU K.28	Semiconductor arrestor assemblies for telco installations	Primary	Primary	ROW

*CPE = Customer Premise Equipment
**ROW = Rest of World

Agency Requirements for Telecom Applications

A large number of agency requirements are imposed upon telecommunications circuits to simulate telecom hazards caused by lightning, power cross, and power induction. The most common specifications are Telcordia GR-1089, Telcordia GR-974, TIA-968-A, UL1459, UL497/497A/497B, UL60950, ITU K.11, ITU K.20/K.21, and ITU K.28.

Table 1 shows the standards in place for telecom applications. Developed for secondary overvoltage protection applications, SiBar devices were designed to assist telecom equipment in meeting the requirements of ITU Recommendations K.20 and K.21 and may be used in coordination with the PolySwitch TR600-150-RB device to meet UL1459 and TIA-968-A.

Lightning, power cross, and power induction tests specified by the agencies can be separated into two levels of sub-test for the three conditions. These sub-tests are often called "Type A" tests and "Type B" tests. "Type A" tests relate to more common fault conditions; the equipment under test must continue to operate after being subjected to this level of tests. "Type B" tests relate to rare fault conditions which are more severe; the equipment must not cause a fire when subjected to these tests, but the equipment does not have to be operable after these tests (although continued operation is desirable).

In response to a transient surge, a thyristor folds back to provide a low-impedance path to ground. The circuit must contain enough impedance to limit the fault current below the peak pulse current (I_{PP}) rating of the thyristor. The overcurrent protector typically does not operate during a lightning pulse.

Lightning waveforms are defined by their peak open circuit voltage, their short-circuit peak pulse current (I_{PP}), and the open and short-circuit waveform. The waveform is specified by the wave front, which is the rise time times a constant of 1.25 (τ_R x 1.25), and the decay time, which is the time from the beginning of the wave to 50% of I_{PEAK}, τ_D. For example a 10/1000 100A wave has a peak current of 100A, a 10 μs wave front (τ_R= 8μs), and a duration of τ_D=1000μs. Figure 2 shows a typical lightning overcurrent waveform.

To fully define the lightning waveform (simulated by a power source), the open-circuit voltage and shape, as well as the short-circuit current and shape, must be defined. The more area under the wave, the more energy transferred into the system and the greater the protection requirements. A comparison of various lightning surge requirements by specification appears in Table 2.

For power induction and power contact, if the fault voltage is below the device breakover voltage, the thyristor will remain in a high-impedance state. If the fault voltage exceeds the breakover voltage, the thyristor will conduct a large surge current through the overcurrent protection device and itself to shunt the harmful energy away from the load.

The overcurrent protector needs to be designed to prevent the resulting current from damaging the equipment or causing a fire. The survival of the equipment depends on system parameters, fault level, fault duration, and the coordination between the overcurrent and overvoltage device.

Device Construction and Operation

To understand how SiBar devices assist telecom equipment in meeting industry specifications, the four symmetrical layers of a thyristor chip may be drawn as shown in Figure 3.

Reviewing the left hand side of the symmetrical "chip," the layout can be simplified to depict two

Figure 2. Typical Overcurrent Lightning Waveform

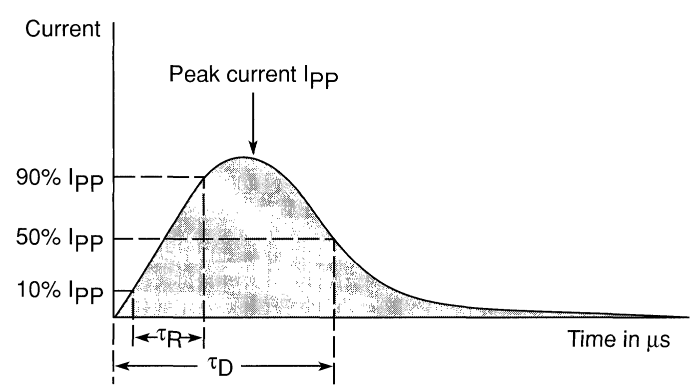


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Table 2. Comparison of various agency lightning surge requirements by specification

Agency standard		Open-circuit voltage waveshape (μs)	Peak voltage (kV)	Short-circuit current waveshape (μs)	Peak current (A)
Telcordia GR-1089	Surge 1	10/1000	0.6	10/1000	100
	Surge 2	10/360	1.0	10/360	100
	Surge 3	10/1000	1.0	10/1000	100
	Surge 4	2/10	2.5	2/10	500
	Surge 5	10/360	1.0	10/360	25
TIA-968-A – Type A		10/160	1.5	10/160	200
		10/560	0.8	10/560	100
TIA-968-A – Type B		9/720	1.0	5/320	25
		9/720	1.5	5/320	37.5
ITU K.17		10/700	1.5	5/310	38
ITU K.20		10/700	1.0	5/310	25/100*
VDE 0433		10/700	2.0	5/200	50
RLM 88, CNET		0.5/700	1.5	0.2/310	38

*For ITU K.20, secondary protector must be able to accommodate 25A lightning, primary protector must accommodate 100A.

transistors and a P-type resistor as shown in Figures 4 and 5.

During normal operation, voltage is applied across the two terminals. As voltage increases from anode to cathode, avalanche breakdown in the PNP transistor allows current I to begin to flow. The increasing avalanche current flows from the anode through the PNP transistor and then through the P-resistor to the cathode. Voltage across the P-resistor as a result of I biases "on" the NPN transistor. When the NPN transistor is biased "on", the PNP is rapidly switched "on" causing the device to "foldback". The device is latched "on" due to the collector current of the PNP driving the base of the NPN transistor and likewise the collector current of NPN driving the base of the PNP.

SiBar devices are N-type devices and have an IV characteristic as shown in Figure 6. Terminology for specific points of the IV curve are defined as follows:

I_{PP} (non-repetitive peak pulse current): Rated maximum value of peak pulse current of specified

Figure 3. Basic Diagram of Thyristor Chip

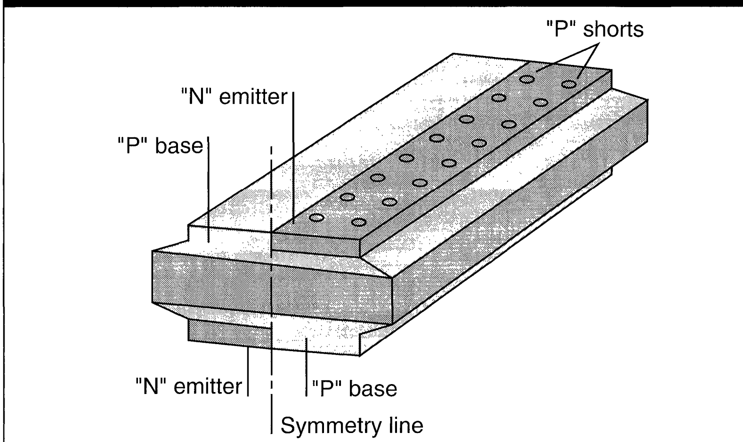
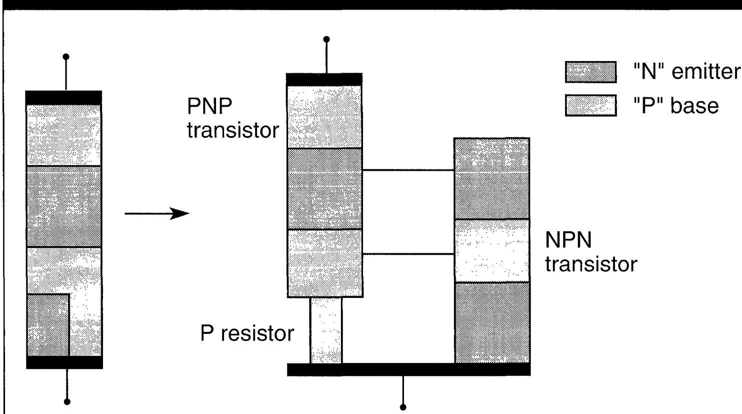


Figure 4. Cross Section of One Side of a Thyristor Chip



amplitude and waveshape that may be applied without damaging the device.

I_T (on-state current): The current through the device during the on-state condition.

V_T (on-state voltage): The voltage across the device in the on-state condition at a specified current, I_T.

I_H (hold current): The minimum current required to maintain the device in the on-state.

I_{BO} (breakover current): The instantaneous current flowing at the breakover voltage, V_{BO}.

V_{BO} (Breakover voltage): The maximum voltage across the device in the breakdown region, measured under specified voltage rate-of-rise and current rate-of-rise.

I_{SD} (off-state current): The DC value of the current that results from the application of the off-state voltage, V_D.

V_D (off-state voltage): The DC voltage when the device is in the off-state.

I_{BR} (breakdown current): The current through the device in the breakdown condition.

V_{BR} (breakdown voltage): The voltage across the device in the breakdown region prior to the switching point at a specified breakdown current, I_{BR}.

Figure 5. Equivalent Circuit of a Thyristor Chip

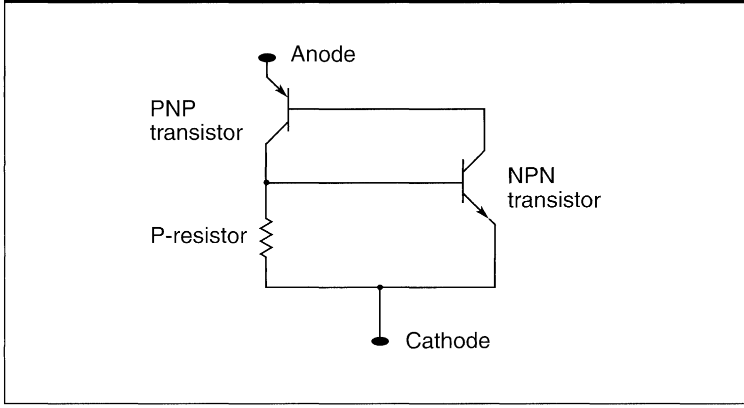
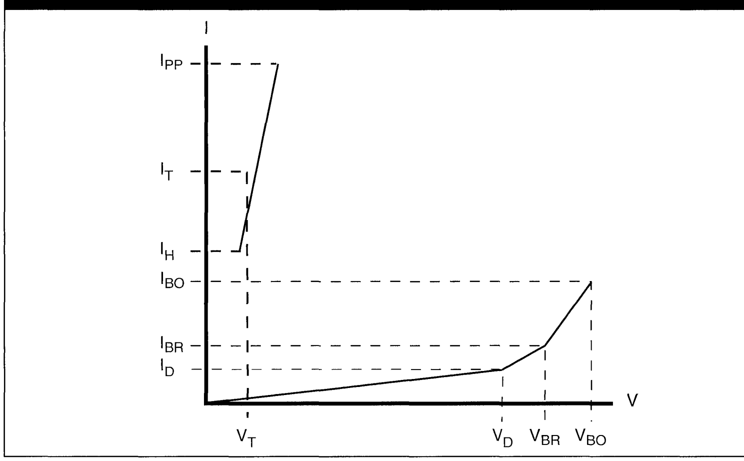


Figure 6. Characteristic Curve and Terminology for a SiBar Device



Device Design Parameters

Leakage current (I_D)

The leakage current, I_D, is the amount of current that flows through the device during the off-state condition. The leakage current should be as low as possible to minimize loss in the circuit. The leakage current is measured at 50V and at V_{DM}, which is approximately 90% of the breakdown voltage. The measurement is made at 50V because this is the typical voltage present on a standard telephone line. The upper voltage, V_{DM}, is defined at an acceptable current of 5µA.

Hold current (I_H)

The hold current, I_H, is the critical current flowing through the device below which the device resets from the "on" state to the "off" state. The designer must choose the device so that the supply current would drop below the hold current after a transient event, causing the device to reset.

Off-state voltage (V_D)

The off-state voltage is the rated voltage that keeps the device in an "open-circuit" condition. The designer must select a device that has a maximum off-state voltage rating (V_{DM}) greater than the peak ringing voltage plus the DC supply voltage to minimize nuisance operation.

Breakover voltage (V_{BO})
The breakover voltage, V_{BO}, is the voltage at which the device folds back. The breakover voltage is the maximum voltage that will appear across the device and the circuit it is protecting. For the designer, the maximum value of the breakover voltage is the critical value. The circuit needs to be designed to withstand voltages up to the maximum V_{BO} level without damage.

2

Breakdown voltage (V_{BR})
The breakdown voltage, V_{BR}, is the voltage at which the device goes into the avalanche region and begins to conduct. The device is beginning to clamp the voltage, but it has not yet reached the breakover voltage.

On-state voltage (V_T)
The on-state voltage, V_T, is the voltage across the device when it has folded back and is conducting. While not directly a critical parameter in selecting the device, V_T may be used to calculate the power dissipated in the device when it is in the on state. The higher the V_T for a given current, the higher the power dissipated by the device.

Peak pulse current (I_{PP})
The peak-pulse-current rating I_{PP} is dependent upon the transient current waveshape. The circuit must be designed to ensure the surge current expected during operation is within the device ratings.

Maximum current rate-of-rise (di/dt)
The di/dt rating is the maximum rate of current rise the device can withstand without being damaged. The damage of a device under di/dt occurs when the concentration of surge current is applied on a localized area of the thyristor chip.

Maximum voltage rate-of-rise (dv/dt)
The dv/dt rating of the device is the maximum rate of voltage rise the device can withstand without turning on. For voltage rates-of-rise greater than this value, the device could potentially fold back without exceeding the breakover voltage.

Capacitance (C_O)
When inserted into a circuit, the device capacitance loads the protected circuit. For high-speed digital lines the device capacitance needs to be as low as possible to reduce signal loss. Capacitance for SiBar devices is typically between 20pF to 50pF depending on voltage and measurement frequency.

Peak on-state surge current (I_{TSM})
The devices are typically used in coordination with overcurrent protection devices like the PolySwitch TR series to protect against AC power cross and power induction. To design the appropriate protection circuit, the designer needs to know the performance of the overvoltage device when it is subjected to a power cross or power induction surge. Testing and modeling of the SiBar devices have been performed to determine the maximum allowable current for various time durations. The results are given as an I_{TSM} vs. Time curve, shown in Figure 7.

Device Reliability Testing
The following reliability tests are conducted on SiBar devices to ensure long term performance:

Autoclave (PTH)
This test measures device resistance to moisture penetration and the resultant effects of galvanic corrosion.

High-Temperature Storage Life (HTSL)
This test accelerates failure mechanisms that are thermally activated through the application of extreme temperatures.

Temperature Cycling (TC)
This test evaluates the device's ability to withstand both exposure to and transitions between extreme temperatures and exposes excessive thermal mismatch between materials.

High-Humidity, High-Temperature Reverse Bias (H3TRB)
This test measures moisture resistance of plastic encapsulated devices under bias.

High-Temperature Reverse Bias (HTRB)
This test aligns mobile ions by temperature and voltage stress to form high-current leakage paths between junctions.

Agency Approvals
Raychem's new line of SiBar devices have been tested and have gained UL Recognition per UL497B.

Design Considerations
When selecting devices for a particular application be sure to ask the following questions:

1. What is the breakover voltage required?
When selecting a component, decide at what point the device should change from high- to low-impedance to protect the load.

In other words, what minimum voltage does the designer want to protect against? The maximum V_{BO} must be less than this value.

2. What is the required "off-state" voltage?
The maximum rated operating voltage of the device (V_{DM}) must be greater than the system continuous operating voltage, defined as the sum of the peak ringer (AC) voltage plus the DC battery voltage.

3. What peak-pulse-current is required?
The peak-pulse-current rating of the device (I_{PP}) must be greater than the maximum surge current specified for the system. If not, additional resistance may be required to reduce the pulse current to within the device pulse rating.

4. What hold current is required?
The hold current defines when the overvoltage device should "reset" (switch from low-impedance to high-impedance to return the system back to normal). The device I_H must be greater than the source current of the system or else it will continue to stay in the low-impedance state.

Figure 7. Peak On-State Surge Current vs. Time for a SiBar Device

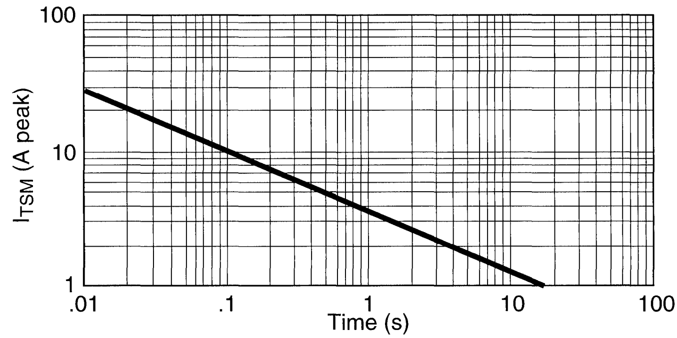
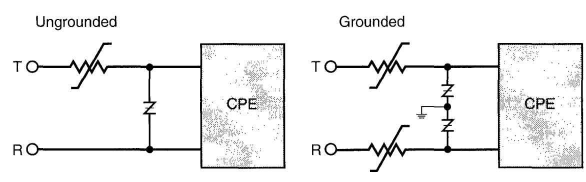
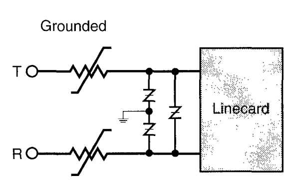


Figure 8. Customer Premise Equipment with SiBar and PolySwitch Devices

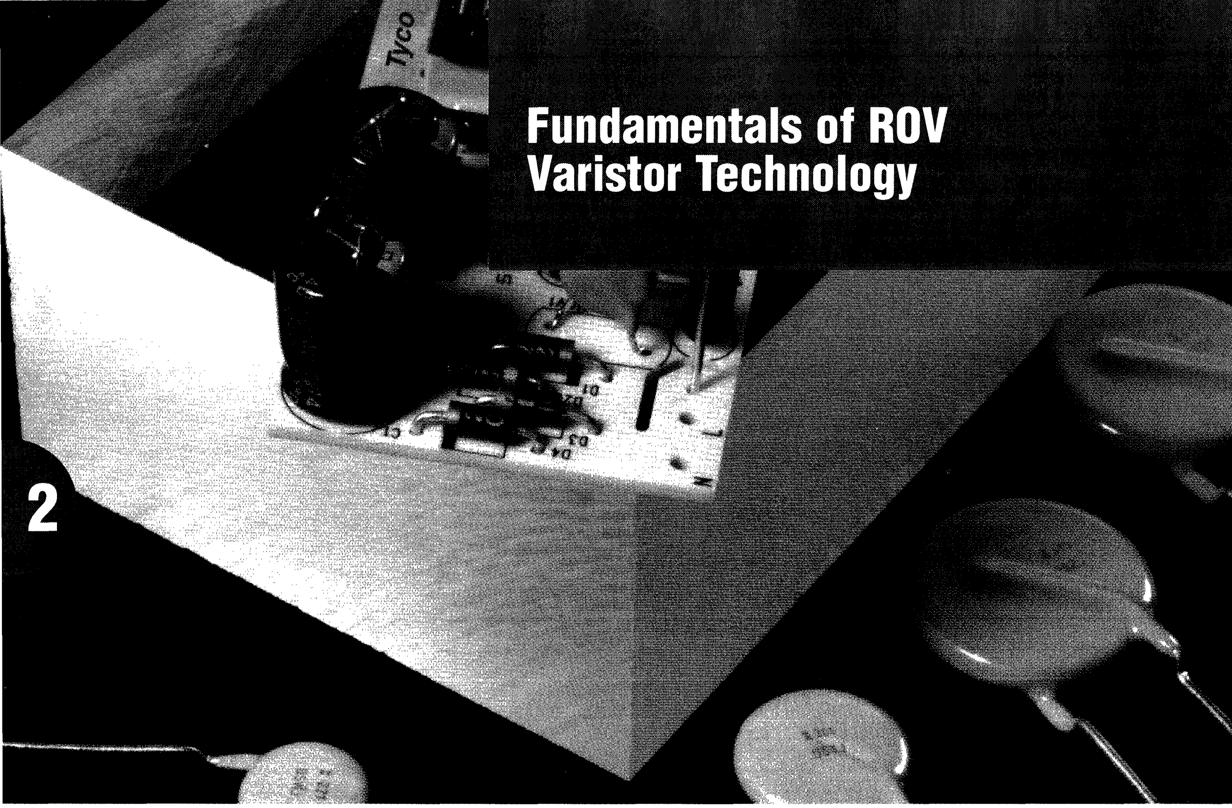


Symbol Key:
SiBar thyristor surge protector—transient voltage protector
PolySwitch resettable device—overcurrent protection device

Figure 9. Network Equipment protected with SiBar and PolySwitch Devices*



*Tip-to-Ring SiBar thyristor is optional: refer to SiBar application notes (www.circuitprotection.com)



Fundamentals of ROV Varistor Technology

2

ROV Varistor Technology

Fundamentals of ROV Varistor Technology

A varistor is a variable resistor—a voltage dependent, non-linear device whose resistance decreases as the voltage applied across the device increases. The voltage-current relationship (commonly represented in a V-I characteristic curve) of a varistor device is defined and depicted by the equation below and the graph in Figure 1.

$I = KV^{\alpha}$

Where:

K : Is a constant dependent on the geometry and materials of the varistor device

$\alpha = \frac{\log I_1/I_2}{\log V_1/V_2}$: Represents the degree of non-linearity of the device's conduction; (I_1,I_2) and (V_1,V_2) are the current and voltage values used in the measurement of α.

The symmetrical and steep breakdown characteristics depicted in the V-I characteristic curve enable varistors to provide fast transient voltage suppression. The alpha, "α", of the device represents the degree of non-linearity, or steepness of the V-I characteristic curve. In general, high alpha values are desirable since they provide a more stable clamping voltage (i.e., the voltage across the device remains relatively constant for a large increase in current).

An ROV device is a varistor fabricated using a Zinc Oxide (ZnO) powder, sintered with other metal oxide ceramics. The resulting structure is a polycrystalline ceramic that consists of distributed

Figure 1. Typical V-I Characteristic Curve of a Varistor

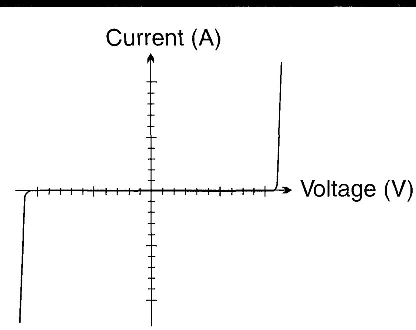
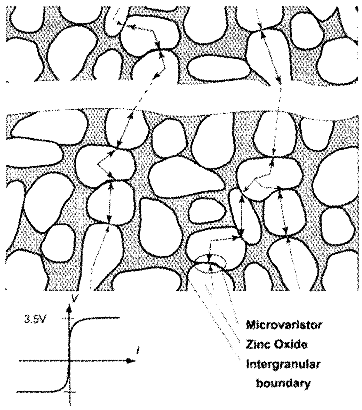


Figure 2. Polycrystalline Structure of a Metal Oxide Varistor



ZnO grains, separated by other metal oxide ceramics. This polycrystalline structure is depicted in Figure 2.

The boundary of two adjacent ZnO grains creates a p-n junction-like semiconductor characteristic which blocks current conduction at low voltage levels and provides non-linear current conduction at higher voltage levels.

The number of adjacent ZnO grain boundaries (connected in series or in parallel) in a device determines the electrical properties of the device such as varistor voltage, current handling capability and energy absorption capability:

Varistor voltage: A greater number of adjacent boundaries in series (i.e., the thickness of the device) leads to a higher varistor voltage value

Current handling: A greater number of adjacent boundaries in parallel (i.e., the area of the device) leads to a higher current handling capability

Energy absorption: A greater number of adjacent boundaries in series and parallel (i.e., the volume of the device) leads to higher energy absorption capability

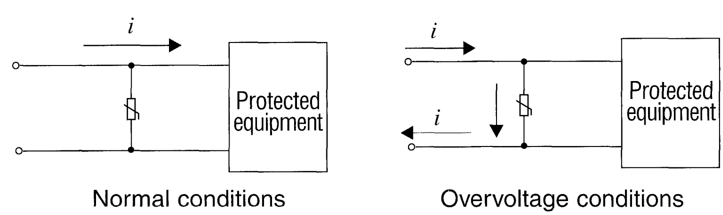
Since ROVs are composed of many ZnO grains spread throughout the device, they are able to effectively and uniformly absorb energy and dissipate heat throughout the device.

Fundamentals of ROV Overvoltage Protection Theory

Electronic equipment and components have been designed to function properly when used within their specified current and voltage ratings. When these ratings are exceeded during operation, the equipment or components may sustain permanent damage and they may cease to operate. Common sources of overvoltage conditions are lightning, AC power contact and power induction. Other electrical components may be susceptible to shifts in system ground potential, increasing the need for overvoltage protection.

ROV devices may be installed in parallel with the equipment or components to be protected. In the event of an overvoltage condition, ROV devices switch rapidly from a high to a low impedance state, thus clamping the transient voltage across the components to a safe operating level. Under normal operating conditions, the overvoltage device appears as a high impedance device (virtually open circuit, with minimal leakage current) and should not affect normal system operation. (Refer to Figure 3.)

Figure 3. Varistor Operation Conditions



Examples of Applications

Power Supply Protection

Table 1. Varistor Selection Examples for Power Supplies

Power Supply Voltage	Suggested ROV Device
100–120 V_{AC}	ROV*DDS*201K (ROV*DDS*221K, ROV*DDS*241K, ROV*DDS*271K)[1]
240 V_{AC}	ROV*DDS*K391K (ROV*DDS*431K, ROV*DDS*471K)[1]
12 V_{DC}	ROV*DDS*220L
24 V_{DC}	ROV*DDS*390K
48 V_{DC}	ROV*DDS*680K

DD: Diameter of the varistor device

S: Series (-: Standard series; H: High surge series; E: Extra high surge series)

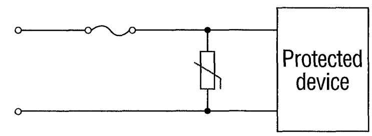
K: ±10% tolerance in varistor voltage

L: ±20% tolerance in varistor voltage

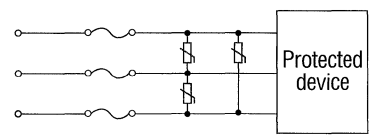
[1]: These varistor voltage ROV devices may be used if there is high variance in the input voltage

* In some applications, a polymeric PTC device such as a Raychem Circuit Protection's PolySwitch device may be used instead of a fuse to provide a preferred solution.

Figure 4. Power Supply Protection



AC single phase or DC circuit*



AC three-phase circuit with line-line protection*

Line Voltage Protection

Table 2. Varistor Selection Examples for Line-Ground Circuits

Line Voltage	Possible ROV Device
110 V_{AC}	ROV*DDS*201K and higher[1]
220 V_{AC}	ROV*DDS*361K and higher[1]

DD: Diameter of the varistor device

S: Series (-: Standard series; H: High surge series; E: Extra high surge series)

K: ±10% tolerance in varistor voltage

L: ±20% tolerance in varistor voltage

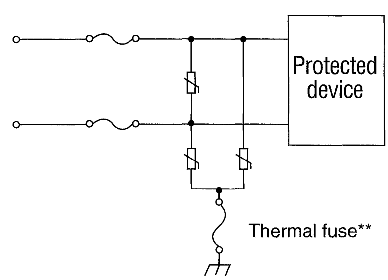
[1]: A higher varistor voltage ROV device could be used if there is the possibility of floating voltage in the circuit

* In some applications, a polymeric PTC device such as a Tyco Electronics PolySwitch device may be used instead of a fuse to provide a preferred solution.

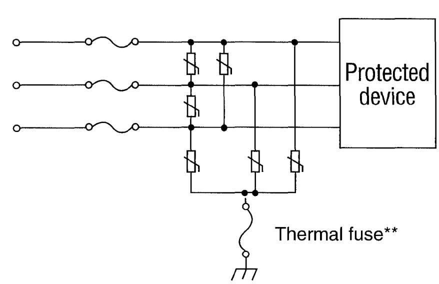
** Fuse current selection if thermal fuse is used in series with varistor to protect from follow-on surge current if varistor is damaged.

Varistor diameter	5mm	7mm	10mm	14mm	20mm
Nominal fuse current	≦1A	≦3A	≦5A	≦10A	≦15A

Figure 5. Line Voltage Protection



AC single phase circuit with line-line and line-ground protection*



AC three-phase circuit with line-line and line-ground protection*

Figure 6. Appliance Protection

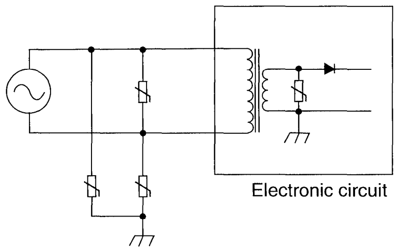


Figure 7. Security System Protection

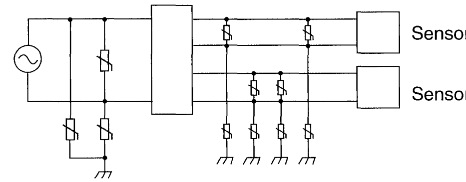


Figure 8. Motor Protection

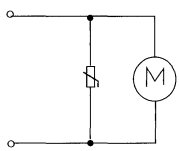
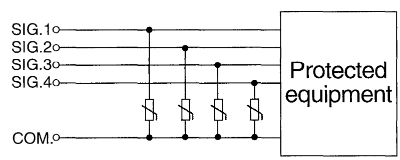


Figure 9. Data Line Protection



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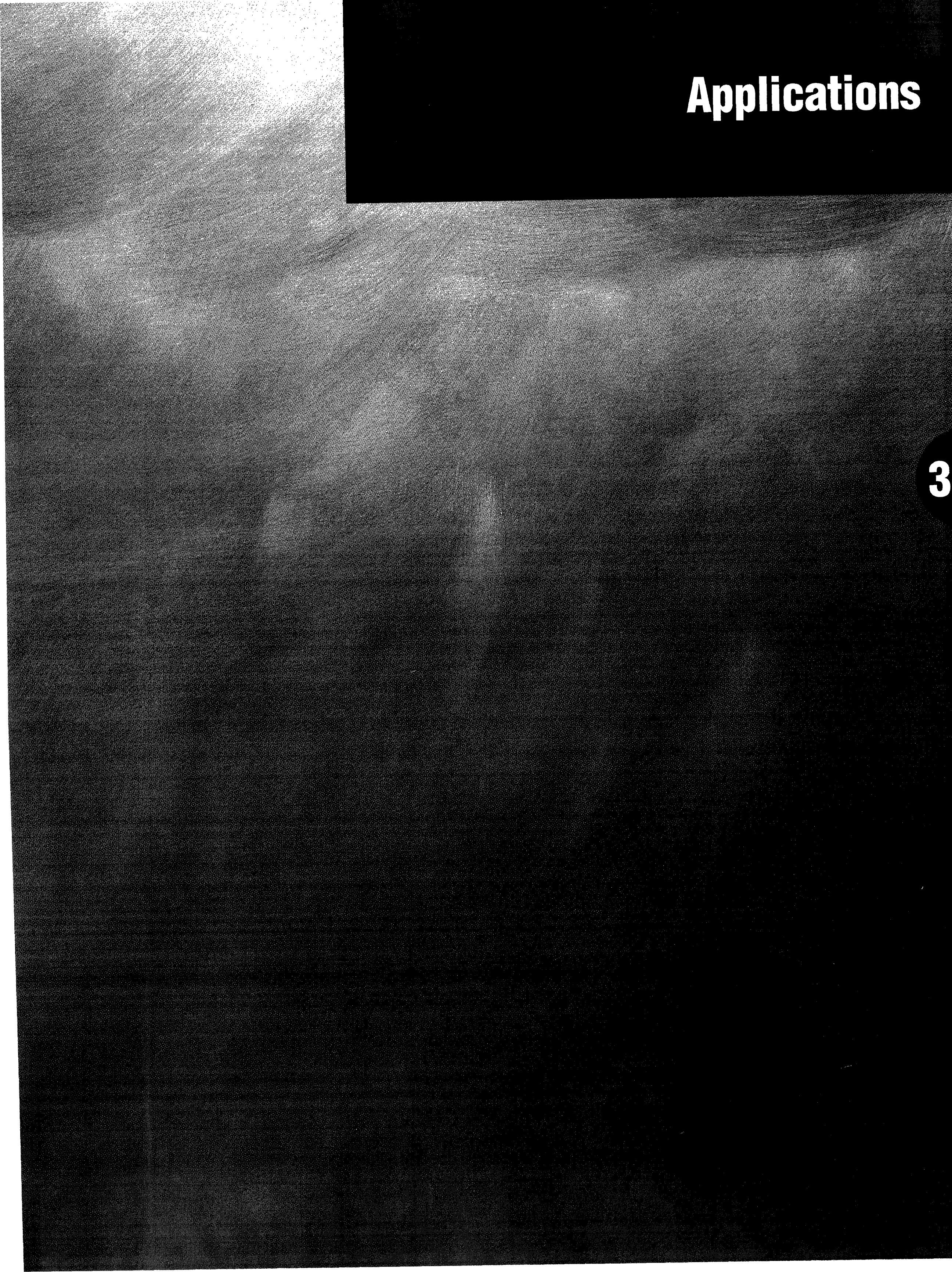


Applications

3

This section provides a summary of applications where PolySwitch resettable devices, SiBar thyristor surge protectors, and ROV devices are used, followed by detailed information on each application, either in the form of an application note or an application overview.

Special devices are manufactured to handle performance requirements that may be outside of the performance specifications of the standard products listed in this Databook. Please contact a customer service representative to discuss your special product needs.

3

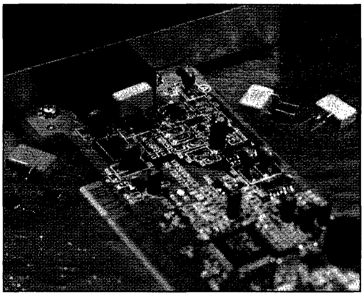
⚠ WARNING:

- Operation beyond the maximum ratings or improper use may result in device damage and possible electrical arcing and flame.
- The devices are intended for protection against occasional overcurrent or overtemperature fault conditions and should not be used when repeated fault conditions or prolonged trip events are anticipated.
- Contamination of the PPTC material with certain silicon based oils or some aggressive solvents can adversely impact the performance of the devices.
- Device performance can be impacted negatively if devices are handled in a manner inconsistent with recommended electronic, thermal, and mechanical procedures for electronic components.
- Operation in circuit with a large inductance can generate a circuit voltage ($L\ {}^{di}/_{dt}$) above the rated voltage of the PolySwitch resettable device.

Users should independently evaluate the suitability of and test each product selected for their own application.

Applications Summaries

Telecommunications and Networking



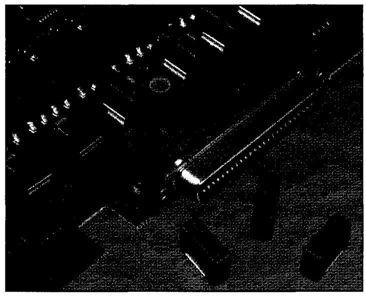
UL60950 and TIA-968-A, (formerly FCC part 68) Requirements

UL 60950 and TIA-968-A describes electrical hazards from which Customer Premise Equipment in North America must be protected. Provides resettable circuit protection recommendations.

Application Note/Overview
Found on page 63.

Product Information
TR600, TS600, and TSM600, see Telecom and Networking Section, page 301.

TVB, see SiBar Thyristor section, page 339.



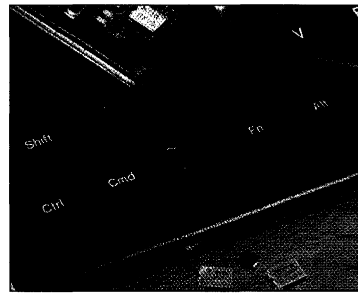
GR-1089: North America Network Equipment

GR-1089 describes electrical hazards against which Public Switched Telephone Network equipment in North America should be protected. Provides resettable circuit protection solutions.

Application Note/Overview
Found on page 71.

Product Information
TR600, TS600, and TSM600, see Telecom and Networking section, page 301.

TVB, see SiBar Thyristor section, page 339.



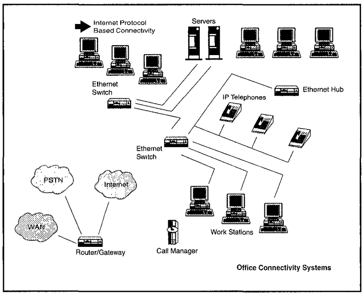
ITU-T Recommendations

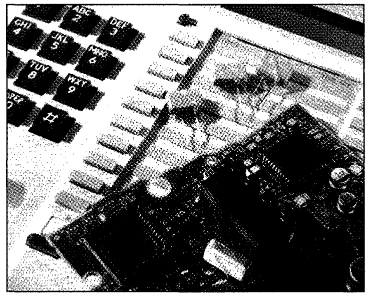
ITU-T provides resistibility recommendations for central office (K.20), customer premise (K.21) and access network (K.45) equipment. Provides an overview of recommendations and resettable circuit protection solutions.

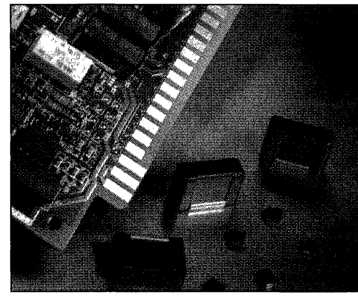
Application Note/Overview
Found on page 76.

Product Information
TC250, TR250, TS250, and TSV250, see Telecom and Networking section, page 301.

TVB, see SiBar Thyristor section, page 339.







Short-haul/Intrabuilding Protection Requirements

Communications equipment that is not directly connected to the Public Switched Telephone Network is subjected to lower level hazards. Circuit protection recommendations for LAN, WLL, VoIP and other intrabuilding applications.

Application Note/Overview

Found on page 86.

Product Information

TR250, TS250, TSL250, and TSV250, see Telecom and Networking section, page 301.

TVB, see SiBar Thyristor section, page 339.

Customer Premise Equipment

To protect subscribers against faults entering from outside wiring, CPE equipment is designed with power cross and lightning protection components. Recommended protection solutions based on regional requirements.

Application Note/Overview

Found on page 91.

Product Information

RXE, see Radial-leaded section, page 217.

SMD, see Surface-mount section, page 187.

TR250, TR600, TS250, TS600, TSV250, and TSM600, see Telecom and Networking section, page 301.

TVB, see SiBar Thyristor section, page 339.

ROV, see ROV section, page 351.

Analog Linecards

Central office line cards are subject to transient overcurrent and overvoltage faults, which may be generated from nearby power cross, power induction, and lightning events. Circuit protection recommendations based on regional agency specifications are provided.

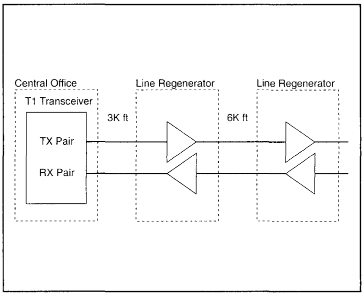
Application Note/Overview

Found on page 93.

Product Information

TR250, TR600, TS250, TS600, TSV250, and TSM600, see Telecom and Networking section, page 301.

TVB, see SiBar Thyristor section, page 339.



T1/E1 Equipment

T1/E1 transmission equipment must be protected against transient power cross and lightning faults which may enter on outside plant wiring. Circuit protection recommendations based on regional agency specifications are provided.

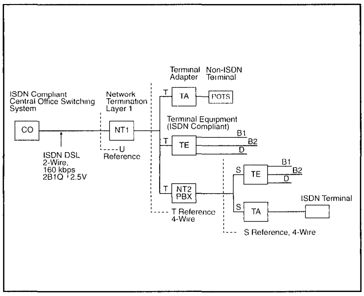
Application Note/Overview

Found on page 95.

Product Information

TR250, TR600, TS250, TS600, TSV250, and TSM600, see Telecom and Networking section, page 301.

TVB, see SiBar Thyristor section, page 339.



ISDN Equipment

ISDN CO and CPE equipment must be protected against transient power cross and lightning faults which may enter via outside plant wiring. Circuit protection recommendations based on regional agency specifications are provided.

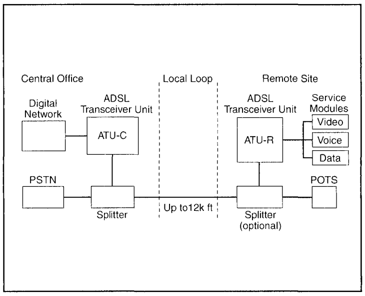
Application Note/Overview

Found on page 97.

Product Information

TR250, TR600, TS250, TS600, TSV250, and TSM600, see Telecom and Networking section, page 301.

TVB, see SiBar Thyristor section, page 339.



ADSL Equipment

ADSL modems and splitters must be protected against both external and intrabuilding faults. Resettable protection solutions are provided based on regional requirements.

Application Note/Overview

Found on page 99.

Product Information

TR250, TR600, TS250, TS600, TSV250, and TSM600, see Telecom and Networking section, page 301.

TVB, see SiBar Thyristor section, page 339.

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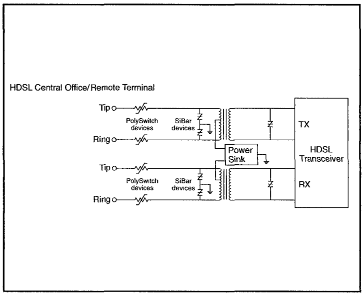
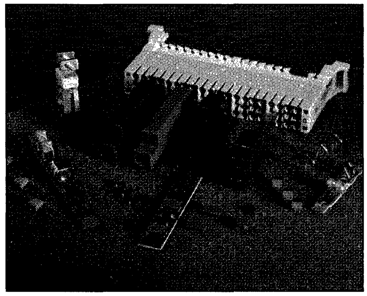
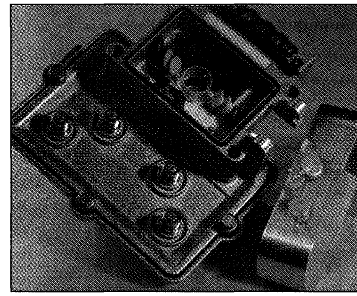






HDSL Equipment

HDSL equipment must be protected against transient power cross and lightning faults which may enter on outside plant wiring. Circuit protection recommendations based on regional agency specifications are provided.

Application Note/Overview
Found on page 101.

Product Information
TR250, TR600, TS250, TS600, TSV250, and TSM600, see Telecom and Networking section, page 301.

TVB, see SiBar Thyristor section, page 339.

MDF Modules/Primary Protection

Circuit protection recommendations for MDF and primary protection modules which protect telecom central offices and customer premises against hazardous power cross and lightning faults.

Application Note/Overview
Found on page 103.

Product Information
TC250, TR250, TS250, and TSV250, see Telecom and Networking section, page 301.

Cable Telephony/Cable Power Passing Tap

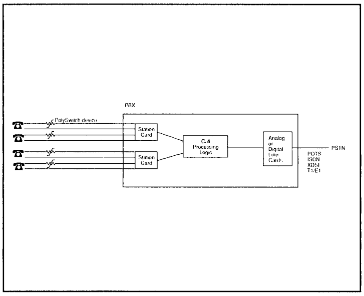
Cable telephony electronics that are powered via twisted pair or coaxial cable are susceptible to power faults passed through the cable plant. Protection in the power passing taps decreases the risk of these faults.

Application Note/Overview
Found on page 104.

Product Information
BBR, TR250, TR600, TS250, TS600, TSL250, TSV250, and TSM600, see Telecom and Networking section, page 301.

TVB, see SiBar Thyristor section, page 339.

ROV, see ROV section, page 351.



PBX and Key Telephone Systems

Provides circuit protection recommendations to protect PBX and Key Telephone Systems against power faults and short circuits.

Application Note/Overview

Found on page 106.

Product Information

RXE, see Radial-leaded section, page 217.

miniSMD and SMD, see Surface-mount section, page 187.

TR250, TR600, TS250, TS600, and TSM600, see Telecom and Networking section, page 301.

TVB, see SiBar Thyristor section, page 339.

5V/12V Power Line Protection

The connection of a 12-volt line from the power supply instead of a 5-volt line can cause a high current inrush that can damage the other components in the circuit. Reverse polarity can cause damage to the tantalum capacitors, causing the capacitor to fail in a short-circuit mode. Applications include hard disk drives, CD-ROM, CD-RW, DVD, and other storage devices.

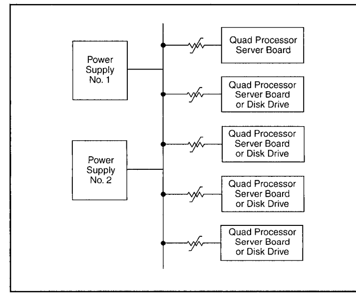
Application Note/Overview

Found on page 108.

Product Information

RUE and RUSB, see Radial-leaded section, page 217.

nanoSMD, microSMD, and miniSMD, see Surface-mount section, page 187.



Backplane and RAID Protection

Power backplane applications allow for field-serviceable and field-replaceable cards and drives to maximize the “up-time” of products. During card or drive replacements, the power on the backplane is live. Circuit protection is employed to minimize safety risks, comply with IEC60950 Safety Requirement Clause 1.2.8.7 – Hazardous Energy Levels, and protect against short circuits caused by incorrect insertion of cards.

Application Note/Overview

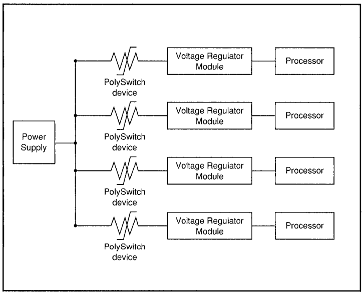
Found on page 109.

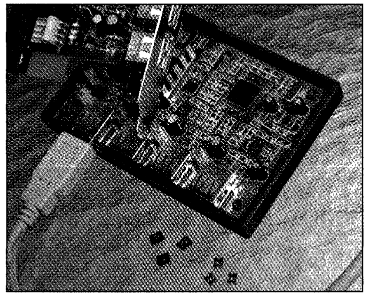
Product Information

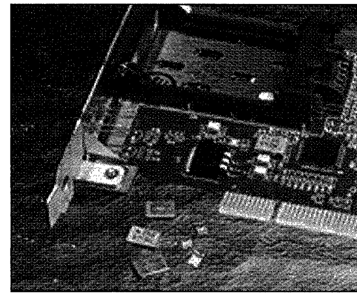
RGE and RXE, see Radial-leaded section, page 217.

microSMD, miniSMD, and SMD, see Surface-mount section, page 187.

ROV, see ROV section, page 351.







CPU Protection

Voltage regulation modules (VRMs) are used to supply power to processors. Due to load-change transients, processors can draw up to 13A. Also, during normal operation the current demand can still change by as much as 7A as processor activity levels change. These high-current immediate demands can cause components to fail. Circuit protection helps prevent the VRM from damaging the processor in the event of a VRM failure.

Application Note/Overview

Found on page 110.

Product Information

RGE and RUE, see Radial-leaded section, page 217.

SMD, see Surface-mount section, page 187.

Device Bay

Due to hot-swappable bays, the device bay specification recommends overcurrent protection for high availability situations such as servers and industrial computers. In addition, device bay devices can provide an externally accessible port such as IEEE1394 or USB.

Application Note/Overview

Found on page 111.

Product Information

RGE and RUE, see Radial-leaded section, page 217.

microSMD, miniSMD, and SMD, see Surface-mount section, page 187.

Fibre Channel

A fault, such as a short circuit, during testing or hot-swapping a PCI card can cause significant damage. Incorrect insertion of the GBIC or a foreign object placed into the connector can also cause permanent damage to the system. Protection on the PCI bus input is typically used as well as a secondary protector for the GBIC I/O.

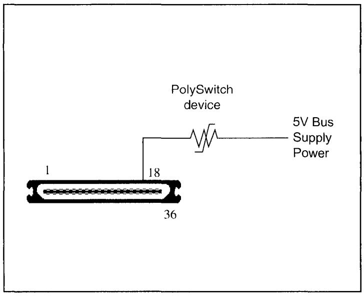
Application Note/Overview

Found on page 112.

Product Information

RUE, see Radial-leaded section, page 217.

miniSMDC110 and miniSMDC260, see Surface-mount section, page 187.



IEEE 1284 Parallel Data Bus

The connector sources up to 350mA at 5V. A misconnection of the connectors or a foreign metal object placed into the connector can cause a large overcurrent that could damage system electronics.

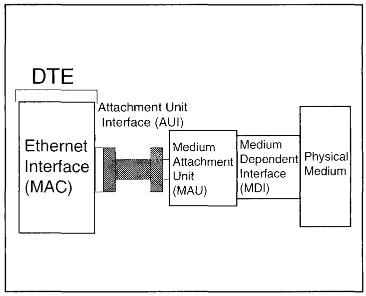
Application Note/Overview

Found on page 113.

Product Information

RXE, see Radial-leaded section, page 217.

nanoSMD, microSMD, and miniSMD, see Surface-mount section, page 187.



IEEE 802.3 Ethernet LAN (incl. Powered Ethernet)

The auxiliary unit interface (AUI) consists of signal circuits, power, and ground. Per the IEEE 802.3 standard, the Voltage Plus circuit is capable of operating at 12-15 V_{DC} for currents up to 500mA. In addition, per section 7.5.2.5, the source shall provide protection for this circuit against an overload condition. Powering IP devices such as IP phones over the ethernet cable introduces the potential for a short circuit and/or FET failure, causing service interruption.

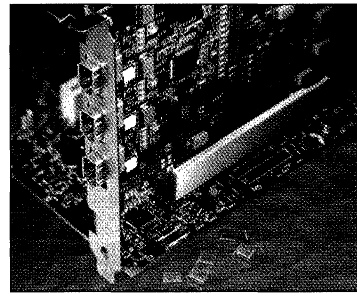
Application Note/Overview

Found on page 114.

Product Information

AUI: RUE and RXE, see Radial-leaded section, page 217.

Powered ethernet: miniSMDC110/16, miniSMDC075, and SMD030-2018, see Surface-mount section, page 187.



IEEE 1394 FireWire, i.Link

IEEE 1394's complex power architecture provides up to 1.5A at voltages of 8-33V. PolySwitch devices provide short-circuit protection in this high-power, hot-plugging environment.

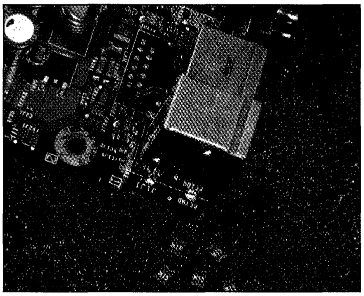
Application Note/Overview

Found on page 115.

Product Information

RTE, see Radial-leaded section, page 217.

SMD, see Surface-mount section, page 187.



I/O Ports

To meet regulatory agency requirements (UL60950), these ports must have a way of interrupting or limiting the current in the event of an overload or short circuit.

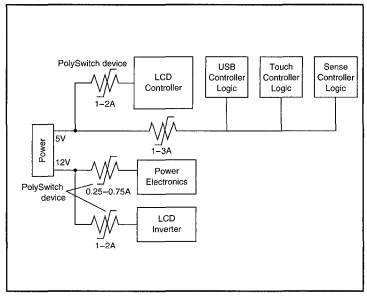
Application Note/Overview

Found on page 118.

Product Information

RUE and RUSB, see Radial-leaded section, page 217

nanoSMD, microSMD, miniSMD, and SMD, see Surface-mount section, page 187.



LCD Monitors

Power for LCDs is supplied from the 5V and 12V buses. The LCD controller itself and the surrounding controller logic are powered from the 5V bus. The LCD inverter and the electronics on the board are powered from the 12V bus. Misconnections and mishandling during assembly or while in use can cause large overloads and short circuits in the system, damaging expensive components.

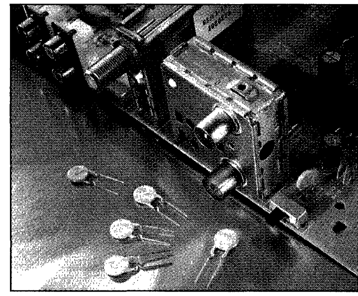
Application Note/Overview

Found on page 119.

Product Information

RUE and RXE, see Radial-leaded section, page 217.

nanoSMD, microSMD, and miniSMD, see Surface-mount section, page 187.



LNB Satellite Set-Tops

A short-circuit overload to the power supply can occur if the central pin in the coaxial cable connection to the receiver is bent or crushed against the connector during installation. It can also occur any time the user disconnects the antenna from the receiver.

Application Note/Overview

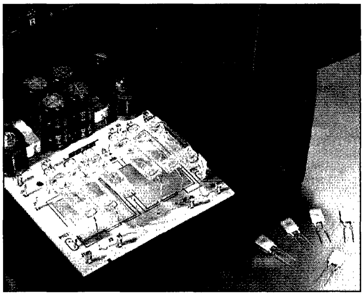
Found on page 120.

Product Information

miniSMD and SMD, see Surface-mount section, page 187.

RXE, see Radial-leaded section, page 217.

ROV, see ROV section, page 351.



Loudspeakers

High-powered amplifiers used with low-powered speakers may overdrive the speaker coils with excessive power during sustained high volumes. Low-powered amplifiers may be overdriven so that clipping occurs. This causes an upward frequency shift of power that can overload the tweeters. Digital recordings, including compact discs, with their ability to reproduce high-frequency material, place extra strain on tweeters. PolySwitch devices can help the design engineer solve these problems.

Application Note/Overview

Found on page 121.

Product Information

SPK, please contact your local Raychem Circuit Protection representative for information.

RXE, see Radial-leaded section, page 217.

PC Cards and Sockets

Short circuits from external sources are the primary hazards for PC cards. The cards need protection from large current inrushes that can damage the PC card or the PC card bus.

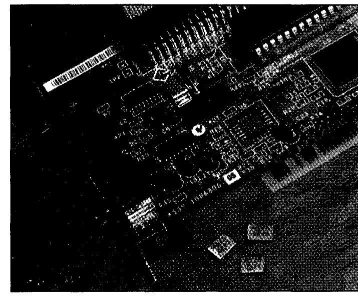
Application Note/Overview

Found on page 125.

Product Information

RUE and RUSB, see Radial-leaded section, page 217.

nanoSMD, microSMD, and SMD, see Surface-mount section, page 187.



SCSI

The SCSI bus TERMPWR line can draw significant amounts of current. When a short circuit occurs, that can increase beyond 8A.

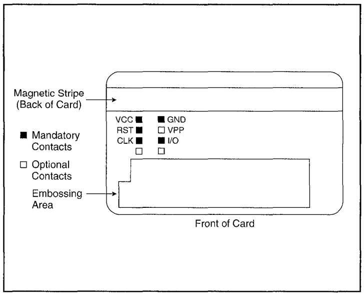
Application Note/Overview

Found on page 126.

Product Information

RUE and RXE, see Radial-leaded section, page 217.

microSMD, miniSMD, and SMD, see Surface-mount section, page 187.



Smart Card Readers

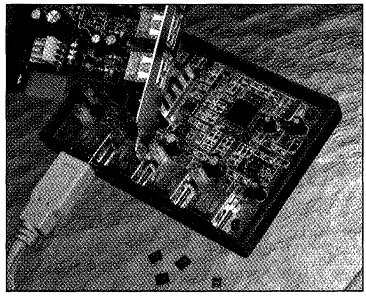
Smart cards are powered from the readers' Vcc. Defective cards or foreign objects placed into the reader can cause a short circuit and permanently damage the reader.

Application Note/Overview

Found on page 128.

Product Information

microSMD010, see Surface-mount section, page 187.



Universal Serial Bus (USB)

PolySwitch devices provide short-circuit protection in this hot-plugging environment for USB hosts, self-powered and bus-powered hubs.

Protected power switches: Provide overcurrent protection and port switching.

Application Note/Overview

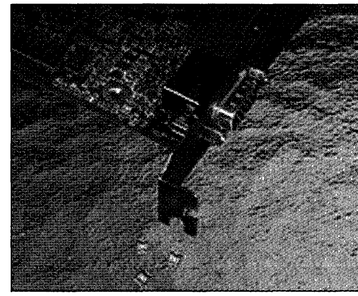
Found on page 129.

Product Information

RUE and RUSB, see Radial-leaded section, page 217.

For protected power switches, please visit our website for more detailed product information.

nanoSMD, microSMD, and miniSMD, see Surface-mount section, page 187.



Video Ports (VESA, DDC, DVI)

Protects video ports on PCI video cards and motherboard video ports from faults on the 5-volt interface line in DDC circuits. These ports are designed for EnergyStar compliance.

Application Note/Overview

Found on page 133.

Product Information

RUE and RUSB, see Radial-leaded section, page 217.

nanoSMD, microSMD, miniSMD, and SMD, see Surface-mount section, page 187.

Multimedia

Portable Electronics

POS Equipment

Equipment connected to telephone lines can be subject to power cross, induction, and lightning surge hazards. Scanner motors and ditherers need protection against jams and stalls.

Application Note/Overview
Found on page 134.

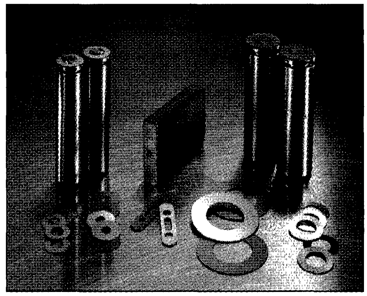
Product Information
RUE and RXE, see Radial-leaded section, page 217.

miniSMD and SMD, see Surface-mount section, page 187.

TR and TS, see Telecom and Networking section, page 301.

TVB, see SiBar Thyristor section, page 339.

ROV, see ROV section, page 351.



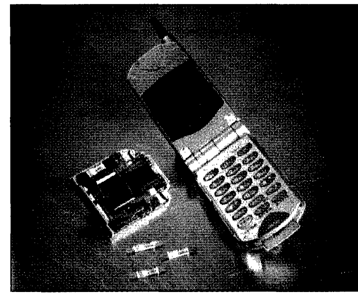
Lithium Cells and Battery Packs

External shorts, runaway charging conditions, or abusive charging can cause considerable damage to primary and secondary lithium cells. Rechargeable lithium batteries are used in notebook computers and cellular phones, as well as other portable electronic applications.

Application Note/Overview
Found on page 135.

Product Information
LR4, LTP, SRP, TAC, VLR, and VTP, see Strap Battery section, page 275.

Lid assemblies of lithium cells vary by manufacturer. PolySwitch disc devices are considered custom products. Please contact your local Raychem Circuit Protection representative for information.

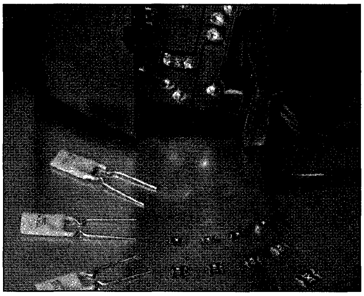


Rechargeable Battery Pack Protection

Due to external shorts, runaway charging conditions, or abusive charging, considerable damage can be sustained in both battery cells and pack surroundings. The most common applications are nickel-cadmium (NiCd), nickel-metal-hydride (NiMH), and lithium ion (Li-ion) battery packs for cellular phones, laptop/notebook computers, and other portable electronic applications.

Application Note/Overview
Found on page 136.

Product Information
LR4, LTP, SRP, TAC, VLR, VLP, and VTP, see Strap Battery section, page 275.



Linear AC/DC Adapters

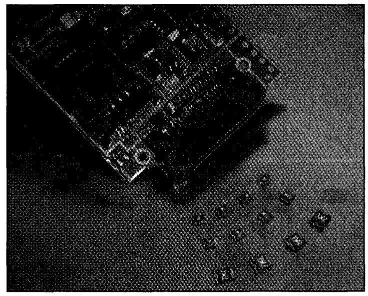
Linear AC/DC adapters, or "wall warts", have applications in both battery charging applications and as low cost DC power supplies for a variety of consumer equipment. Short circuits or excessive current draw can result in transformer winding overtemp. PolySwitch devices help meet UL requirements.

Application Note/Overview
Found on page 139.

Product Information
RTE, RUE, and RXE, see Radial-leaded section, page 217.

nanoSMD, microSMD, miniSMD, and SMD, see Surface-mount section, page 187.

ROV, see ROV section, page 351.

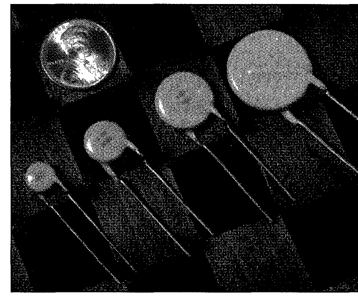


Portable Electronics Input Port Protection

The use of an incorrect or faulty adapter/charger can irreparably damage unprotected portable electronics equipment. Typical applications include cellular phones, PDAs, and digital cameras.

Application Note/Overview
Found on page 141.

Product Information
nanoSMD, microSMD, and miniSMD, see Surface-mount section, page 187.



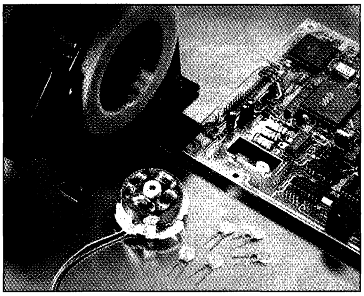
LVR and ROV Devices Help Designers Meet IEC 61000-4-5 Requirements for AC Mains Applications

Overcurrent and overvoltage protection are often considered as two separate elements during the design process. As a result, protection strategies can result in multiple component solutions that can be costly. Additionally, synergies between protection devices can be overlooked as overvoltage and overcurrent protection are often viewed as completely unrelated conditions. With PolySwitch LVR devices and Raychem Metal Oxide Varistors (ROV), Raychem Circuit Protection offers designers a complete solution that helps enhance product protection and reliability.

Application Note/Overview
Found on page 143.

Product Information
LVR, see Radial-leaded section, page 217.

ROV, see ROV section, page 351.



Electromagnetic Loads

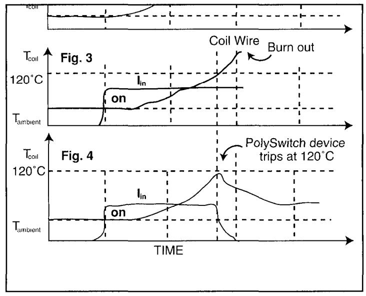
Electromagnetic loads can be susceptible to many problems. Incorrect use of solenoids, valves, and motors can lead to device failure and circuit damage.

Application Note/Overview
Found on page 146.

Product Information
RGE, RUE, and RXE, see Radial-leaded section, page 217.

miniSMD and SMD, see Surface-mount section, page 187.

ROV, see ROV section, page 351.



Solenoid Protection

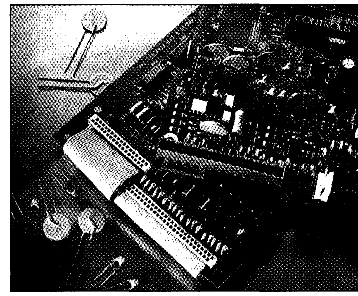
Solenoids are used in various PC and peripheral applications such as printer feed trays and CD/CD-RW/DVD tray mechanisms. A PolySwitch device can be used to protect the coil assembly of the solenoid when a sensor fails or if the armature fails to retract, thus causing the coil temperature to increase and burn out the coil wire.

Application Note/Overview
Found on page 153.

Product Information
RGE, RHE, RUE, and RXE, see Radial-leaded section, page 217.

miniSMD and SMD, see Surface-mount section, page 187.

ROV, see ROV section, page 351.



Process and Industrial Controls

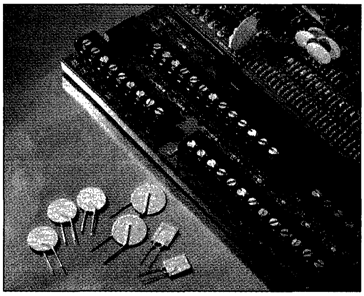
Pinched cables and incorrectly installed/connected cables lead to shorts, overheating, component failures, and burned circuit board traces.

Application Note/Overview
Found on page 154.

Product Information
RHE, RTE, RUE, and RXE, see Radial-leaded section, page 217.

miniSMD and SMD, see Surface-mount section, page 187.

ROV, see ROV section, page 351.



Security and Fire Alarm Systems

Short circuits in the sensor lines, overheating of the battery, protection against telecom faults, different current requirements, and helping to meet UL864 requirements create a need for circuit protection.

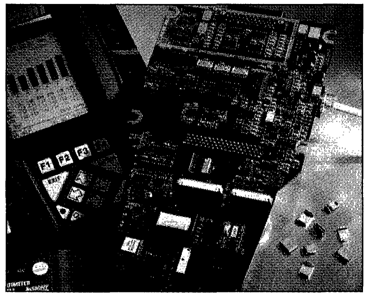
Application Note/Overview
Found on page 159.

Product Information
RGE, RUE, and RXE, see Radial-leaded section, page 217.

TR, see Telecom and Networking section, page 301.

TVB, see SiBar Thyristor section, page 339.

ROV, see ROV section, page 351.



Test and Measurement Equipment

Power supplies, communication ports, test probes, and battery packs are all vulnerable to overcurrent faults because of incorrect connections or damaged cables.

Application Note/Overview
Found on page 160.

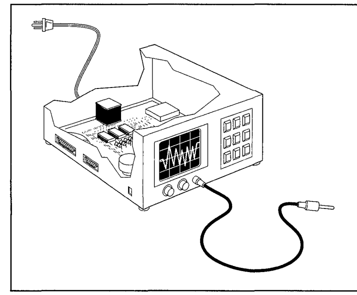
Product Information
RTE, RUE, and RXE, see Radial-leaded section, page 217.

miniSMD and SMD, see Surface-mount section, page 187.

TR, see Telecom and Networking section, page 301.

TVB, see SiBar Thyristor section, page 339.

ROV, see ROV section, page 351.



Medical Electronics

An electromedical device can experience overcurrent conditions in the secondary side of its internal power transformer, in one of its communication ports, and through its probes and voltage/current input terminals. A portable unit can also experience overcurrent conditions in its battery packs.

Application Note/Overview
Found on page 161.

Product Information
RTE, RUE, and RXE, see Radial-leaded section, page 217.

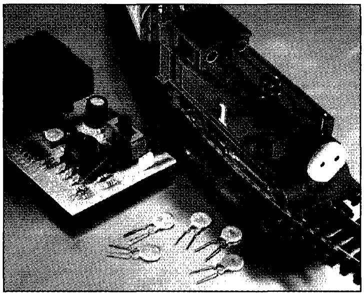
miniSMD and SMD, see Surface-mount section, page 187.

TR, see Telecom and Networking section, page 301.

TVB, see SiBar Thyristor section, page 339.

ROV, see ROV section, page 351.

Transformers



A short circuit can cause high currents, which produce high temperatures and can damage the power supply.

Application Note/Overview

Found on page 162.

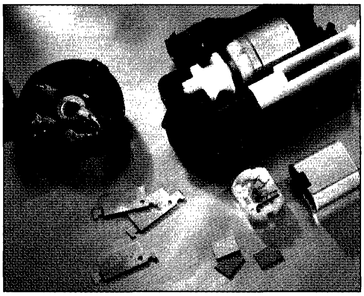
Product Information

RGE, RHE, RUE, and RXE, see Radial-leaded section, page 217.

SMD, see Surface-mount section, page 187.

ROV, see ROV section, page 351.

Automotive Actuators & Medium-size Motors



Automobile electric motors overheating can damage temperature sensitive components. These fault conditions are usually temporary so devices with a reset capability. Most motor protection devices are custom built to work with a particular motor, and quite often for a specific application. PolySwitch™ devices have been used for several years in automotive applications.

Application Note/Overview

Found on page 164.

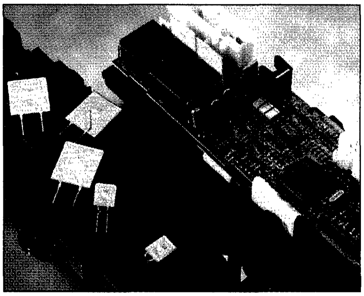
Product Information

AGR and AHR, see Automotive section, page 253.

Please contact your local Raychem Circuit Protection representative for information on terminal devices (TD) or custom chip devices.

ROV, see ROV section, page 351.

Printed Circuit Board Trace Protection



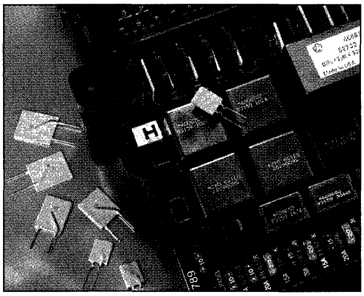
To provide an increasing number of functions and interconnections on the surface area of tighter-packed and smaller printed circuit boards, the width of the copper traces must be reduced. However, these "black box" control modules are now controlling a greater number of high-powered accessories, such as power windows, power seat adjusters, remotely controlled door locks, and radio & GPS antennas. To help protect these delicate printed circuit board traces against damage from overcurrent conditions, PolySwitch resettable devices may be used.

Application Note/Overview

Found on page 167.

Product Information

AHR, AGR, AHS, and ASMD, see Automotive section, page 253.



Automobile Harness Protection

The wiring harness architecture of automobiles has undergone considerable change as vehicle electrical and electronic content has increased over recent years. Using resettable circuit protection that does not need to be driver accessible, such as PolySwitch PPTC devices, offers a number of solutions that may be used separately or in combination.

Application Note/Overview

Found on page 169.

Product Information

AGR, AHS, and ASMD, see Automotive section, page 253.

ROV, see ROV section, page 351.

DC Cigarette Lighter Adapter –Charger Protection

The connectors used to plug into automobile Cigarette Lighter Power Outlets often include a charger circuit for a mobile phone, an after market hands-free device, or other battery operated equipment. The whole assembly must operate over a wide range of temperatures and charging conditions that combine the harsh automotive environment with stringent electrical requirements. Typically overcurrent protection such as a PolySwitch PPTC device is combined with overvoltage protection, at the input to the charger.

Application Note/Overview

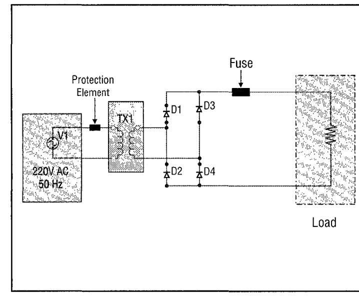
Found on page 171.

Product Information

See the Surface-mount section, page 187.

See the Radial-leaded section, page 217.

See the Automotive section, page 253.



Protecting Automotive Battery Chargers from Fault Failures

Service station and “do-it-yourself” battery chargers provide a low cost means of charging a flat or heavily discharged battery. However, when battery cables are attached incorrectly, or the clamps or clips touch each other accidentally, the resulting fault condition may cause a blown fuse or equipment damage. A PolySwitch PPTC device along with a Raychem MOV is an obvious choice to address an overcurrent situation on the secondary side.

Application Note/Overview

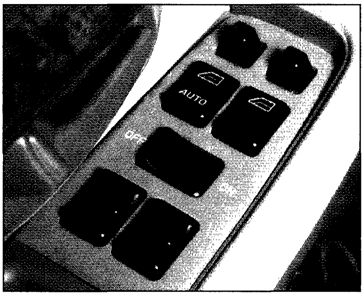
Found on page 172.

Product Information

See Automotive section, page 253.

ROV, see ROV section, page 351.

See the Radial-leaded section, page 217.



One-Touch-Down Circuit for Power Windows and Power Sunroofs Using a PolySwitch PPTC Device

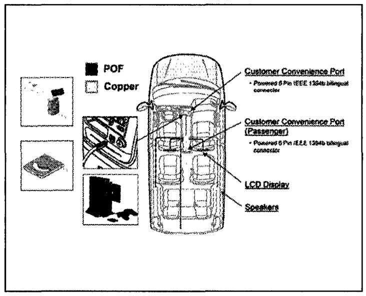
Raychem Circuit Protection's One-Touch-Down circuit employs a PPTC device that functions both as a sense component and a switch component, replacing the sense resistor, comparator, driver and control circuitry used in traditional power window and sunroof circuits. PPTC devices provide net cost savings through reduced component count and reduction in wire size.

Application Note/Overview

Found on page 176.

Product Information

AHR AGR, AHS, ASMD, see Automotive section, page 253.



PolySwitch Device Applications for Automotive IEEE 1394 Networks

Connecting lifestyles from the home to the vehicle is an emerging trend in the automotive industry. The ability to interface consumer electronic devices and allow for quick installation in vehicles is now being facilitated through a standard global interface. In this hot-pluggable automotive environment, where the consumer is connecting and disconnecting peripherals on a powered port, the potential for short circuit damage is clearly present, and PolySwitch devices are an effective solution.

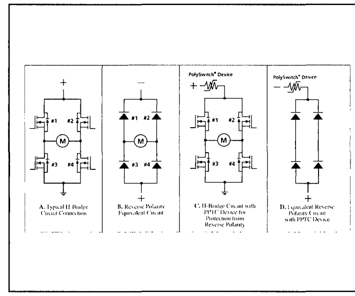
Application Note/Overview

Found on page 174.

Product Information

See Automotive section, page 253.

See Surface-mount section, page 187.



H-Bridge Protection from Reverse Battery Damage

Automotive electronics must be protected from reverse polarity power sources, that may occur when jumper cables are connected to the wrong polarity of a dead or excessively discharged battery, or when a new battery is installed backwards. Without protection, excessive heating can lead to failures in electronic modules or inadvertent activation of vehicle loads such as solenoids and motors, which can lead to unsafe conditions.

Application Note/Overview

Found on page 179.

Product Information

See Automotive section, page 253.

See Surface-mount section, page 187.

See Radial-leaded section, page 217.

ROV, see ROV section, page 351.

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UL60950 and TIA-968-A Requirements
Application Note

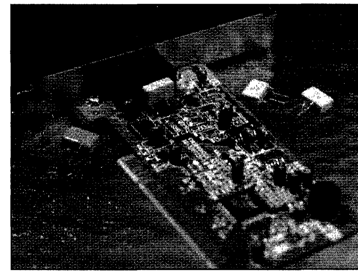
Problem/Solution
Subscriber equipment, also known as customer premise equipment (CPE), includes any equipment that is connected to the telecommunications network and located at a customer's site. Examples of this type of equipment are telephones, set-top equipment, fax machines, answering machines, modems, and PBX systems.

This equipment is prone to hazards caused by lightning surges, power contact, and power induction. If left unprotected from these hazards, CPE may fail to operate or may risk the safety of subscribers and maintenance personnel.

In North America, agency requirements such as UL60950 and TIA-968-A, (formerly FCC part 68) set a minimum performance standard for CPE. A PolySwitch resettable overcurrent device may be used in conjunction with a SiBar thyristor surge protector to assist equipment manufacturers in meeting these agency requirements.

CPE Industry Specifications: UL60950 and TIA-968-A
This note describes methods that can be used to meet the standards for secondary protection of subscriber premise equipment in North America, specifically UL60950 and TIA-968-A. Special attention will be given to solutions involving resettable overvoltage and overcurrent devices.

TIA-968-A Standards
Lightning tests for CPE are governed by the Telecommunications Industry Association Regulations TIA-968-A. Table 1 provides further details on the actual tests. The intent of the prescribed surge tests is to ensure that network operation will not be adversely affected by any equipment connected to it, should that equipment fail. TIA requirements state that this lightning surge must not cause any opening or shorting of the equipment—for example, if a fuse is used for



overcurrent protection it must not blow during the test surge.

UL60950 Standards
The power contact and power induction requirements for CPE are specified by Underwriters Laboratories in section 6.6 of the UL60950 3rd Edition, Safety of Information Technology Equipment, Including Electrical Business Equipment. This standard has been merged with the UL1459 Standard for Technology Equipment to become the relevant standard for all telecommunications (CPE) and information technology equipment (ITE).

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Table 1. TIA-968-A Lightning Surge Requirements

Spec Type and Level	Primary Protection?	Waveform (µs, open circuit)	Voltage (V, open circuit)	Current (A, short circuit)	No. of Hits	Test Results	Note
Lightning Type A							
Metallic	Not specified	10/560	800	100	2	A	
Longitudinal	Not specified	10/160	1,500	200	2	A	1
Lightning Type B							
Metallic	No	9/720	1,000	25.0	2	B	
Longitudinal	No	9/720	1,500	37.5	2	B	1

Test Results:

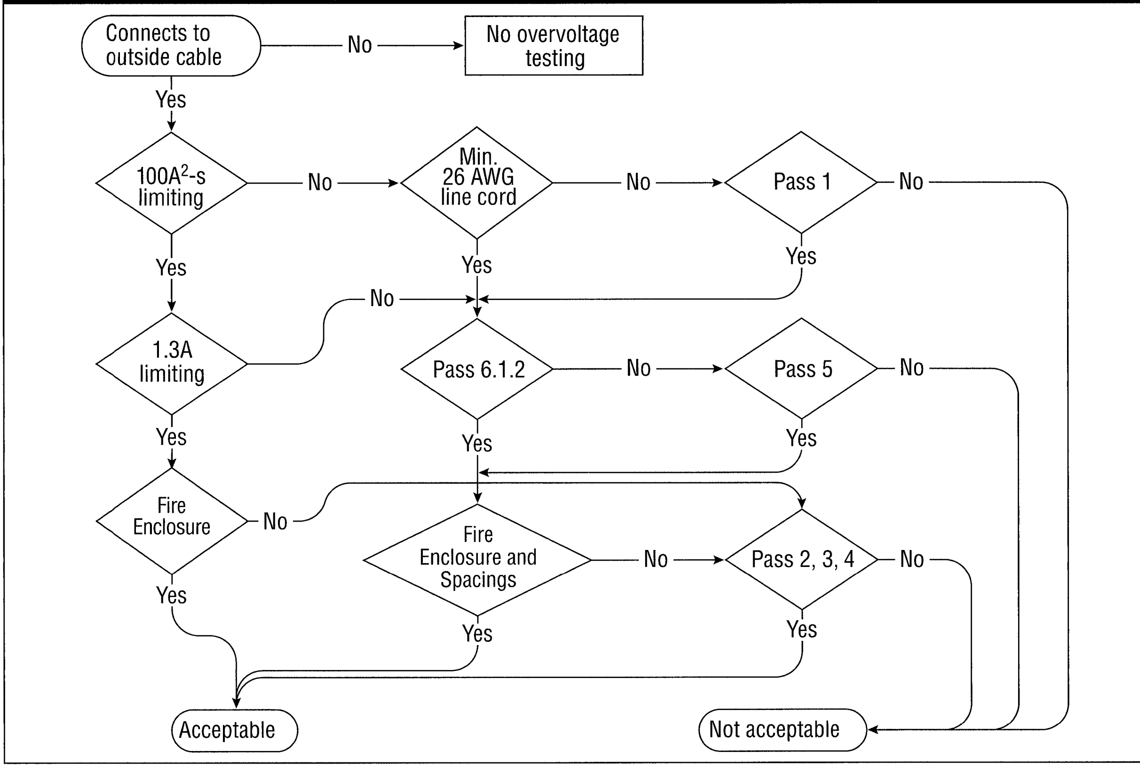
A = Product must remain safe; integrity of the network is maintained (R > 5 milliOhms).

B = Product must remain operational; no permanent open or short.

Notes:

1 = Longitudinal surge is tip-and-ring pair to ground.

Figure 1. UL60950-1 3rd Edition Overvoltage Flow Chart



As of April 1, 2000, all new equipment may only be listed to UL60950 3rd Edition. Listings previously granted under earlier versions of UL60950 and under UL1459 will remain valid until April 1, 2005.

Late in 2000, UL and CSA published a new version of UL/CSA 1950 as UL/CSA 60950. The requirements for overvoltage protection remain unchanged from those discussed in this note.

The flowchart shown in Figure 1 reproduces Figure 6C from UL60950-1 (pg. 212) and provides the allowable pathways for meeting the power contact and powerinduction requirements in section 6.6 of the standard.

Starting from the right, three common paths are:

1. A "performance" path comprising testing the equipment to diamonds "Pass 1," "Pass 5," and "Pass 2, 3, 4."

2. A "construction" path comprising meeting the requirements of diamonds "Min. 26 AWG line cord," "Pass 6.1.2," and "Fire Enclosure and Spacings."

3. A "construction using current-limiting" path comprising meeting the requirements of diamonds "100A²-sec. limiting," "1.3A limiting," and "Fire Enclosure."

"Performance" Path

The performance path comprises meeting the decision diamonds on the far right side of Figure 1. It comprises testing the equipment — hence the term "performance" — to essentially the same set of requirements that are contained in UL1459 and CSA C22.2 No. 225. These test requirements are described in Annex NAC of UL60950-1 and summarized in Table 2 below.

In meeting the requirements of this path, an OEM will have ensured that the equipment complies with the overvoltage conditions which have been traditionally agreed to by the telecommunications industry. In addition, protection coordination with building wiring and primary overvoltage protectors is obtained, since passing Test 1 requires that the equipment limit fault energy to less than 100A²-seconds under 600V power contact conditions.

Raychem Circuit Protection offers PolySwitch devices in both surface-mount (TS/TSM600 family) and radial-leaded (TR600 family) form factors, which can assist OEMs in meeting the requirements of the performance path.

"Construction" Path

The construction path requires meeting the three vertical diamonds in the center of Figure 1. The construction requirements were developed to provide an equivalent level of equipment safety to the performance path[1], though differences exist in performance and design. There are three requirements to meet:

- **Min. 26 AWG Line Cord**
  To meet this requirement, the manufacturer must either supply a telecommunications line cord comprising 26 AWG wire or a larger wire size, or describe the necessity of using such wire in the safety instructions. An example of such a statement is provided in Annex NAA: "CAUTION — To reduce the risk of fire, use only No. 26 AWG or larger telecommunications line cord." The rationale for this line cord exemption is that a cord of this size or larger will not melt through and present a shock or fire hazard under the equivalent energy contained in Test Condition 1 (600V/40A/1.5 seconds).

- **Pass 6.1.2**
  Section 6.1.2 of the standard ensures that there is appropriate electrical isolation of the telecommunications network from ground. Compliance is checked by inspection and by performing an AC or DC insulation strength test at 1.5kV between the telecommunications network voltage (TNV) circuit and unearthed parts of the equipment expected to be

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Table 2. Performance Path Test Requirements

Test	Connection[1]	Test Condition	Passing Criteria[2]
1	M, L, F	600V, 40A, 1.5 sec.	a, b1, b2, c
2	M, L, F	600V, 7A, 5 sec.	a, c
3	M, L, F	600V, 2.2A, 30 min. or until open circuit — if open circuit test at 3A	a, c
3A	M, L, F	600V, I < 2.2A so no open circuit to produce max. heating, 30 min.	a, c
4[3]	M, L, F	V < conduction voltage, I < 2.2A to produce maximum heating, 30 min. or until open circuit	a, c
5	L	120V, 25A 30 min. or until open circuit	a, b1, c

Notes:

1 = Connection:
- M = differential mode (metallic) — apply voltage source across tip-and-ring
- L = common mode (longitudinal) — apply voltage source from tip-to-ground and ring-to-ground
- F = four-wire test mode — apply voltage from pair 1 to pair 2

2 = Passing Criteria:
- a = No charring of cheesecloth indicator
- b1 = fuse or wiring simulator (Bussman MDL-2A fuse) does not interrupt
- b2 = $I^2t < 100A^2$-sec.
- c = Meet dielectric withstand or leakage current requirements after test

3 = To be done if voltage limiter operated in test 3.

held during normal use (e.g., telephone handset). For parts that can be touched by a test finger or that provide connection to other equipment, a voltage of 1.0kV is used. The test is conducted by slowly raising the voltage to the appropriate level and holding it for 60 seconds. Passing the test requires that there be no insulation breakdown, and current flow should not exceed 10mA.

If surge suppressors bridge the TNV circuit insulation, they must have a minimum DC sparkover voltage equal to 1.6 times the rated voltage of the equipment (e.g., 120 or 240V times 1.6). They are typically removed during the insulation strength test.

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The rationale for this test comes from the possibility that the telephone line may be subject to power cross from the 120V mains circuit. Voltages of 1.0 or 1.5kV confirm the adequacy of the insulation under these conditions. If the equipment is grounded, surge suppressors will typically bridge the TNV circuit and ground and therefore must be able to withstand the mains voltage with some margin. An alternative procedure which is allowed per Figure 1 is to perform Test 5 shown in Table 2 (120V, 25A, 30 min.).

- **Fire Enclosure and Spacings**
  The most critical and often the most difficult element to meet in following the construction path is to provide a Fire Enclosure with the appropriate spacings. The spacings separate the TNV circuit from internal materials, some of which may be potentially flammable.

  In the standard, a Fire Enclosure is a structure designed to minimize the possible emission of flame, molten metal, flaming or glowing particles, or flaming drops. The enclosure must meet strict requirements for size and spacing of any holes in the structure, depending on the materials used for the enclosure and the flammability rating of components enclosed within. The Fire Enclosure itself must meet certain flammability tests described in Annex A of the standard. These tests comprise applying the flame from a Bunsen burner directly to the material (five applications of five seconds duration each) and confirm that no flaming or molten materials fall from the test sample and ignite a cheesecloth indicator. In order to meet these requirements, Fire Enclosures are typically made of either metal or specially formulated flame-rated plastics.

  The Spacings requirement places an additional burden on the construction. All parts of the TNV circuit must be separated from materials of flammability class V-2 or lower by 25 mm of air or a flammability barrier made from materials of class V-1 or better. In addition, parts in the TNV circuit must be separated from openings in the sides or top of the Fire Enclosure by at least 25 mm of air or a barrier of class V-1 or better. The flammability class rating refers to the resistance of these materials to combustion after application of a direct flame, class V-0 being the highest rated material.

  The use of Fire Enclosures has been well established in the computer industry as a way of mitigating potential hazards. The addition of the Spacings requirement is a recognition that TNV circuits may be subject to overvoltages as high as 600V with energies as much as 100A^2-seconds. Without any overcurrent protection in place, these fault conditions could produce arcing and internal component explosions. By requiring a Fire Enclosure and Spacings, the standard minimizes the possibility of an unsafe condition resulting from these events.

"Construction Using Current-Limiting" Path

This path achieves the safety of the ITE through a combination of current-limiting and the use of a Fire Enclosure as shown by the three diamonds on the left-hand side of Figure 1. A unique feature of this path is that compliance may be achieved through inspection without performing any testing, thus saving a manufacturer the time, money, and risk of not passing the tests. The three diamonds comprise the following requirements:

- **100A^2-sec. Limiting**
  This diamond establishes the requirement to limit fault energy to less than 100A^2-seconds per the 600V/40A Test Condition 1 as described in Table 1 on page 63. The standard allows that circuits or components which have been listed to UL497A or CSA C22.2 No. 226, Secondary Protectors for Communications Circuits, may be used to meet this requirement without additional testing. The overvoltage test requirements of UL497A and CSA C22.2 No. 226 are essentially the same as those in UL1459; however, an ITE OEM

must understand that UL497A is not a "component" specification, but is in fact an "equipment" specification used for listing multi-component protection modules. As described above, if such a module is used in the equipment, this diamond can be passed without testing.

- **1.3A Limiting**
  Meeting the requirements of this diamond requires that the TNV circuit contains a method for limiting current to 1.3A maximum steady state that also complies with UL497A. An example cited by the standard is a 1.0A rated fuse. Note that meeting the 1.3A limiting specification is not automatically achieved by meeting the UL497A requirements, an example being a 1.6A fuse which by definition will not limit current to 1.3A.

- **Fire Enclosure**
  The Fire Enclosure requirements are described in the Fire Enclosure and Spacings discussion. This decision diamond does not require the additional Spacings conditions because current-limiting is already provided for in the previous diamonds

  As stated previously, a key benefit of following this path is that performance testing is not required. Raychem Circuit Protection's surface-mount PolySwitch TS600-170, TS600-200 and TSM600-250 products have received component recognition under UL497A for use as power cross protection for this pathway. The devices have been tested and determined to be in compliance with the 100A^2-sec. limiting and 1.3A limiting power cross protection requirements of the safety standard. As such, they may be used together with a suitable Fire Enclosure (as previously described) to satisfy the requirements of UL60950-1 with no additional testing required.

  An alternative to providing the Fire Enclosure can be seen by following the "No" path at the "Fire Enclosure" decision diamond and moving to the "Pass 2, 3, 4" diamond. Since Tests 2, 3, and 4 are also subsets of the UL497A requirements, circuit protection modules or discrete components used to meet the "100A^2-sec. limiting" diamond should also pass these tests.

Construction and Test Path

In working through the standard with equipment manufacturers and UL, there is another interesting and valid path—the "construction and test" path. This path comprises meeting the requirements of diamonds "Min. 26 AWG line cord," "Pass 6.3.3" or "Pass 5," and "Pass 2, 3, 4". This path provides for the safety of the equipment by testing to a subset of the overvoltage tests (Tests 2, 3, 4, and 5 or section 6.3.3), and by ensuring the 100A^2-sec. energy withstand capabilities of the equipment through use of the Min. 26 AWG line cord.

From an equipment design perspective, this pathway is interesting because it avoids the potential engineering difficulties of providing a Fire Enclosure with Spacings.

Choosing the Appropriate Path

Each of the potential paths provides a means for designing safe equipment per the overvoltage requirements of the standard, but the paths are clearly not equivalent in the performance of the equipment that results. By using a Fire Enclosure and Spacings to meet the Construction Path, the equipment designer is essentially controlling and limiting the damage following an overvoltage event on the telecommunications line. By using circuit protection components, either for the Performance Path or the Construction with Current Limiting Path, the equipment designer meets the safety requirement by limiting and interrupting current. In addition, this type of protection provides additional protection coordination with the building wiring and primary overvoltage protection devices. The latter benefit is not required by the UL60950 standard but may be desirable in some installations.

Application Details

The typical overvoltage and overcurrent protection circuits are shown in Figure 2 for ungrounded CPE and in Figure 3 for grounded CPE. The series overcurrent protection should provide resettable overcurrent protection, mainly against power cross events. Overvoltage protection in parallel with the CPE load should provide resettable overvoltage protection as well.

Surge tests may be either metallic, defined as applying the surge between tip-and-ring, or longitudinal, defined as applying the surge between both tip-and-ring lines tied together and ground. In an ungrounded system, the longitudinal test should not cause the overvoltage or overcurrent protection to operate. For grounded systems, a voltage above the threshold of the overvoltage protection will cause either the protection between the tip-and-ground, or

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the ring-and-ground, or both, to activate. Note that the third overvoltage protector shown for grounded systems in Figure 3 is optional, but if included can provide increased protection in the case of tip-ring faults.

When an overvoltage is applied between tip-and-ring at the input, the voltage across the overvoltage protection device will increase until the overvoltage device begins to operate (clamp or fold back). With the overvoltage protection device in the activated state, current is conducted through the overcurrent devices, and diverted around the circuit to be protected. For short surges such as lightning, the overcurrent devices should be selected such that they do not interrupt current, so the circuit can immediately return to normal operation when the overvoltage event passes. For longer overvoltage events such as AC power cross or power induction, the overcurrent protector operates, protecting the end equipment, wiring, and overvoltage devices.

For voltages below the threshold of the overvoltage device, or when faults in the circuit to be protected occur, an excessive amount of current could be drawn from the power source. In this case, the overcurrent protection operates to prevent damage to the wiring or circuit.

Designing Resettable Solutions

PolySwitch resettable devices are positive temperature coefficient (PTC) devices that increase significantly in resistance ("trip") in response to an overcurrent surge. SiBar TSP devices are silicon crowbar devices that shunt from a high to a low impedance in response to

Figure 2. Ungrounded CPE Design

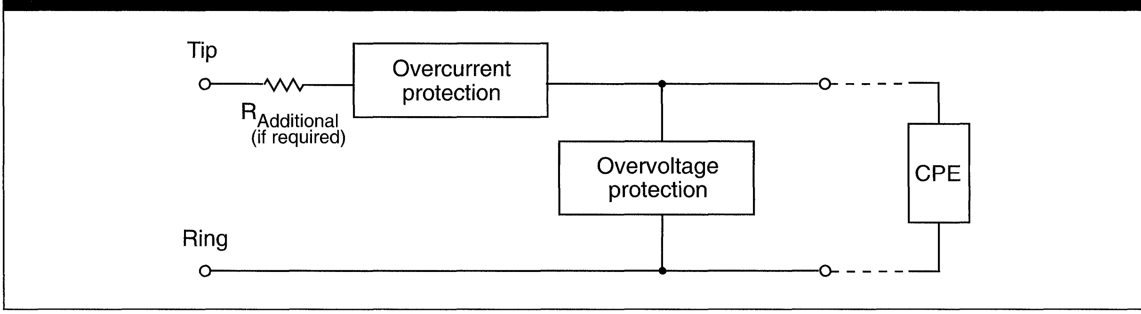
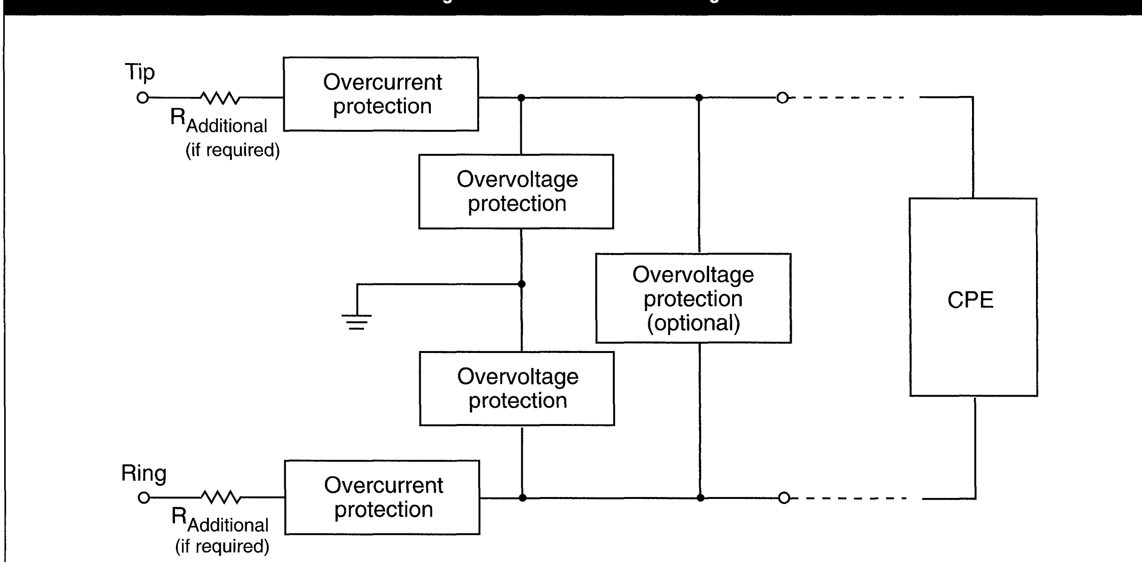


Figure 3. Grounded CPE Design



an overvoltage surge, such as those caused by lightning, power cross, and power surge.

For *lightning surges*, the SiBar device will crowbar to a low impedance, diverting current around the protected circuit and preventing excessive voltages from appearing at the terminals of the device to be protected. The surge current capability of the SiBar device must be considered when designing to protect against a lightning surge. Four waveforms are specified by TIA-968-A and detailed in Table 1. The 10/160µs and 10/560µs waveforms apply to both opencircuit and short-circuit conditions. For these two surges, the TIA-968-A requires only that a hazardous failure not occur. The equipment does not have to be operational after these tests.

In addition, to comply with the TIA-968-A specification, the equipment must be operational after the tests.

The most robust design addresses the worst-case fault currents and waveforms, with the equipment surviving all tests operationally. To survive operationally, the surge current that passes through the SiBar device must be less than or equal to its surge rating. The TVBxxxSA devices are rated at 70A for the 10/560 waveform and 100A for the 10/160 waveform, thus additional line impedance is needed to reduce the surge current to below the SiBar TVBxxxSA rating. The total amount of resistance required can be calculated by first looking at the impedance of the surge generator. An 800V open circuit voltage and 100A shortcircuit current implies a source impedance of:

$$R_{source} = V_{open\ circuit}/I_{short\ circuit} = 800V/100A = 8\Omega$$

To reduce the 10/560 current to 70A, the completed circuit must have a total impedance of:

$$R_{total} = V_{open\ circuit}/I_{rating} = 800V/70A = 11.5\Omega$$

The additional resistance necessary is:

$$R_{additional} = R_{total} - R_{source} = 11.5\Omega - 8\Omega = 3.5\Omega$$

A 1500V open-circuit voltage and 200A short-circuit current implies a source impedance of:

$$R_{source} = V_{open\ circuit}/I_{short\ circuit} = 1500V/200A = 7.5\Omega$$

To reduce the 10/160 current to 100A the completed circuit must have a total impedance of:

$$R_{total} = V_{open\ circuit}/I_{rating} = 1500V/100A = 15\Omega$$

The additional resistance necessary is:

$$R_{additional} = R_{total} - R_{source} = 15\Omega - 7.5\Omega = 7.5\Omega$$

A grounded system must pass both tests operationally; therefore, a minimum of 7.5Ω must be inserted in the line to reduce the current to within the SiBar device rating.

For ungrounded systems, only a metallic test applies; therefore, a minimum of 3.5Ω is required.

For applications which require low series impedance, the higher-surge-rated TVBxxxSC family can be used with no additional series resistance.

For *ungrounded systems*, the additional resistance can be put in either the tip or ring line as shown in Figure 2.

As shown in Figure 4, a PolySwitch TRF600-150 or TS600-170 device provides the necessary resistance.

For *grounded systems*, the current path can be between tip-and-ring, tip-and-ground, or ring-and-ground. To protect the overvoltage device from failure in a grounded system, the additional resistance needs to be placed in both tip and ring as shown in Figure 3. As shown in Figure 5, a TRF600-150-RB provides the necessary resistance.

As discussed, the use of a PolySwitch device may provide some or all of the necessary resistance. Refer to the latest PolySwitch datasheets for the available resistance range to reduce the lightning surges as defined by TIA-968-A to within the SiBar device rating. Using less or no resistance will allow higher currents to pass through the SiBar TVBxxxSA device which may damage the device and cause it to fail short. This failure mode is not allowed by the TIA; therefore, a higher current rated TVBxxxSC thyristor should be used in these designs.

Since TR600, TS600, and TSM600 devices are designed to pass the TIA-968-A requirements without tripping, the use of a PolySwitch

Figure 4. Suggested Arrangement to Meet TIA-968-A for an Ungrounded CPE Design

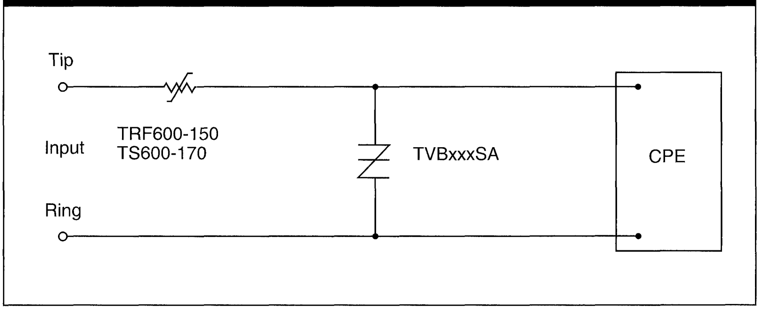
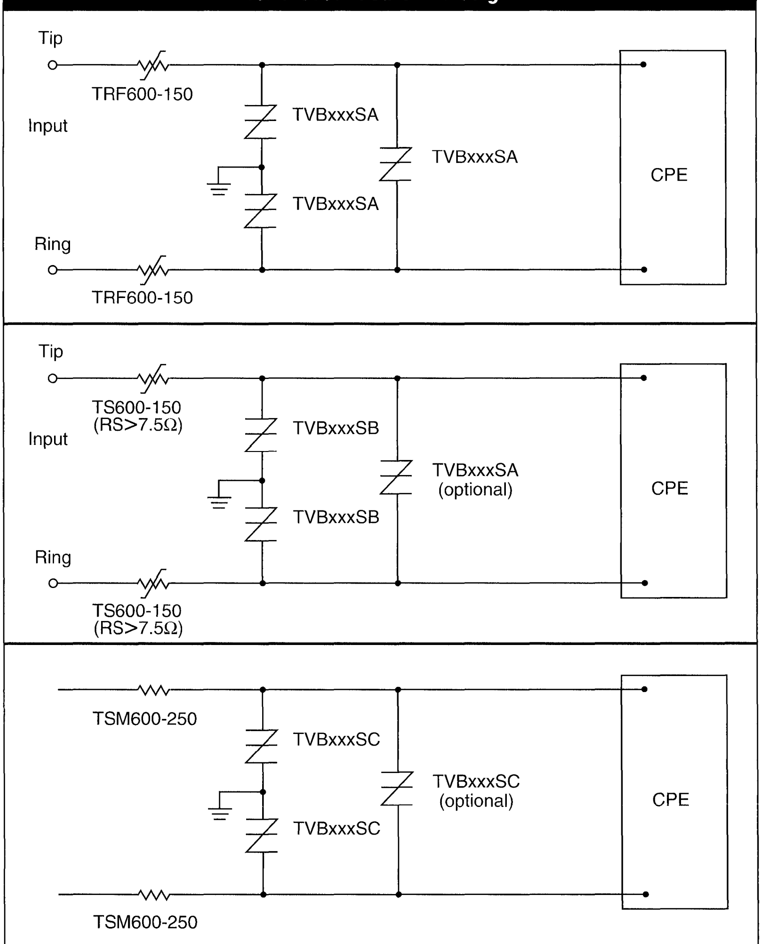


Figure 5. Suggested Arrangement to Meet TIA-968-A for a Grounded CPE Design



device with the appropriately rated SiBar device can provide a fully resettable solution for ungrounded and grounded systems as shown in Figures 4 and 5.

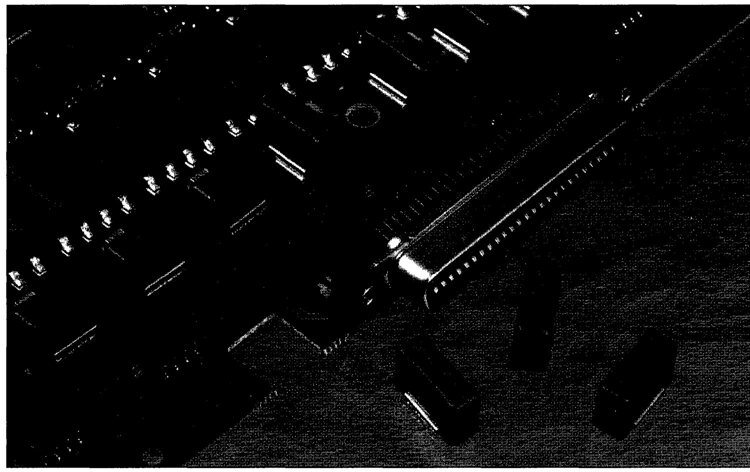
Device Selection

Choose the SiBar TVBxxxSA or TVBxxxSC series and PolySwitch TR600,TS600, or TSM600 devices for a coordinated, resettable solution to assist CPE manufacturers in meeting the specification requirements of UL60950 and TIA-968-A. Select a SiBar device with a rated off-state voltage V_{DM} closest to but greater than the system's peak operating voltage.

GR-1089: North America Network Equipment
Application Note

Modern public switched telephone network (PSTN) equipment frequently has an electronic interface to the network that is subject to the same overvoltage and overcurrent stresses that have plagued the telecommunications system since its inception. Legacy network equipment interfaces tolerated these overstresses well, but the electronic interface is much less robust.

While the objectives of network protection in the past were primarily to prevent injury and fire, the new network protection must also prevent damage. This note discusses the electrical overstresses to which telecommunications systems are exposed, the protection methods used to control the exposure, the Telcordia GR-1089 specification for Electromagnetic Compatibility and Electrical Safety (which governs the performance of the protectors), protective devices, and design considerations for communications network equipment in North America. Refer to the "ITU Recommendations" application note on page 76 for applications outside North America.



The Problem: Electrical Overstresses on the Telecommunications System

Overstresses in the form of overvoltage and overcurrent can occur in telecommunications systems due to lightning and through interaction with the AC power network. The Telcordia specification (formerly published by Bellcore) is based on many years of field experience and careful measurement of these overstresses.

Lightning surge is the most common source of overstresses. Currents may enter suspended cables by direct or indirect strike, or they may enter buried cable by the action of ground currents.

Since telephone cables very often share a pole or common-use trench and ground rod with the AC power system, some level of induced current is almost always measurable on the tip- and -ring conductors. When a fault occurs in the power system, these currents can become large. Three types of overstress occur on telecommunications circuits as a result of power system faults:

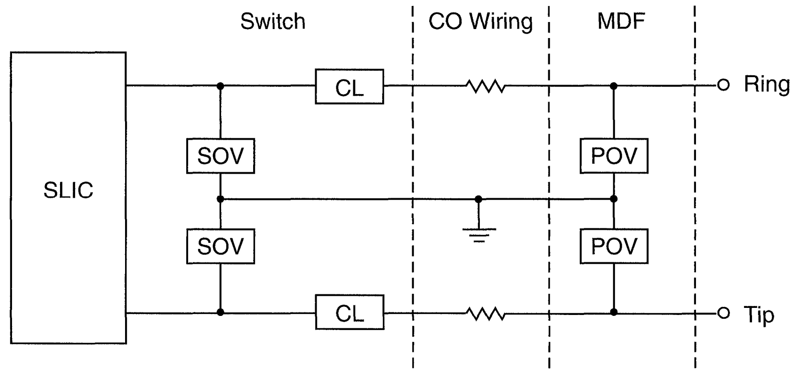
1. *Power cross* occurs when the power lines make electrical contact with the telephone circuit conductors. A power cross can drive large currents through the telephone cables.

2. *Power induction* occurs when neighboring power lines carry a heavy current due to a fault or switching transient.

3. *Ground potential rise* occurs when high currents due to a power fault or lightning surge to ground result in a significant potential difference between the point of the fault and the ultimate earth ground.

Overstresses also occur in two modes, longitudinal and metallic. *Longitudinal mode* refers to the case where the overstress is present between tip-and-ring and ground. Longitudinal overstresses are the more common type and occur during power induction or power crosses where both conductors have the same exposure to the hazard. Lightning-induced overstresses are also typically longitudinal in the absence of any imbalance resulting from terminating equipment.

Figure 1. Simplified Model of Central Office End of Subscriber Loop



CL = Current limiting device
CO = Central office
MDF = Main distribution frame
POV = Primary overvoltage protecton device
SLIC = Subscriber line interface card
SOV = Secondary overvoltage protection device

Metallic mode refers to the case where the overstress is present between tip-and-ring. Metallic overstresses can also be generally due to an imbalance in the network; for example, when a protector on one side of the line conducts, but the protector on the other side does not.

The Solution

Protection Methods

Line protection networks are traditionally split into primary, secondary, and sometimes tertiary components. Primary protectors have greater energy-handling capacity than secondary or tertiary protectors; however, the activation threshold for primary protection components is often less precise than for secondary protection components. Figure 1 is a simplified model of a conventional central office subscriber loop driven by an electronic interface. The figure shows the location of the various protection components.

Primary protection is the first level of protection from an overstress event occurring in the outside plant. Primary protection devices typically reside in the main distribution frame (MDF) for central office (CO) equipment, and at building entrances. Primary protection is intended to divert all overstresses above a loosely defined threshold away from the protected equipment and into a reliable earth ground. Primary protection is generally the property of the operating company, and specifications for primary protectors provide the minimum level of protection that the telephone company guarantees its customers. Primary protectors always contain overvoltage protection devices, and may contain overcurrent protection devices as well.

Secondary protection operates on the residual voltages and currents passed by the primary protection. Secondary protection devices are usually located on the equipment to be protected and are the responsibility of the equipment manufacturer. The requirements for secondary protection are determined by standards and the customer's expectations. Secondary protection was originally intended to prevent fire and injury due to shock, but is now also tasked with preventing damage. Secondary protection usually contains both overvoltage devices and current-limiting devices. Overvoltage protection is necessary to prevent damage to the equipment and shock hazards. Current-limiting devices are necessary to prevent damage to the wiring and the overvoltage devices; they also serve to coordinate the actions of the primary and secondary overvoltage devices, since the secondary protectors usually operate at a lower threshold than the primary protectors.

Table 1. GR-1089

Spec Type and Level	Primary Protection?	Waveform (μ sec, open circuit)	Voltage (V, open circuit)	Current (A, short circuit)	No. Hits	Test Results*
*Lightning***						
Level 1, Surge 1	No	10/1000	600	100	±25	A
Level 1, Surge 2	No	10/360	1,000	100	±25	A
Level 1, Surge 3	No	10/1000	1,000	100	±25	A
Level 1, Surge 4	No	2/10	2,500	500	±10	A
Level 1, Surge 5	No	10/360	1,000	25	±5	A
Level 2, Surge 1	No	2/10	5,000	500	±1	B

Spec Type and Level	Primary Protection?	Volts (Vrms) (open circuit)	Current (Arms) (short circuit)	Duration (seconds)	No. Hits	Test Results*
Power Induction						
Level 1, Test 1	No	50	0.33	15 min	1	A
Level 1, Test 2	No	100	0.17	15 min	1	A
Level 1, Test 3	No	600 max.	1 (at 600V)	1	60	A
Level 1, Test 4	Yes	1,000	1.00	1	60	A
Level 1, Test 6	No	600	0.50	30	2	A
Level 1, Test 7	No	440	2.20	2	5	A
Level 1, Test 8	No	600	3.00	1.1	5	A
Level 1, Test 9	Yes	1000	5.00	0.4	5	B
Level 2, Test 3	No	600	7.00	5	1	B
Level 2, Test 4	No	600 max.	2.2 (at 600V)	15 min	1	B
Power Contact						
Level 2, Test 1	No	120, 277	25.00	15 min	1	B
Level 2, Test 2	No	600	60.00	5	1	B

*A = Must continue to operate after test.

B = Must not cause fire.

**Additional lightning requrements with respect to protection coordination are specified in GR-1089 issue 3. These shall be effective in January 2006.

Notes:

1 = May apply either Surges 1, 2, 4, 5 or Surges 3, 4, 5.

2 = This test is to be done on 12 tip-and-ring pairs simultaneously.

3 = Run test at 200, 400, and 600Vrms, and just below OV protective device breakover voltage.

4 = Surge applied to tip-and-ring pair simultaneously.

3

Standards Governing PSTN Equipment: GR-1089

Based on the best available information, Telcordia has written the GR-1089 standard to control the overstresses that can appear on PSTN. Equipment passing tests in this standard can be expected to operate satisfactorily on the PSTN, even when subjected to the overstresses discussed previously. Table 1 shows some of the GR-1089 requirements.

Note: Telcordia Technologies, formerly Bellcore, now publishes the GR-1089 and other relevant documents.

Protective Devices

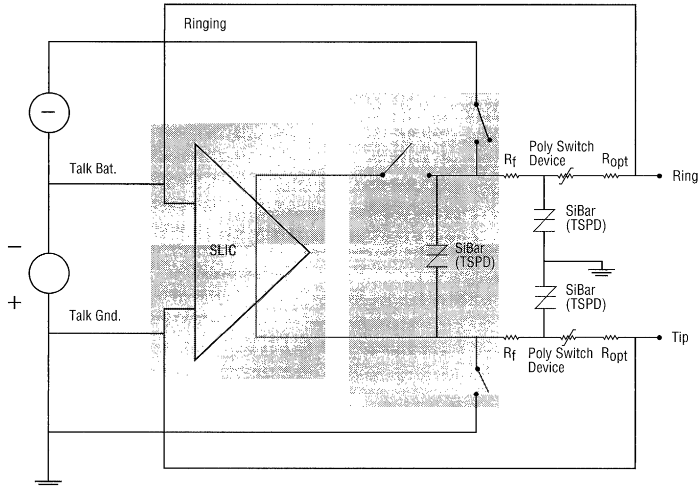
Protective devices are generally classed as current-limiting or voltage-limiting. *Current-limiting devices* are most important in protecting the equipment from long duration faults, during which joule heating can result in a fire hazard, or can damage thermally sensitive components. *Voltage-limiting devices* are intended to prevent dielectric breakdown of component or system insulation, which could cause high currents, arcing, and other potential hazards.

Current-limiting can be accomplished using a resistor, fuse, or PTC (positive temperature coefficient) device. Resistors are rarely an acceptable solution because an expensive high-power resistor is required. Specially designed fuses may be used; however, they are susceptible to nuisance tripping and must be replaced after operation. In addition, lightning robust fuses generally have a higher hold current than PTC devices, thereby letting through higher levels of fault current. The preferred solution is an active element, such as a PTC device, which has low resistance in normal operation and high resistance in fault states. These devices are self-resetting in that they return to normal operation after the fault has cleared and the power is removed from the circuit.

Overvoltage limiters can be either foldback devices or voltage clamping devices. Foldback devices switch to a very low impedance in the presence of an overvoltage event, diverting the fault current away from the protected circuit. Clamping devices pass only the current necessary to limit the voltage to the maximum allowed. Foldback devices are typified by thyristors, surge protector devices and gas discharge tubes. Clamping devices are commonly metal oxide varistors (MOVs) and avalanche diodes.

Figure 2. Simplified Example of a Line Card Design

(refer to Table 2 for recommended divice solution)



The use of an optional resistance R_{opt}, and a current-sensing feedback resistor R_f, is explained in Telcordia GR-1089.

Protection Design Example

Figure 2 illustrates a line-card design having an electronic network interface and on-board secondary protection. The interface is provided by a SLIC (subscriber line interface circuit) chip having an automatic line-balancing feature. The line-balancing feature requires a current-sensing resistance in tip-and-ring for operation.

The secondary protection consists of a series overcurrent limiter in both the tip and ring lines and secondary overvoltage-limiting device applied tip-to-ground and ring-to-ground. A third overvoltage device applied tip-to-ring is recommended in this application to provide improved protection from metallic surges.

PolySwitch TR600, TS600, or TSM600 devices have been designed to assist equipment designers in meeting the power induction and power cross requirements of GR-1089. SiBar TVBxxxSC thyristors have been designed to meet the lightning requirements of GR-1089 with no additional series impedance. The SC series thyristors are the preferred secondary overvoltage protection solution because of their high energy-handling capability, tight protection voltage specifications, low off-state power dissipation, low capacitance, and small size.

Telecom circuits can be protected by the combination of TSM600 PolySwitch devices and TVBxxxSC thyristors. No application resistance is needed (R_{opt}) to comply with all Telcordia GR-1089 requirements.

When designing with the PolySwitch TR600 or TS600 devices, an optional 10Ω, 2W resistor (labeled R_{opt} in Figure 2) is needed if the circuit is to be subjected to the GR-1089 Level 1, Surge 3 lightning test. However, the 10Ω resistor R_{opt} may be omitted if the Level 1, Surge 1 and Surge 2 tests are used as allowed by the specification. If the TSM600 device is used, the circuit can be subjected to the GR1089 Level 1, Surge 3, lightning test with no additional series resistance. The current-sensing resistance is the sum of all the resistances in the feedback loop, which in this case comprises the sum of R_f, and the resistance of the TR600, TS600, or TSM600 device. A typical value for the required current-sensing resistance is 100Ω.

Assuming the nominal resistance of the TR600-160 is 8Ω, the feedback resistor Rf in this example needs to be 92Ω.

Since R_f is protected by the secondary protector, it does not need to withstand the GR-1089 lightning impulses. Instead, it needs to withstand only the I^2t let-through of the current-limiting device. The use of PolySwitch devices typically results in lower I^2t let-through energies than when comparative fuses are used. Therefore, smaller, less expensive resistors can be used in these applications.

Table 2. Recommended Protection Devices for GR-1089 Requirements

Requirement	Poly Switch Overcurrent Device	Additional Resistance	Si Bar Overvoltage (TSPD)
Fully resettable	TSM600-250	None	TVBxxxSC
Fully resettable Level 1, Surge 1, 2, 4, 5	TR600-160 or TS600-200*	None	TVBxxxSB TVBxxxSC
Fully resettable Level 1, Surge 3, 4, 5	TR600-160 or TS600-200*	10Ω**	TVBxxxSB TVBxxxSC
Non-resettable overcurrent	FT600	0Ω	TVBxxxSC

Low-resistance (–RA) and resistance-binned (–B-0.5) parts are available for applications where line balance is required.

** Recommended resistor: 10Ω, 2 watt, wirewound (Dale WSC-2 or equivalent).

Need for Coordinated Protection

The overcurrent protection device will protect the thyristor in case of power induction and power cross faults where the AC voltage exceeds the thyristor breakover voltage. GR-1089 tests such as Level 1, Test 3, and Test 4 are representative examples of such a situation. To prevent the thyristor from being damaged, it is important to coordinate the time-to-trip performance of the overcurrent protection device with the time-to-damage characteristic of the thyristor, ensuring that the overcurrent device reacts before the thyristor is damaged. Contact Raychem Circuit Protection if you require more detailed information on overcurrent and overvoltage device coordination.

When used in combination with other protective components, the TR600, TS600, TSM600, and TVB SiBar Thyristors series devices may be used to assist network equipment in meeting the protection requirements of GR-1089. Table 2 outlines some examples of how PolySwitch devices, fuses, resistors, and SiBar thyristors can be combined to meet Telcordia GR-1089 requirements.

Device Selection

The rated off-state operating voltage (V_{DM}) of the SiBar thyristor device must be greater than the system continuous operating voltage. This value is defined as the sum of the peak ringer (AC) voltage plus the DC battery voltage. Refer to SiBar Thyristor product section for more information.

PolySwitch TR600, TS600, and TSM600 devices may be obtained in low-resistance (–RA) and resistance-binned (–B-0.5) device ranges to achieve optimum tip-and-ring balance. See Section 4 or visit www.circuitprotection.com for more information on these options.

ITU-T Recommendations
Application Note

Telecommunication equipment has become ever more sensitive to overvoltage and overcurrent hazards on telephone lines. Conventional transformer-based architectures have been replaced by sensitive IC-based architectures. At the same time, the dependence on telecommunication systems and the increased competition between telecom operators has increased the need for highly reliable telecommunication network equipment with low maintenance costs.

Overvoltage and overcurrent hazards usually result from lightning, from transients induced by adjacent power lines, from direct contact with power lines, or from malfunctioning subscriber equipment. These hazards may destroy valuable network equipment and even cause injury to subscribers and maintenance personnel. The rising cost of advanced telecommunication system failure, the increase of unattended equipment in remote locations, and subscribers' high service expectations all make loss of a telephone line from overcurrent faults unacceptable. Consequently, a number of telecom equipment manufacturers have turned to resettable overcurrent protection devices, such as the PolySwitch device, and foldback devices, such as the SiBar device, in order to increase the reliability and safety of equipment and reduce the cost of maintenance.

The Problem
All network equipment is exposed to two types of electrical hazards. The first hazard results from natural lightning strikes that can sometimes directly hit a network, though more often they induce high-voltage spikes in the pair of telephone wires. These spikes can damage sensitive electronic equipment at either end of the network, and therefore they need to be shunted to ground by using overvoltage devices such as SiBar devices.

The second hazard comes from induced AC power currents or from direct AC power contact. If the voltage of an overcurrent event is below the breakover voltage of the overvoltage protection, the result is continuous current into the equipment, which can damage downstream electronic components. On the other hand, when the voltage of the overcurrent fault is higher than the breakover voltage of the overvoltage protection device, then the overvoltage device itself needs to be protected from prolonged exposure to high current. A PolySwitch overcurrent protection device used in conjunction with a SiBar device can provide protection against both events.

Industry Recommendations: ITU-T
In most of the world, network switching and transmission equipment manufacturers must meet requirements, such as those recommended by the ITU-T (Telecommunication Standardization Sector of the

International Telecommunication Union). The ITU-T issues publications and recommendations on the protection of telecommunication equipment. The most relevant ITU-T recommendations are listed in Table 1.

The continual evolution of telecommunication networks leads to the evolution of standards worldwide. The ITU-T committee will shortly publish a revised set of recommendations within the K series. Described in the following pages are some of the requirements included in the K.20 and K.21 recommendations.

Recommendation K.20, relating to telephone exchanges and similar switching centers, is summarized in Table 2 and Figures 1a, 1b, 1c, 2, and 3. The ITU-T distinguishes between unexposed and exposed areas. Unexposed areas have low lightning activity and relatively low soil resistivity. Cities often are classi-fied as unexposed areas. All other environments are classified as exposed areas (mainly rural areas). The equipment is usually expected to operate satisfactorily in both environments. The test conditions with agreed primary protection simulate proper functioning in the more severe environments.

Recommendation K.21 deals with subscribers' terminals and assumes that line protectors are fitted externally to the equipment in exposed areas. It is summarized in Table 3.

Upcoming modifications in the ITU-T K series recommendations

The ITU-T committee has been reviewing the K.20 and K.21 recommendations. Soon to be published is a new set of recommendations:

- **K.44** seeks to establish fundamental testing methods and criteria for the resistibility of telecommunication equipment to overvoltages and overcurrents for use by network operators and manufacturers. This recommendation is overarching and thus will not specify either test levels or particular acceptance criteria for specific equipment. The appropriate test levels and test points will be contained in the specific product family recommendations (K.20, K.21, K45).
- **K.20** will specify resistibility requirements and test procedures for telecommunication equipment installed in a telecommunication center.
- **K.21** will specify resistibility requirements and test procedures for telecommunication equipment installed in or on a customer premise.

Table 1. Most Relevant ITU-T Publications

Directives concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines.
Recommendation K.11 Principles of protection against overvoltages and overcurrents.
Recommendation K.12 Characteristics of gas discharge tubes for the protection of telecommunications installations.
Recommendation K.20 Resistibility of telecommunication switching equipment to overvoltages and overcurrents.
Recommendation K.21 Resistibility of subscribers' terminals to overvoltages and overcurrents.
Recommendation K.28 Characteristics of semiconductor arrestor assemblies for the protection of telecommunications installations.
Recommendation K.30 Characteristics of self-restoring current-limiting devices.
Recommendation K.36 Selection of protective devices.
Recommendation K.44 Resistibility of telecommunication equipment to overvoltages and overcurrents.
Recommendation K.45 Resistibility of access network equipment to overvoltages and overcurrents.

- **K.45** will specify resistibility requirements and test procedures for telecommunication equipment installed between a telecommunication center and customer premise.

Following either K.20, K.21, or K.45 is based on the type of grounding employed at the location of the equipment. For grounding recommendations related to K.20, K.21, and K.45 equipment, refer to recommendations K.27, K.31, and K.35 respectively.

Recommendations will include lightning, power induction, and power contact tests. These will include both "basic" and "enhanced" level tests, with optional higher power induction levels and a lightning coordination test. Resettable protection is required to meet the enhanced power contact test.

Please contact your local Raychem Circuit Protection representatives for the latest information on the status and timing of ITU-T regulatory changes.

Overcurrent Solution

PolySwitch overcurrent protection devices are positive temperature coefficient (PTC) devices that are resettable devices designed to protect sensitive telecommunications network equipment from overcurrent faults. When an overcurrent fault occurs, the resistance of a TR250, TC250, TS250, or TSV250 PolySwitch device increases from its base resistance, by several decades, to a much higher resistance, effectively isolating the fault. In its high-resistance state the surface

(continued on page 82)

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Table 2. Summary of ITU-T K.20, Resistability of telecommunications equipment installed in customer premises to overvoltage and overcurrents, Edition February 2000. This summary pertains to test conditions for ports connected to external symmetric pair cables.

	Test No.	Test Description	Test Circuit and Waveshape	Basic Test Levels	Enhanced Test Levels	Number of Tests	Primary Protection	Acceptance Criteria
Single port lightning tests	1.1.a[1]	inherent longitudinal	Figure 1 and Figure 2 10/700 µs	$U_{C(MAX)}$ = 1.0 kV R = 25Ω	$U_{C(MAX)}$ = 1.5 kV R = 25Ω	5 of each polarity	None	A
	1.1.b[1]	inherent transverse	Figure 1 10/700 µs R = 25Ω	$U_{C(MAX)}$ = 1.0 kV Figure 3a & 3b R = 25Ω	$U_{C(MAX)}$ = 1.5 kV	5 of each	None polarity	A
	1.2.a[2]	coordination longitudinal	Figure 1 and Figure 2 10/700 µs	$U_{C(MAX)}$ = 4 kV R = 25Ω	$U_{C(MAX)}$ = 4 kV R = 25Ω	5 of each polarity	Special test protector (Note 3, next page)	A
	1.2.b[2]	coordination transverse	Figure 1 and Figure 3a & 3b 10/700 µs	$U_{C(MAX)}$ = 4 kV R = 25Ω	$U_{C(MAX)}$ = 4 kV R = 25Ω	5 of each polarity		During the test, the special test protector must operate at $U_C = U_{C(MAX)}$
Multiple port lightning tests	1.3[3]	inherent longitudinal	Figure 1 and Figure 4 10/700 µs	$U_{C(MAX)}$ = 1.5 kV R = 25 Ω	$U_{C(MAX)}$ = 1.5 kV R = 25 Ω	5 of each polarity	None	A
	1.4[4,5]	longitudinal	Figure 1 and Figure 4 10/700 µs	$U_{C(MAX)}$ = 4 kV R = 25Ω	$U_{C(MAX)}$ = 6 kV R = 25Ω	5 of each polarity	Agreed primary protector (Note 4, next page)	A
Lighting current tests	1.5[4,6]	Single port	8/20 µs current generator and Figure 2	I = 1 kA/wire R = 0Ω	I = 5 kA/wire R = 0Ω	5 of each polarity	None	A
	1.6[4,6]	Multiple port	8/20 µs current generator and Figure 4	I = 1 kA/wire Limited to 6 kA total R = 0Ω	I = 5 kA/wire Limited to 30 kA total R = 0Ω	5 of each polarity	None	A
Power induction tests	2.1.a[1]	inherent longitudinal and earth potential rise	Figure 5 and Figure 2	$W_{SP(MAX)}$ = 0.2 A^2s Frequency = 16 2/3, 50 or 60 Hz $U_{A.C.(MAX)}$ = 600 V	$W_{SP(MAX)}$ = 0.2 A^2s Frequency = 16 2/3 50 or 60 Hz $U_{A.C.(MAX)}$ = 600 V	5	None	A
	2.1.b[1]	inherent transverse	Figure 5 and Figure 3a & 3b	R = 600Ω t = 0.2 s	R = 600Ω t = 0.2 s	5	None	A
	2.2.a[2]	inherent/ coordination longitudinal and earth potential rise	Figure 5 and Figure 2	$W_{SP(MAX)}$ = 1 A^2s Frequency = 16 2/3, 50 or 60 Hz $U_{A.C.(MAX)}$=600 V R = 600Ω	$W_{SP(MAX)}$ = 10 A^2s Frequency = 16 2/3, 50 or 60 Hz $U_{A.C.(MAX)}$=1500 V R = 200Ω	5	Special test protector (Note 3, next page)	A
	2.2.b[2]	inherent/ coordination transverse	Figure 5 and Figure 3a & 3b	t = 1.0 s (Note 1, next page)	$t_{(MAX)}$ = 2 s (4-1/K.20) (Note 2, next page)	5		A
Mains power contact tests	3.1.a[7,8]	longitudinal	Figure 5 and Figure 2	$U_{A.C.}$ = 230 V Frequency = 50 or 60 Hz t = 15 min for each test resistor R = 10, 20, 40, 80, 160, 300, 600 and 1000Ω.	$U_{A.C.}$ = 230 V Frequency = 50 or 60 Hz t = 15 min for each test resistor R = 10, 20, 40, 80, 160, 300, 600 and 1000Ω	1	None	For basic level: Criterion B. For enhanced level: Criterion A for test resistors 160, 300 and 600 W, Criterion B for the other resistor
	3.1.b[7,8]	transverse	Figure 5 and Figure 3a & 3b	See acceptance criteria column.	See acceptance criteria column.	1	None	

[1] This test does not apply when the equipment is designed to be always used with primary protection.
[2] When the equipment contains high current carrying components which eliminate the need for primary protection, refer to 10.1.1/K.44.
[3] The multiple port test is simultaneously applied to 100% of the ports, limited to a maximum of 8 ports. This test does not apply when the equipment is designed to be always used with primary protection.
[4] The multiple port test is simultaneously applied to 100% of the ports, limited to a maximum of 8 ports.
[5] When the equipment contains high current carrying components which eliminate the need for primary protection, do not remove these components and do not add primary protection.
[6] This test only applies when the equipment contains high current carrying components which eliminate the need for primary protection.
[7] Refer to I.1.4 of K.44/Appendix I for guidance on performing this test.
[8] When the equipment is designed to be always used with primary protection, perform this test with the special test protector.

Note 1: The test conditions for the Test 2.2 (basic test level) may be adapted to the local conditions, by variation of the test parameters within the following limits, so that I^2t equal to = 1 A^2s is fulfilled: $U_{A.C.(MAX)}$ = 300 V........600 V, selected to meet local conditions; t≤1.0 s, selected to meet local conditions; R≤600 W, is to be calculated according to equation 1:

$$R = U_{A.C.(MAX)}\sqrt{\frac{t}{1A^2s}}$$

Note 2: For Test 2.2 (enhanced test level), the equipment shall comply with the specified Criterion for all voltage/time combinations bounded (on and below) by the 10 A^2s voltage/time curve defined by equation 1 and boundary conditions in 2.1.a through 3.1.b in Table 2.

Note 3: Special test protector is a component or circuit used to replace the agreed primary protector for purposes of confirming coordination. More information can be found in ITU-T K.44 section 8.4.

Note 4: Agreed primary protection is a type of surge protective device that is used to protect the equipment based on an agreement between manufacturer and the network operator. The agreed primary protection can be nothing if it has been agreed that no external protection elements need to be used. More infomation can be found in ITU-T K.44.

Table 3. Summary of ITU-T K.21, Resistability of telecommunications equipment installed in customer premises to overvoltage and overcurrents, Edition October 2000. This summary pertains to test conditions for ports connected to external symmetric pair cables.

	ITU Test No.	Test Description	Test Circuit and Waveshape	Basic Test Levels	Enhanced Test Levels	Number of Tests	Primary Protection	Acceptance Criteria
Single port lightning tests	1.1.a[1]	inherent longitudinal	Figure 1 and Figure 2 10/700 µs	$U_{C(MAX)} = 1.5$ kV R = 25Ω	$U_{C(MAX)} = 6$ kV R = 25Ω	5 of each polarity	None	A
	1.1.b[1]	inherent 10/700 µs	Figure 1 and transverse R = 25Ω	$U_{C(MAX)} = 1.5$ kV Figure 3a & 3b R = 25Ω	$U_{C(MAX)} = 1.5$ kV	5 of each	None polarity	A
	1.2.a[2]	coordination longitudinal	Figure 1 and Figure 2 10/700 µs	$U_{C(MAX)} = 4$ kV R = 25Ω	$U_{C(MAX)} = 6$ kV R = 25Ω	5 of each polarity	Special test protector (Note 3, next page)	A During the test, the special test protector must operate at $U_C = U_{C(MAX)}$
	1.2.b[2]	coordination transverse	Figure 1 and Figure 3a & 3b 10/700 µs	$U_{C(MAX)} = 4$ kV R = 25Ω	$U_{C(MAX)} = 6$ kV R = 25Ω	5 of each polarity		
Multiple port lightning tests	1.3[3]	inherent longitudinal	Figure 1 and Figure 4 10/700 µs	$U_{C(MAX)} = 1.5$ kV R = 25 Ω	$U_{C(MAX)} = 1.5$ kV R = 25 Ω	5 of each polarity	None	A
	1.4[4,5]	longitudinal	Figure 1 and Figure 4 10/700 µs	$U_{C(MAX)} = 4$ kV R = 25Ω	$U_{C(MAX)} = 6$ kV R = 25Ω	5 of each polarity	Agreed primary protector (Note 4, next page)	A
Lighting current tests	1.5[4,6]	Single port	8/20 µs current generator and Figure 2	I = 1 kA/wire R = 0Ω	I = 5 kA/wire R = 0Ω	5 of each polarity	None	A
	1.6[4,6]	Multiple port	8/20 µs current generator and Figure 4	I = 1 kA/wire Limited to 6 kA total R = 0Ω	I = 5 kA/wire Limited to 30 kA total R = 0Ω	5 of each polarity	None	A
Power induction tests	2.1.a[1]	inherent longitudinal and earth potential rise	Figure 5 and Figure 2	$W_{SP(MAX)} = 0.2$ A²s Frequency = 16 2/3, 50 or 60 Hz $U_{A.C.(MAX)} = 600$ V	$W_{SP(MAX)} = 0.2$ A²s Frequency = 16 2/3 50 or 60 Hz $U_{A.C.(MAX)} = 600$ V	5	None	A
	2.1.b[1]	inherent transverse	Figure 5 and Figure 3a & 3b	R = 600Ω t = 0.2 s	R = 600Ω t = 0.2 s	5	None	A
	2.2.a[2]	inherent/ coordination longitudinal and earth potential rise	Figure 5 and Figure 2	$W_{SP(MAX)} = 1$ A²s Frequency = 16 2/3, 50 or 60 Hz $U_{A.C.(MAX)}$=600 V R = 600Ω	$W_{SP(MAX)} = 10$ A²s Frequency = 16 2/3, 50 or 60 Hz $U_{A.C.(MAX)}$=1500 V R = 200Ω	5	Special test protector (Note 3, next page)	A
	2.2.b[2]	inherent/ coordination transverse	Figure 5 and Figure 3a & 3b	t = 1.0 s (Note 1, next page)	$t_{(MAX)} = 2$ s (4-1/K.20) (Note 2, next page)	5		A
Mains power contact tests	3.1.a[7,8]	longitudinal	Figure 5 and Figure 2	$U_{A.C.} = 230$ V Frequency = 50 or 60 Hz t = 15 min for each test resistor R = 10, 20, 40, 80, 160, 300, 600 and 1000Ω.	$U_{A.C.} = 230$ V Frequency = 50 or 60 Hz t = 15 min for each test resistor R = 10, 20, 40, 80, 160, 300, 600 and 1000Ω	1	None	For basic level: Criterion B. For enhanced level: Criterion A for test resistors 160, 300 and 600 W, Criterion B for the other resistor
	3.1.b[7,8]	transverse	Figure 5 and Figure 3a & 3b	See acceptance criteria column.	See acceptance criteria column.	1	None	

[1] This test does not apply when the equipment is designed to be always used with primary protection.

[2] When the equipment contains high current carrying components which eliminate the need for primary protection, refer to 10.1.1/K.44.

[3] The multiple port test is simultaneously applied to 100% of the ports, limited to a maximum of 8 ports. This test does not apply when the equipment is designed to be always used with primary protection.

[4] The multiple port test is simultaneously applied to 100% of the ports, limited to a maximum of 8 ports.

[5] When the equipment contains high current carrying components which eliminate the need for primary protection, do not remove these components and do not add primary protection.

[6] This test only applies when the equipment contains high current carrying components which eliminate the need for primary protection.

[7] Refer to I.1.4 of K.44/Appendix I for guidance on performing this test.

[8] When the equipment is designed to be always used with primary protection, perform this test with the special test protector.

[9] If the inherent protection of the port under test contains surge protective devices that are connected to ground, $U_{C(MAX)}$ of 1.5 kV shall be used instead of 6 kV

[10] If equipment has an insulted case, the 6 kV test is applied with equipment wrapped in conductive foil and the foil is connected to the generator return.

Note 1: The test conditions for the Test 2.2 (basic test level) may be adapted to the local conditions, by variation of the test parameters within the following limits, so that I^2t equal to = 1 A^2s is fulfilled: $U_{A.C.(MAX)}$ = 300 V........600 V, selected to meet local conditions; t≤1.0 s, selected to meet local conditions; R≤600 W, is to be calculated according to equation 1:

$$R = U_{A.C.(MAX)} \sqrt{\frac{t}{1A^2s}}$$

Note 2: For Test 2.2 (enhanced test level), the equipment shall comply with the specified Criterion for all voltage/time combinations bounded (on and below) by the 10 A^2s voltage/time curve defined by equation 1 and boundary conditions in 2.1.a through 3.1.b in Table 3.

Note 3: Special test protector is a component or circuit used to replace the agreed primary protector for purposes of confirming coordination. More information can be found in ITU-T K.44 section 8.4.

Note 4: Agreed primary protection is a type of surge protective device that is used to protect the equipment based on an agreement between manufacturer and the network operator. The agreed primary protection can be nothing if it has been agreed that no external protection elements need to be used. More infomation can be found in ITU-T K.44.

Figure 1. ITU-T K.44 0/700 µs Voltage Surge Generator

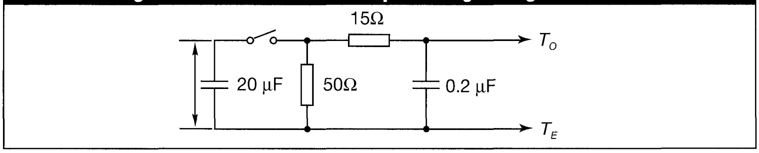


Figure 2. Example of Test Circuit for Longitudinal Overvoltage or Overcurrent Tests on a Single Port

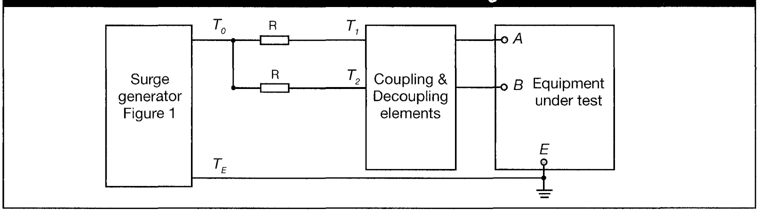


Figure 3a. Example of Test Circuit for Tranverse Overvoltage or Overcurrent Tests on Single Port—Terminal A to Ground

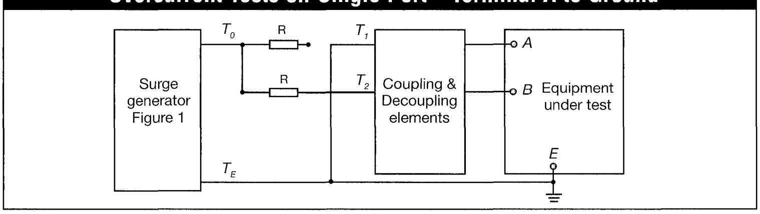


Figure 3b. Example of Test Circuit for Tranverse Overvoltage or Overcurrent Tests on Single Port—Terminal B to Ground

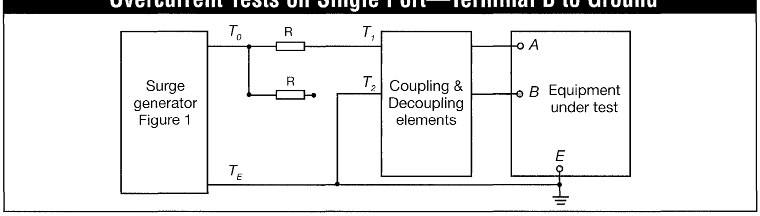


Figure 4. Example of Test Circuit for Longitiudinal Overvoltage and Overcurrent Tests on Multiple Ports

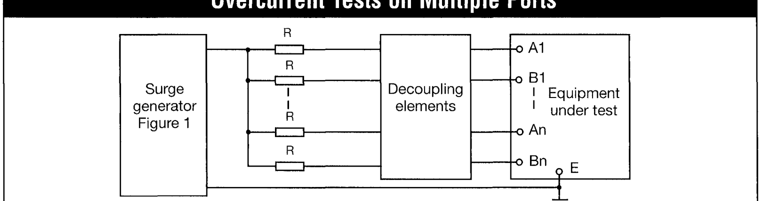
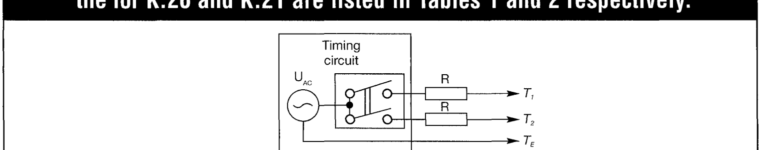


Figure 5. Power Induction, Power Contact and rise of nuetral potential generator. Appropriate values for current limiting resistors, R, are listed in the for K.20 and K.21 are listed in Tables 1 and 2 respectively.



temperature of the device will be approximately 120°C. A small trickle current will maintain the PolySwitch device in its high-resistance state, dissipating little power. Once the fault condition and power are removed, the PolySwitch device—unlike a fuse—will reset to a low impedance state so normal telephone operation can resume.

Fast Tripping

At currents between 200 and 350mA, PolySwitch 250V devices will trip before damage to the line interface can occur. PolySwitch devices, however, are not tripped by lightning-induced transients. Most alternate solutions, like fuses, that are lightning robust will not trip until an overcurrent fault of more than 500mA exists, allowing a much larger current to pass into the subscriber line interface card (SLIC). This higher level can damage telecommunication equipment.

PolySwitch devices typically trip faster than ceramic PTC devices, limiting power let-through and allowing downstream electronic components such as secondary overvoltage devices and resistors to be sized smaller.

Small Size, Multiple Form Factors

PolySwitch devices are typically smaller than ceramic PTC devices for a given resistance. Furthermore, they can be supplied as surface-mount, radial-leaded, and chip-form factors to fit the stringent space requirements of compact protection modules and tightly packed PC boards.

Overvoltage Solution

SiBar thyristors overvoltage protectors are foldback devices which have the current-voltage curve shown in Figure 4. The device is normally in a "high resistance" state for voltages below the breakover voltage. In this state very little current flows through the device when voltage is across the device. When the voltage exceeds the breakover voltage, the device "folds back", creating a low-impedance path and effectively shorting out the overvoltage condition. The device will remain in this low-impedance state until the current through the device is decreased below its hold rating. SiBar devices are designed so that the I_{HOLD} of the device is typically >200mA, above the maximum loop current in the telecom system. After an overvoltage event has passed, the device can reset to its high-impedance state and allow normal system operation to occur.

For a given fault current, the power dissipated in a thyristor is much smaller than a clamp device such as a metal oxide varistor or an avalanche diode, since the voltage across the fold-back device will be smaller. This allows the device to be smaller. The smaller size results in lower capacitance, which is highly desirable for higher speed communication equipment. The silicon-based device allows the breakover voltage to be accurately set, and it will not degrade after multiple fault events. The SiBar devices are supplied in an SMB surface-mount package to meet the space requirements of densely packed electronic boards.

Application

Figure 5 displays a typical protection system employed by network equipment manufacturers in order to comply with ITU-T K.20 requirements. The SiBar device protects the sensitive electronics from fast overvoltage events, including lightning transients. The line feed resistor serves the purpose of regulating the steady-state current to the telephone.

The 250V families of PolySwitch devices provide current limiting that may be required during power contact events that have a voltage lower than the fold-back voltage of the SiBar device. Additionally, the base resistance of the PolySwitch device limits the current during events that exceed the foldback voltage of the SiBar device, thus enabling the SiBar device to survive.

Figure 6. Current-Voltage Curve of a SiBar Foldback Device

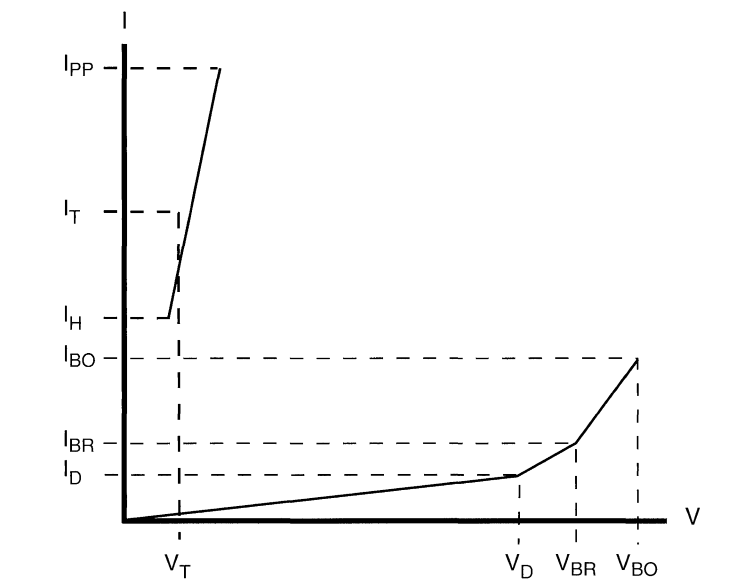


Figure 7. Typical Protection System for Network Equipment

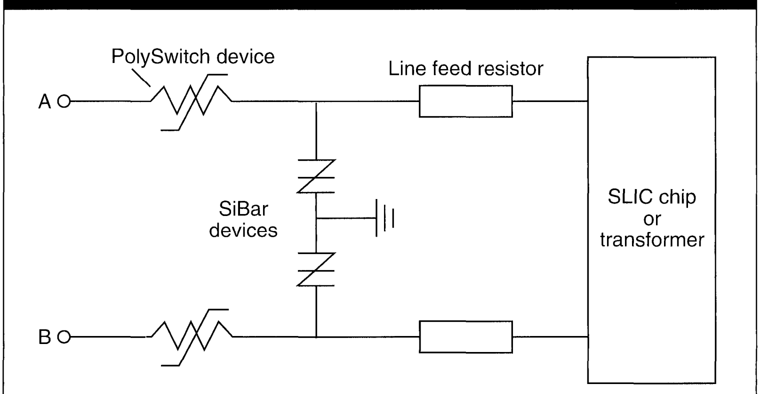


Table 4.
Summary of Field Studies Showing 50/60-Hz AC Overcurrent Faults

Study Location (Author)	Frequency of 50/60 Hz Faults	Characteristics of Faults
Canada (Bell Canada)		Average voltage: 300V
USA (AT&T)		Average voltage: 371V; average current: 2.71A
USA (BellSouth)		Average voltage: 300V
Italy (SIP)		Average voltage: 430V; average current: 2.35A
France (FranceTelcom)	7.3 events per line per year	75% of voltage below 200V
Australia (Telstra)	5 events per line per year	95% of voltage below 600V peak. 98.7% of current below 5A peak.

Table 5. PolySwitch Devices for ITU-T Requirements

Device	I_{hold} (mA)	Resistance (Ω)	Typical Trip Time at 1A (s)
TGC250-120T	120	8.0–13.0	0.6
TR250-120	120	4.0–8.0	1.5
TR250-120T	120	6.0–10.5	0.6
TS250-130	130	6.5–12.0	1.5
TSV250-130	130	4.0–7.0	2.0
TR250-145	145	3.0–6.0	2.0
TR250-180	180	0.8–2.0	10.5

PolySwitch Device Benefits

When a PolySwitch device is installed in the circuit, it provides two important advantages. First, it protects the line feed resistors from overheating. Without a PolySwitch device, during AC sneak current events (that is, currents in the 200mA to 1A range), these resistors do not fuse open. They typically overheat and can damage the circuit board. If a PolySwitch device is installed, it limits the sneak current and prevents overheating of the line feed resistor.

Second, network equipment manufacturers and network operators have to provide a highly reliable telecommunication service, with minimal loss of system availability and minimal maintenance costs. If nonresettable overcurrent protection is used, even after the overcurrent fault is cleared, the circuit will be out of service, and a service technician will have to be dispatched to change the line card or subscriber's terminal. However, with a PolySwitch resettable device, the circuit will reset and telephone service will resume without need for repair or a service call.

The most probable range of overcurrent hazards as measured in field studies is shown in Table 4. Typical currents measured are from 350mA up to 5A.

Device Selection

As described in Figure 5, use of the PolySwitch device requires coordinated design between the line feed resistor, the secondary overvoltage protection device, and the SLIC circuit. Please refer to the TR, TS, TSV product line data for specific information on resistance, switching speed, dimensions, and current and voltage ratings. Please refer to the TVB data section of this Databook for specific information on SiBar devices.

Table 5 shows the most important characteristics of the PolySwitch 250V devices. All of these devices (TR250, TS250, TSV250) are rated to interrupt ITU power faults. Upon inspection of Tables 2 and 3, one notes tests conducted with and without primary protection in place. SiBar TVBxxxSA devices are rated at 50A under a 10/1000-µs waveform. This device rating exceeds all surge currents obtainable under ITU K.20 and K.21 lightning test without primary protection in place. When a primary protector is in place, sufficient line impedance (resistance and/or inductance) must be in place between the primary overvoltage protector and the secondary overvoltage protector to ensure that the primary protector operates under the lightning test.

SiBar devices used in conjunction with TR250, TC250, TS250, and TSV250 devices will assist the designer in meeting the power induction and power contact test conditions specified by ITU K.20 and K.21. The appropriate PolySwitch device and SiBar device must be evaluated and tested for each application.

Hundreds of Millions of Lines Protected

PolySwitch devices are in use all over the world, as resettable overcurrent protection elements in central office switching equipment, digital loop carriers, primary protection modules, subscriber protection equipment, PBXs, and subscriber equipment. A number of newer technologies—such as ADSL modems, T1 repeaters, ISDN lines, and others—have also included PolySwitch resettable device protection.

SiBar devices are designed to assist in meeting the overvoltage requirements of ITU K.20 and K.21 and can be used in secondary applications where PolySwitch devices are currently being used. Please refer to the SiBar-TVB product line data for information and check with your local Raychem Circuit Protection representative.

Short-haul/Intrabuilding Protection Requirements
Application Note

Problem/Solution
The need for data exchange, either locally or over the Internet, has led to a rapid proliferation of intrabuilding communication systems in enterprise, industrial, and residential environments.

Enterprise environments and global local network connectivity systems are rapidly proliferating. These systems interconnect data-based systems, digital telephones using Voice over Internet Protocol (VoIP), the Public Switched Telephone Network (PSTN), and company controlled Wide Area Network (WAN) and others shown in Figure 1 are separated from the external environment by gateways, routers, and switches. More recently wireless networks receivers can also provide access for a business without any physical connection to the PSTN. In the consumer or residential environment, cable-based systems are now available which can provide telephony service through VoIP, again without connecting directly to the PSTN. Circuit protection for this equipment might be different from that for conventional network or customer premise equipment.

In the industrial plant, RS-485 and RS-232 data communications systems provide control and feedback from centralized controllers to remote equipment, frequently through unshielded twisted pair wires. Communications systems in general need to be protected from

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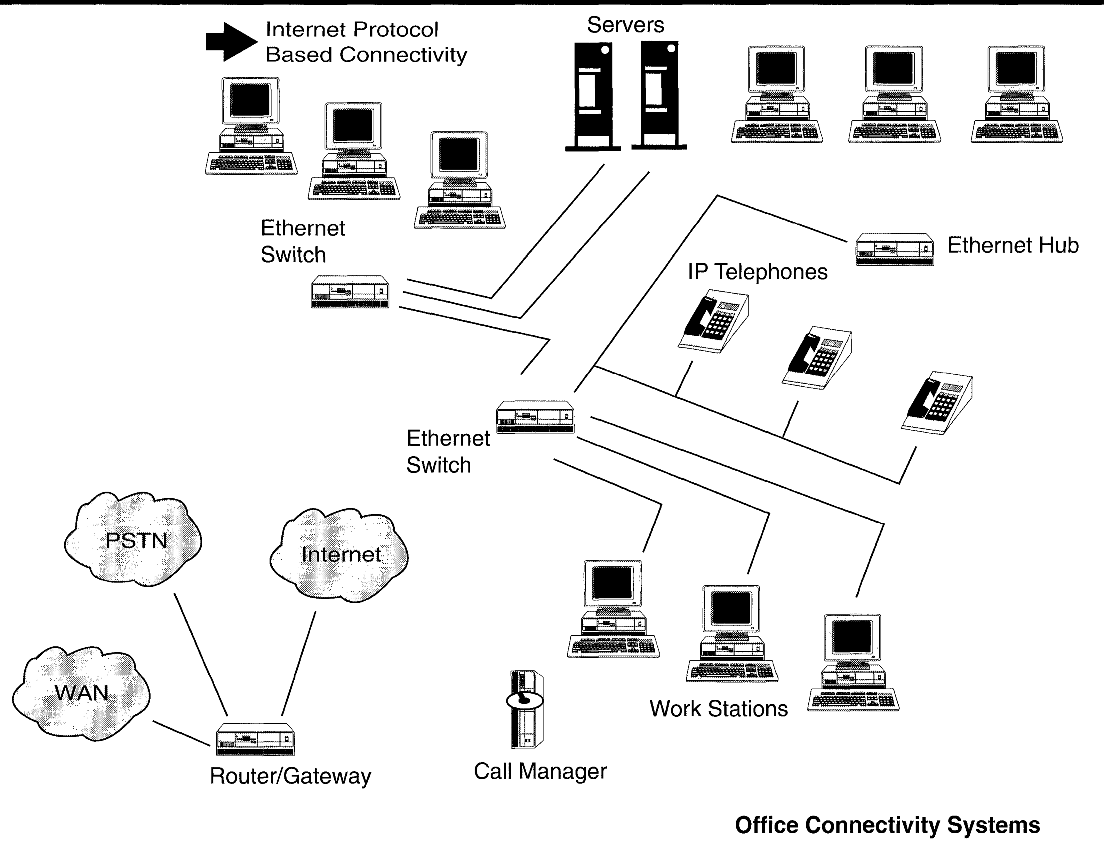
Figure 1. Emerging Enterprise Connectivity Systems Illustrating Intrabuilding Circuit Protection Applications



three basic hazards: power contact, power induction, and lighting. PolySwitch resettable devices and SiBar TSPDS (Thyristor Surge Protection Devices) are available to protect equipment against such faults.

Potential Hazards

While power contact or power induction from interaction with the medium voltage distribution system is not an issue, accidental power cross with low voltage power lines, e.g. 120V or 240V, can be a common occurrence, especially during the initial installation. It is common to hear of industrial data communications lines being miswired with AC power, or an errant staple from a staple gun inadvertently crossing the AC power line and the LAN line. Though not as severe as a power contact with distribution voltages, accidentally applying AC mains voltage to a communications line can create a serious safety hazard and damage or destroy expensive communications equipment.

The threat of lightning in intrabuilding installations is also less severe than for externally connected equipment, but still may present a hazard. Most buildings, especially those in high lightning areas, typically contain a lightning rod or other lightning protection scheme used to shunt direct or induced lightning strikes to ground and thus reduce the interaction with other conductors within the building. Though much less severe than lightning on external lines, overvoltages may still be induced in intrabuilding communications lines when lightning strikes are shunted through these lightning protection systems. Without protection, equipment connected to these lines can be damaged or destroyed and create a safety hazard as well.

Telcordia Intrabuilding Protection Requirements

Residing within the GR-1089-CORE specification published by Telcordia Technologies, (formerly Bellcore), are a set of requirements specifically meant for intrabuilding installations.

The requirements derive from the need to protect customer-resident networking equipment from the AC mains voltage power cross and induced lightning hazards as previously described. Table 1 on page 88 summarizes the key specification elements. These tests apply to a wide range of equipment. Telcordia GR-1089 specifies that: "paired-conductor interface ports shall be tested regardless of what type of traffic they carry or what function they perform. For example, 10 BaseT and 100 BaseT Ethernet and other ports are considered telecommunications ports and shall be tested".

The lightning tests are applied either as a "metallic" waveform, i.e. using a potential difference tip-to-ring, or "longitudinal," i.e. using a potential difference tip-to-ground and ring-to-ground. The lightning waveform should have a rise time of 2µsec and a time-to-half of 10µsec with a short-circuit current of 100A. For each longitudinal and metallic test, one surge is applied using positive voltage and one using negative voltage. The equipment must meet failure criterion A, i.e. it must continue to operate after the test. For example, if a fuse is used in the equipment it is not allowed to open during the test. If a generator capable of producing 2/10µsec surges is not available, an 8/20µsec open-circuit voltage waveform including an additional 6Ω resistor for Surge 1 or 12Ω resistor for Surge 2 may be substituted.

The power contact test comprises a single 120V/25A short-circuit surge applied for 15 minutes. The equipment must meet failure criterion B, i.e. it must not cause a fire as measured by a cheesecloth fire indicator wrapped around the equipment. A "wiring simulator"—typically a 1.6A fuse for test purposes—is also applied in series with the equipment and must not operate during the test. The use of a wiring simulator ensures that the current limiting device can operate fast enough to protect conventional communications wiring from creating a fire hazard within the building.

While 120V is an appropriate test voltage for North American residential and business installations, higher mains voltages may be present in other countries or in certain industrial applications. In these circumstances, it may be appropriate to conduct the power contact test at 250V to cover these applications.

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[1] These tests apply to a wide range of equipment and GR-1089 specifies that paired-conductor interrface ports shall be tested regardless of what type of traffic they carry or what function they perform. For example, 10 baseT and 100 baseT ethernet and other similar ports are considered telecommunications ports and should be tested.

Table 1. Summary of North America Intrabuilding Test Requirements

Spec Type and Level	Connection	Open Circuit Wave Form (µsec)	Open Circuit Voltage (V)	Short-Circuit Current (A)	Number of Surges	Test Results*	Note**
Lightning							
Surge 1	Metallic	2/10	800	100	± 1	A	1
Surge 2	Longitudinal	2/10	1,500	100	± 1	A	1
Spec type and level	**Primary Protection**	**Open Circuit Voltage (V)**	**Short-Circuit Current (A)**	**Duration Min.**	**Number of Surges**	**Test Results***	**Note****
Power Contact Level 2, Test 1	No	120	25	15 min	1	B	2

Note: * A = Must continue to operate after test.
B = Must not cause fire. Also, for equipment located on customer premise, a wiring simulator e.g. Bussman MDQ 1.6A fuse shall not open during the test.

** 1) Alternatively, a 1.2/50µsec (open-circuit voltage) and 8/20µsec short-circuit current waveshape may be used. Same voltages are used–current is limited by a 6Ω resistor for test 1 and 12Ω resistor for test 2.

2) Equipment containing a current-limiting device is to be tested as indicated, and repeated using an available short-circuit current just below the operating threshold of the current-limiting device. Alternatively, if a fuse is used it may be bypassed and the equipment tested at 135% of the rated fuse current.

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Though not shown directly in the Table, Note 2 describes an important additional test which should be carried out if the equipment contains a current-limiting or overcurrent-protective device such as a fuse. In this situation, a power contact test is applied at 120V (or 250V) and a current just below the operating current of the current-limiting device. As an alternative test procedure, the specification states that the fuse can be bypassed and the equipment tested at 135% of the rated fuse current. For other current-limiting devices, it may be appropriate to use a slightly different current, as will be described later. In either case, the objective is to test the impact on the equipment of a fault current just below the operating point of the current limiting device.

ITU Recommendations

Neither ITU-T Recommendations K.20 or K.21 contains specific reference to intrabuilding protection applications. However, Appendix A to K.21 describes one of the purposes of the Recommendation as providing resistibility of equipment to “direct contacts between telecommunications lines and power lines, usually of a low voltage nature” and “surges due to direct and indirect lightning strikes on or near the line plant.”

In this regard the power contact test of ITU-T K.21 is particularly relevant to intrabuilding applications. This test comprises application of mains voltage (230V or as appropriate to the local power system) to the telecom terminals of the equipment for 15 minutes per the circuit diagram shown in Figure 2. The recommended pass-fail criteria is that the equipment should not create a fire hazard as a result of the test.

The resulting current-voltage conditions for equipment per ITU-T K.21 power contact test are essentially identical to those contained in the Bellcore Intrabuilding Specification at our recommended higher voltage. From Figure 2, assuming U_{AC} of 250V is applied to the 10Ω circuit impedance, this will produce a short-circuit fault current of 250V/10Ω = 25A, identical to that of the Bellcore specification. A summary of the recommended power contact test is shown in Table 2.

Intrabuilding Protection Solutions

PolySwitch TR250, TS250, TSL250, and TSV250 devices may be used to help meet both the Telcordia and ITU power contact requirements described in Table 2. Raychem Circuit Protection’s SiBar families of thyristor surge protectors (see section SiBar Thyristor) all meet the lightning requirements previously described in Table 1.

Recommended intrabuilding protection solutions are provided for a cable-based telephony system (See Figure 3) and for a linecard or grounded CPE interface (See Figure 4). As described above, a TR250-120, TS250-130, TSV250-130, or TSL 250-080 device and TVBxxxSA devices meet the requirements of the intrabuilding power cross and lightning requirements, respectively.

Figure 2. ITU-T K.21 Test Circuit for Power Contact

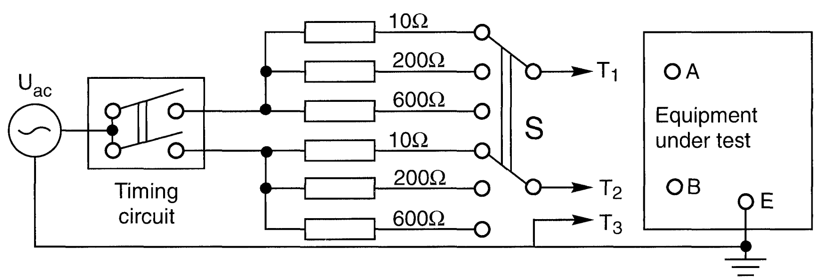

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Table 2. Summary of Power Contact Test Procedures

Spec Type and Level	Open Circuit Voltage	Short-Circuit Current	Duration	Number of Surges	Test Results
Power Contact GR-1089 and ITU-T	250V	25A	15 min.	1	- No fire hazard - Wiring simulator does not open
Note 2 GR-1089	250V	Just below operating point of current-limiting device: - 135% of fuse rated current - 200% of PTC hold current	15 min.	1	- No fire hazard - Wiring simulator does not open

For multi-line applications, such as might be implemented for an apartment building or multi-family dwelling, identical protection is recommended for each twisted pair.

PolySwitch devices are available in both surface-mount (TS250 and TSV250-series) and radial-leaded (TR250-series) form factors. Additional hold currents are available for applications requiring faster time-to-trip or higher holding currents.

Device Selection

Telecommunications equipment which does not interface with the PSTN can have special protection needs. The Bellcore Intrabuilding Specification and a portion of ITU-T Recommendation K.21 provide a set of recommendations for protecting such equipment, examples of which include industrial data communications systems, equipment connected to LANs (e.g. routers and switches), WLL transceivers, and cable-based telephony systems.

TR250, TS250, TSL250, and TSV250 PolySwitch devices can be used with TVBxxxSA SiBar components or other applicable overvoltage protection to meet these needs. Correct selection and implementation of such protection can provide a coordinated, fully resettable solution which helps protect equipment against hazardous real-world fault conditions.

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Figure 3. Fully Resettable Protection Solution for Cable-based Telephony System

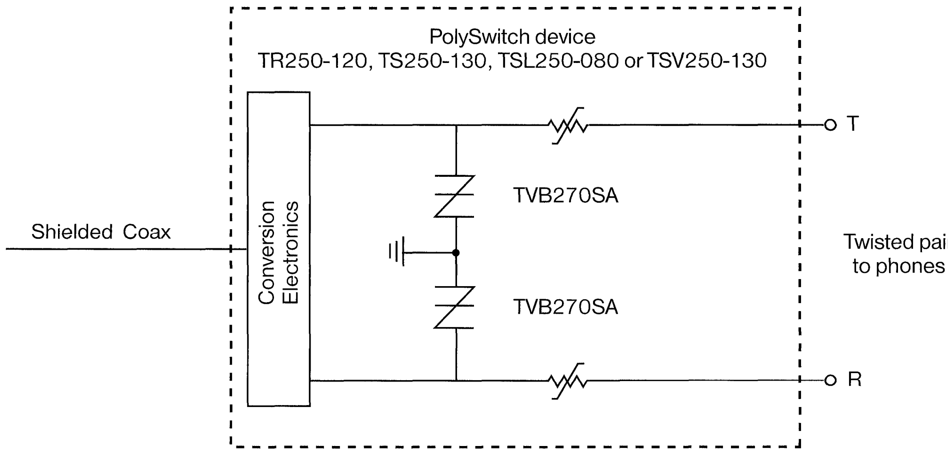
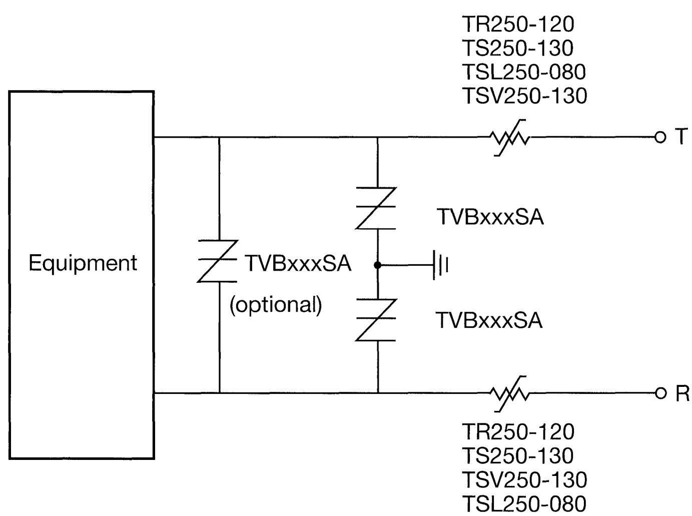


Figure 4. Linecard or Grounded CPE Protection



Customer Premise Equipment
Application Overview

Problem/Solution
Customer premise equipment (CPE), also known as subscriber equipment, includes any equipment that is connected to the telecommunications network and located at a customer's site. Examples of CPE include: 56k modems, cable modems, ADSL modems, phone sets, fax equipment, answering machines, POS equipment and PBX systems.

Since CPE equipment connects to the copper infrastructure of the Public Switched Telephone Network (PSTN), it is subject to overcurrent and overvoltage hazards from AC power cross, power induction, and lightning surges which may appear on the premise wiring. If left unprotected from these hazards, CPE may fail to operate or may risk the safety of subscribers and maintenance personnel. PolySwitch resettable devices and SiBar thyristors provide coordinated resettable protection against these faults, thereby protecting equipment from damage and minimizing field services and warranty costs.

Typical Protection Requirements
In most cases, CPE is powered from the central office with nominal battary voltages around $-48V_{DC}$ and $90V_{RMS}$ ringing signals superimposed when needed. However, TIA-968-A does specify that a CPE system must be designed to also operate with $-56.6V_{DC}$ and a superimposed $150V_{RMS}$ simulated ringing signal. Thus, the actual system implementation must accommodate maximum voltages as high as $268.8V_{PEAK}$—this in turn specifies the rating of the over-voltage device to have a V_{DM}<270V (see SiBar Thyristors section on pg. 339). Corresponding system loop currents typically fall in the 20–70mA range.

Customer premise equipment is generally ungrounded and therefore requiring only metallic protection architecture against lightning and AC power faults as shown in Figure 1. A PolySwitch device can provide overcurrent protection against AC power faults, and a SiBar Thyristor protection against lightning hazards. This interface circuit is generally placed directly behind the RJ-11 jack (or appropriate system interface) to protect downstream circuit components.

Figure 1. Generic CPE Interface

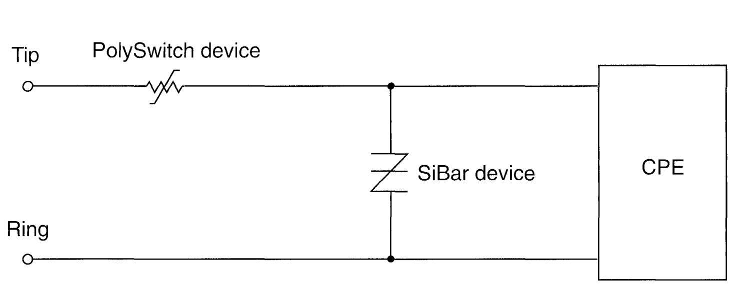
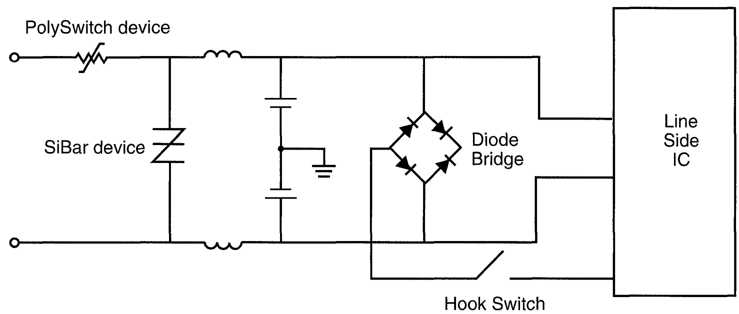


Figure 2 provides recommended protection circuitry for a modem interface, such as may be found on a 56k analog modem, cable modem, set-top box, POS terminal, or digital modem.

Device Selection for Agency Approval Requirements
Protection for customer premise equipment is typically designed to meet the requirements of UL60950 and TIA-968-A for North American use and of ITU-T K.21 for rest-of-world use. Overviews of the requirements for each of these standards can be found as application notes in this Databook.

PolySwitch devices should be selected with voltage ratings based on the regulatory standards for which the equipment is being designed. Surface-mount TS600 or TSM600 and radial-leaded TR600 devices are applicable for North American GR-1089 standards and for UL60950 standards, while surface-mount TS250 and TSV250 and radial-leaded TR250 products are applicable for ITU-T K.21 standards.

Figure 2. Modem Interface

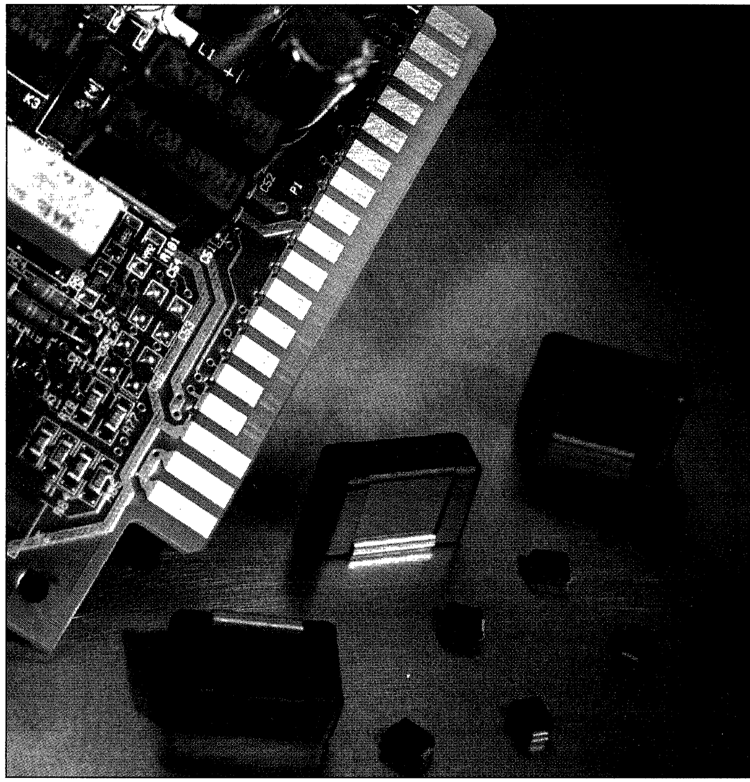


SiBar devices should be selected with surge current ratings based on the regulatory standards for which the equipment is being designed and with off-state voltage ratings based on normal system operation. SiBar thyristor devices with off-state voltage V_{DM} ratings of 270V are applicable for CPE equipment with maximum peak voltages up to $270V_{DM}$. For systems with lower expected voltages, designers should consult Section 4 for devices with lower voltage ratings.

Table 1. Recommended Circuit Protection Devices

Regulatory Standard	PolySwitch Device		SiBar Device
UL1459/UL60950, TIA-968-A, (formerly FCC Part 68)	TS600-170 TRF600-150	(SMT) (Thru-hole)	TVB270SA
ITU-T K.21	TS250-130 TSV250-130 TR250-120 TR250-145	(SMT) (SMT) (Thru-hole) (Thru-hole)	TVB270SA

Analog Linecards
Application Overview



Problem/Solution
Analog linecards are subject to overcurrent and overvoltage hazards from AC power cross, power induction, and lightning surges which may enter the central office via the copper wire infrastructure. Equipment damage and injury present safety concerns in case linecards are left unprotected from these hazards. PolySwitch resettable devices and SiBar thyristors provide matched resettable protection solutions against equipment damage and personnel injury.

Typical Protection Requirements
Typically, analog linecards have -45 to -65V_{DC} battery feeds and ringing signals ranging from 70–100V_{AC}, 20Hz superimposed on the line. Ringing may be integrated directly on the subscriber line interface circuit (SLIC) or may be provided by an external ring generator. Typically currents of 20-70mA are expected on the linecard. Most linecards are grounded and therefore, both longitudinal and metallic protection is required.

PolySwitch resettable devices in series with the tip-and-ring conductors serve to open the line under power cross and power induction conditions. Parallel SiBar overvoltage devices protect the card from damage due to excess voltage buildup such as induced by lightning or high-voltage power cross. On-hook (secondary) overvoltage protection design should account for both DC battery voltage and ringing voltages. Off-hook (tertiary) protection should be designed specifically for the ringing configuration used.

Figure 1 provides the recommended protection circuitry for an analog linecard with an external ring generator.

Figure 2 provides recommended protection circuitry for an analog linecard with an integrated ring generator.

Device Selection
Protection for network linecards is typically designed to meet the requirements of Telcordia GR-1089 for North American use and of ITU-T K.20 for rest of world use. Overviews of the requirements for each of these standards can be found as separate application notes in this Databook.

PolySwitch devices should be selected with voltage ratings based on the regulatory standards for which the equipment is being designed. Surface-mount TS600, TSM600-250, and radial-leaded TR600 devices are applicable for North American GR-1089 standards and for UL60950 standards, while surface-mount TS250, TSV250, TSU600 and radial-leaded TR250 devices are applicable for ITU-T K.20 standard and Telcordia GR-1089 intrabuilding/short-haul protection requirements. The surface-mount TSL250-080 device is also applicable for GR-1089 intrabuilding applications.

SiBar devices should be selected with surge current ratings based on the regulatory standards for which the equipment is being designed and with off-state voltage ratings based on normal system operation. SiBar thyristor devices with off-state voltage V_{DM} ratings of 270V are applicable for on-hook protection for equipment with maximum DC plus ringing voltages up to 270V peak. For systems with lower expected voltages, designers should consult Section 4 for lower voltage-rated devices.

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Figure 1. Analog Linecard with External Ring Generator

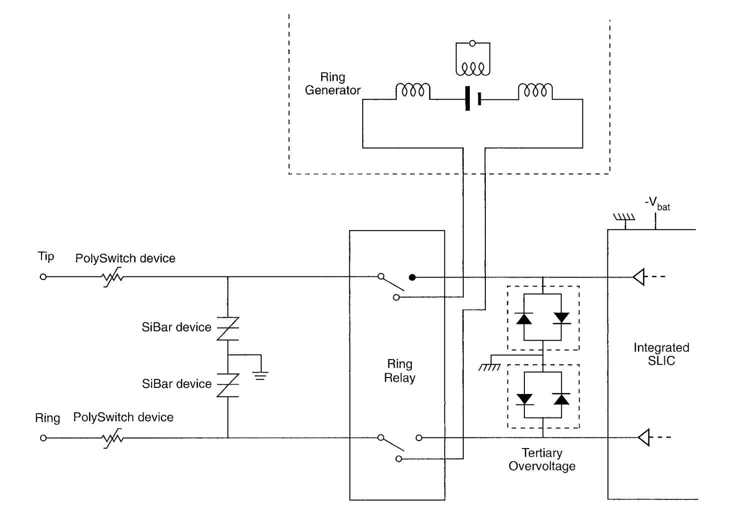


Figure 2. Analog Linecard with Integrated Ring Generator

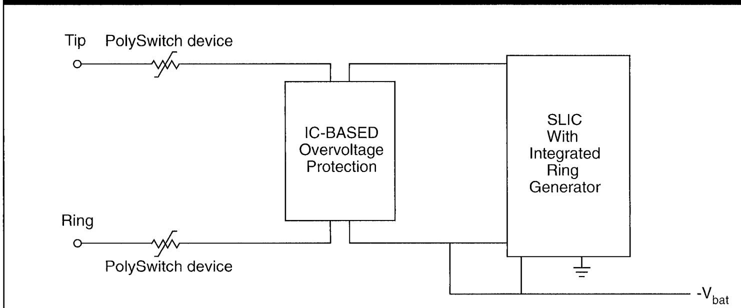


Table 1. Recommended Circuit Protection Devices

Regulatory Standard	PolySwitch Device		SiBar Device
Telcordia GR-1089	TSM600-250	(SMT)	TVB270SC
	TS600-200-RA	(SMT)	TVB270SB
	TR600-160-RA	(Thru-hole)	
ITU-T K.20 Telcordia GR-1089 Intrabuilding	TS250-130-RA	(SMT)	TVB270SA
	TSV250-130	(SMT)	
	TR250-120	(Thru-hole)	
	TR250-145	(Thru-hole)	
Telcordia GR-1089 Intrabuilding	TSL250-080	(SMT)	TVB270SA

T1/E1 Equipment
Application Overview

Problem/Solution
T1/E1 is a digital transmission link with a capacity of 1.544/2.048 Mbps. T1/E1 systems use two copper pairs and are used extensively for connecting networks across remote distances. Line repeaters are required approximately every 6,000 feet to boost signals and maintain signal integrity. Figure 1 depicts the T1/E1 system architecture. The line regenerators may be powered from the central office.

Since T1/E1 equipment connects to the copper infrastructure of the Public Switched Telephone Network (PSTN), it is subject to overcurrent and overvoltage hazards from AC power cross, power induction, and lightning surges. PolySwitch resettable devices and SiBar thyristors provide coordinated resettable protection against these faults, thereby protecting equipment from damage and minimizing field service and warranty costs.

Typical Protection Requirements
Loop powering is generally done with a phantom powering scheme, applying +130V on the transmit pair and -130V on the receive pair. Some systems may be powered at up to ±150V. Loop currents in the range of 60mA-140mA are common. Signal levels on the transmit pair (TX) are typically between 2.4V and 3.6V and up to 12V on the receive (RX) pair due to standing waves.

Figure 1. T1/E1 Systems Architecture

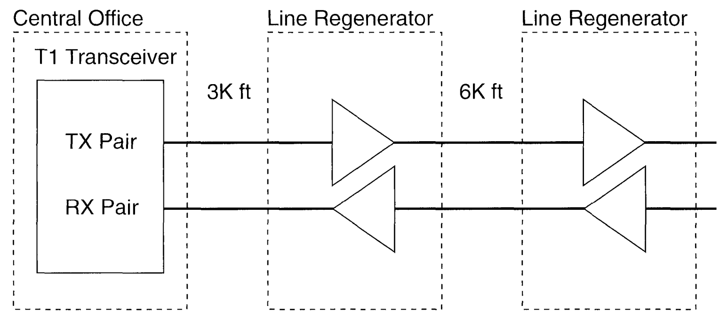


Figure 2. T1/E1 Central Office Transceiver Protection

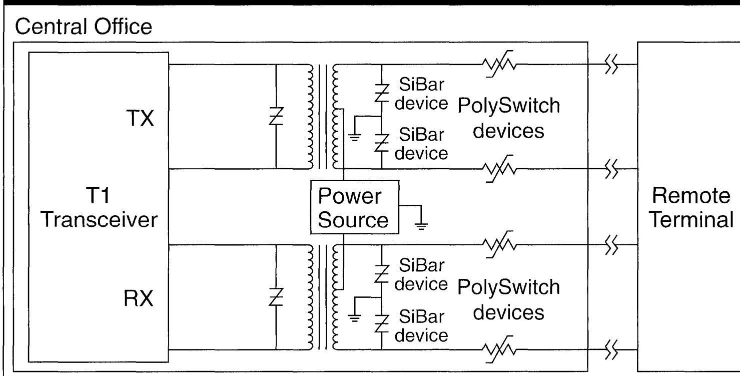
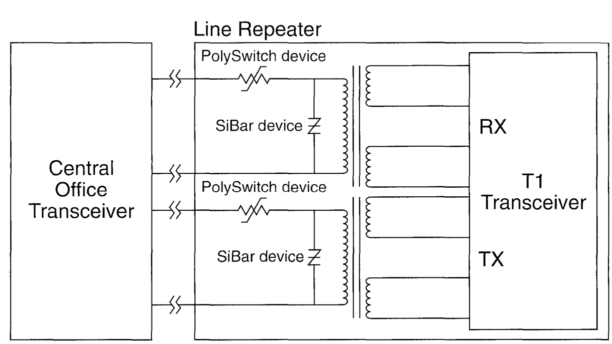


Figure 3. T1/E1 Line Repeater Protection



At the central office (CO), the equipment is grounded, therefore longitudinal protection is required. See Figure 2 for recommended protection circuitry. At the line repeaters the equipment is generally ungrounded, therefore only metallic protection is needed. See Figure 3 for recommended protection circuitry.

Device Selection for Agency Approval Requirements

Protection for telecommunications network equipment is typically designed to meet the requirements of Telcordia GR-1089 for North America installations and of ITU-T K.20 for installations in the rest of the world. Protection for customer premise equipment is typically designed to meet the requirements of UL60950 and TIA-968-A for North American use and of ITU-T K.21 for rest-of-world use. Overviews of the requirements for each of these standards can be found as separate application notes in this Databook.

PolySwitch devices should be selected with voltage ratings based on the regulatory standards for which the equipment is being designed. Surface-mount TS600, TSM600, and radial-leaded TR600 devices are applicable for North American GR-1089 standards and for UL60950 standards, while surface-mount TS250 and TSV250 and radial-leaded TR250 devices are applicable for ITU-T K.20/21 standards as well as for Telcordia GR-1089 Intrabuilding level protection.

SiBar TVB170SA and TVB170SC, and TVB270SB devices with off-state voltage (V_{DM}) ratings of 170V are applicable for T1/E1 systems with loop powering up to 150V. For systems with higher expected voltages, designers should consult Section 4 for higher rated devices.

Tables 1 and 2 provide recommended PolySwitch and SiBar devices for T1/E1 applications.

Table 1. Recommended Circuit Protection Devices for T1/E1 Central Office Transceivers

Regulatory Standard	PolySwitch Device		SiBar Device
Telcordia GR-1089	TSM600-250		
	TS600-200-RA-B-0.5	(SMT)	TVB170SB
	TR600-160	(Thru-hole)	
	TR600-160-RA-B-0.5	(Thru-hole)	
UL1459/UL60950,	TS600-170	(SMT)	TVB170SA (ungrounded)
TIA-968-A	TRF600-150	(Thru-hole)	TVB170SB (grounded)
	TR600-160-RA	(Thru-hole)	
ITU-T K.20/21,	TS250-130	(SMT)	TVB170SA
Telcordia GR-1089 Intrabuilding/Short-haul	TSV250-130	(SMT)	
	TR250-145	(Thru-hole)	
	TRF250-180	(Thru-hole)	

Table 2. Recommended Circuit Protection Devices for T1/E1 Line Repeaters

Regulatory Standard	PolySwitch Device		SiBar Device
Telcordia GR-1089	TSM600-250	(SMT)	TVB170SC (grounded)
	TS600-200-RA	(SMT)	TVB170SB
	TR600-160	(Thru-hole)	
	TR600-160-RA	(Thru-hole)	
UL1459/UL60950,	TSM600-250	(SMT)	TVB170SC (grounded)
TIA-968-A	TS600-170	(SMT)	TVB170SA (ungrounded)
	TRF600-150	(Thru-hole)	TVB170SB (grounded)
	TR600-160-RA	(Thru-hole)	
ITU-T K.20/21,	TS250-130	(SMT)	TVB170SA (grounded)
Telcordia GR-1089 Intrabuilding/Short-haul	TSV250-130	(SMT)	
	TR250-145	(Thru-hole)	
	TRF250-180	(Thru-hole)	

ISDN Equipment
Application Overview

Problem/Solution

Basic Rate Integrated Services Digital Network (ISDN) technology divides the telephone line into 3 digital channels: 2 "B" channels and one "D" channel, all of which can be used simultaneously. The B channels are used to transmit data at rates of up to 64 kbps. The D channel does the administrative work, such as setting up and tearing down the call and communicating with the telephone network. With two B channels, one can make two calls simultaneously. Most of the world's existing telephone network is already digital. Today, the last mile, the section that runs from the local exchange to the home or office, remains an analog connection. ISDN service makes this final leg of the network digital. Typically, the user must be within 18,000 feet of the central office for ISDN service to be available.

ISDN components include:

- specialized ISDN terminals (TE1)
- terminal adapters (TA) which allow the connection of non-ISDN terminal equipment
- network termination devices (NT1 and NT2).

In North America, the NT1 exists as Customer Premise Equipment. Outside North America, the NT1 function is generally provided by the carrier network.

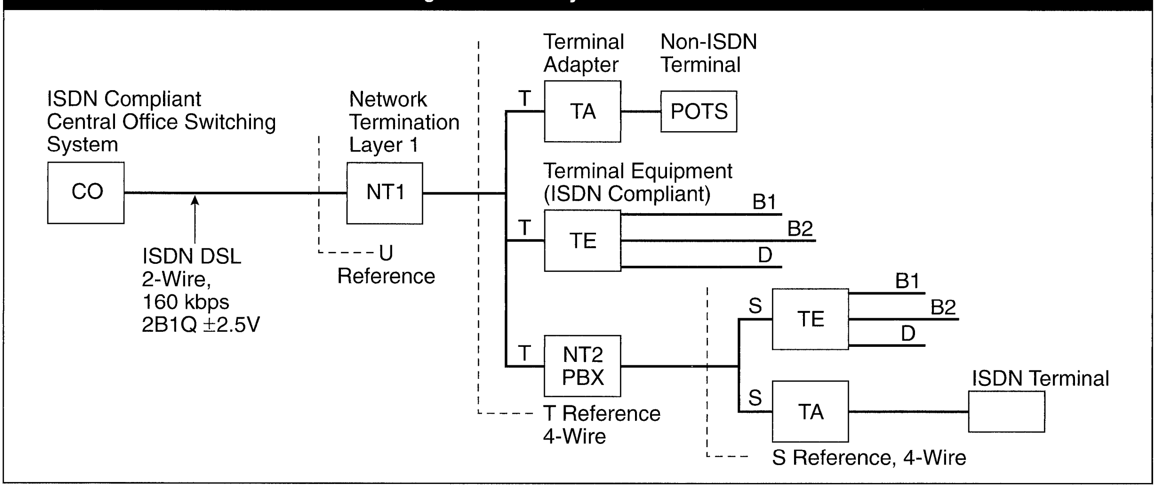
Figure 1 shows these components in the ISDN system architecture.

The T interface is the reference point between the network termination (NT1) and the subscriber equipment (TA, TE or NT2/PBX). The S interface is the reference point between the NT2/PBX and the customer terminals. In the ISDN Basic Rate Interface (BRI), the ISDN S or T interface uses two unshielded twisted pairs to deliver two 64kpbs "B," or bearer, channels and one 16 kbps "D" or data channel. Each of the B channels can carry voice and/or data, while the D channel carries the control and signaling information and up to 9.6 kbps of additional data.

The ISDN U interface is the reference point between the network termination device (NT1) and line-termination equipment in the carrier network. The U interface delivers the same two 64 kbps B channels and one 16 kbps D channel, except that it uses one twisted pair and can operate at 5–10 kilometers from the central office.

Since ISDN equipment connects to the copper infrastructure of the Public Switched Telephone Network (PSTN), it is subject to overcurrent and overvoltage hazards from AC power cross, power

Figure 1. ISDN System Architecture



induction and lightning surges. PolySwitch resettable devices and SiBar thyristors provide coordinated resettable protection against these faults, thereby protecting equipment from damage and minimizing field service and warranty costs.

Typical Protection Requirements

Signaling levels for ISDN are typically +/- 2.5V; however, sealing currents provided to prevent line corrosion and Maintenance Loop Test (MLT) procedures can develop voltages of $150V_{RMS}$ on the line.

Figures 2 and 3 provide circuit protection recommendations for ISDN U- and S/T-interfaces.

Device Selection for Agency Approval Requirements

Protection for telecommunications network equipment is typically designed to meet the requirements of Telcordia GR-1089 for North America installations and of ITU-T K.20 for installations in the rest of the world. Protection for customer premise equipment is typically designed to meet the requirements of UL60950 and TIA-968-A for North American use and of ITU-T K.21 for rest-of-world use. Overviews of the requirements for each of these standards can be found as separate application notes in this Databook.

Figure 2. ISDN U Interface Protection

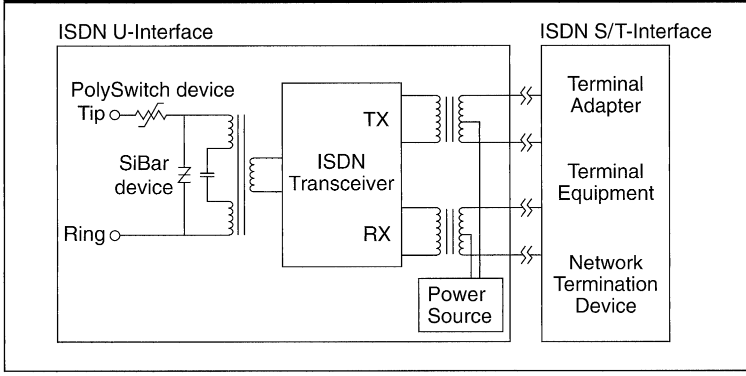
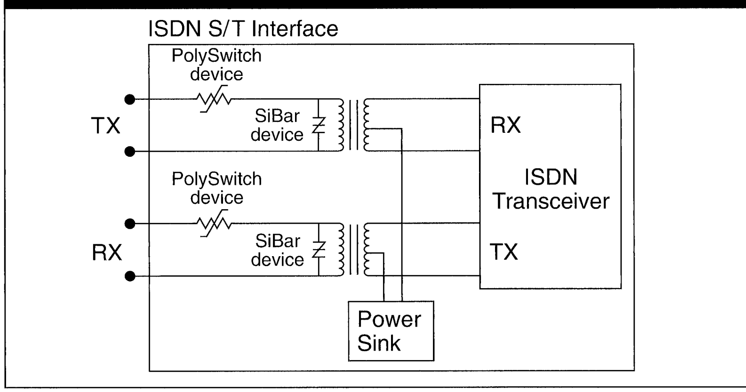


Figure 3. ISDN S/T Interface Protection



PolySwitch devices should be selected with voltage ratings based on the regulatory standards for which the equipment is being designed. Surface-mount TS600, TSM600, and radial-leaded TR600 devices are applicable for North American GR-1089 standards and for UL60950 standards, while surface-mount TS250 and TSV250 devices and radial-leaded TR250 devices are applicable for ITU-T K.20/21 standards, as well as for Telcordia GR-1089 Intrabuilding level protection.

SiBar TVB270SA, TVB270SB, and TVB270SC devices with V_{DM} ratings of 270V are applicable for systems with MLT voltages up to 150V. For systems with lower expected voltages, designers should consult Section 4 for lower rated devices.

Table 1. Recommended Circuit Protection Devices

Regulatory Standard	PolySwitch Device		SiBar Device
Telcordia GR-1089	TS600-200-RA	(SMT)	TVB270SB
	TR600-160-RA	(Thru-hole)	
UL1459/UL60950, TIA-968-A, (formerly FCC part 68)	TS600-170	(SMT)	TVB270SA (ungrounded)
	TRF600-150	(Thru-hole)	TVB270SB (grounded)
ITU-T K.20/21	TS250-130	(SMT)	TVB270SA
Telcordia GR-1089 Intrabuilding	TSV250-130	(SMT)	
	TR250-145	(Thru-hole)	
	TRF250-180	(Thru-hole)	

ADSL Equipment
Application Overview

Problem/Solution

Asymmetric Digital Subscriber Lines (ADSL) employ an asymmetrical digital line technology to provide a transmission rate up to 6.144Mbps from the Central Office Terminal (COT) to the Remote Terminal (RT) and a 640kbps transmission rate from the RT to the COT at distances up to 12,000 feet. See Figure 1 for a typical ADSL system architecture. Splitters at the central office end of the line separate voice-band traffic from data traffic and route them to appropriate switching equipment. At the customer premise, both splitter and splitterless configurations exist.

Since ADSL equipment connects to the copper infrastructure of the Public Switched Telephone Network (PSTN), it is subject to overcurrent and overvoltage hazards from AC power cross, power induction, and lightning surges. PolySwitch resettable devices and SiBar thyristors provide coordinated resettable protection against these faults, thereby protecting equipment from damage and minimizing field service and warranty costs.

Typical Protection Requirements

ADSL is designed to run over standard analog phone lines; therefore, the normal POTS subscriber loop voltages and currents can be expected. ADSL signal voltage is nominally +/-3V. This voltage is superimposed over the POTS ringing voltage that has a maximum of 269V peak, as defined by FCC Part 68.

In general, ADSL transceivers at the central office and the remote site are ungrounded equipment, thereby requiring only metallic protection. Figure 2 shows a reference schematic for ADSL equipment protection.

A second PolySwitch device on the line interface may provide better longitudinal balance and improved ASDL rate performance.

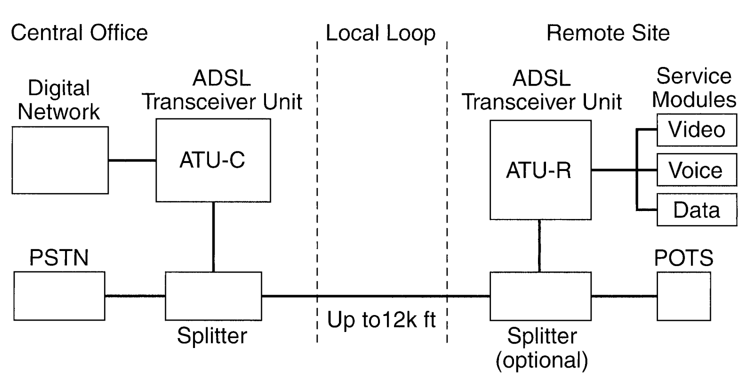
POTS splitters at the central office and the subscriber site consist of a low-pass filter for connection to POTS equipment and DC blocking capacitors for connection to ADSL transmission equipment. Transient protection is supplied at the line interface as shown in Figure 3.

Additional protection against intra-building power faults may be implemented by placing protection devices in the phone and modem interfaces as shown.

Device Selection for Agency Approval Requirements

Protection for telecommunications network equipment is typically designed to meet the requirements of Telcordia GR-1089 for North America installations and of ITU-T K.20 for

Figure 1. ADSL System Architecture



installations in the rest of the world. Protection for customer premise equipment is typically designed to meet the requirements of UL60950 and TIA-968-A for North American use and of ITU-T K.21 for rest-of-world use. Overviews of the requirements for each of these standards can be found as separate application notes in this Databook.

PolySwitch devices should be selected with voltage ratings based on the regulatory standards for which the equipment is being designed. Surface-mount TS600 and radial-leaded TR600 devices are applicable for North American GR-1089 standards and for UL60950 standards, while surface-mount TS250 and TSV250 devices and radial-leaded TR250 devices are applicable for ITU-T K.20/21 standards as well as for Telcordia GR-1089 Intrabuilding level protection.

SiBar devices should be selected with surge current ratings based on the regulatory standards for which the equipment is being designed and with off-state voltage ratings based on normal system operation. SiBar TVB270SA, TVB270SB, and TVB270SC devices with off-state voltage V_{DM} ratings of 270V are applicable for most ADSL systems.

Table 1 provides recommended PolySwitch and SiBar devices for ADSL and POTS splitter applications.

Figure 2. ADSL Equipment Protection

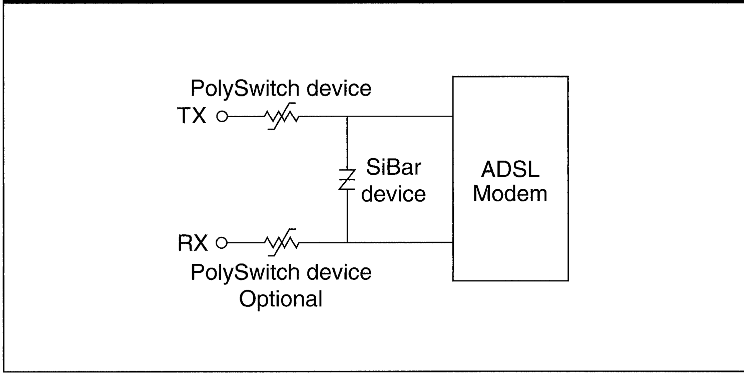


Figure 3. POTS Splitter Protection

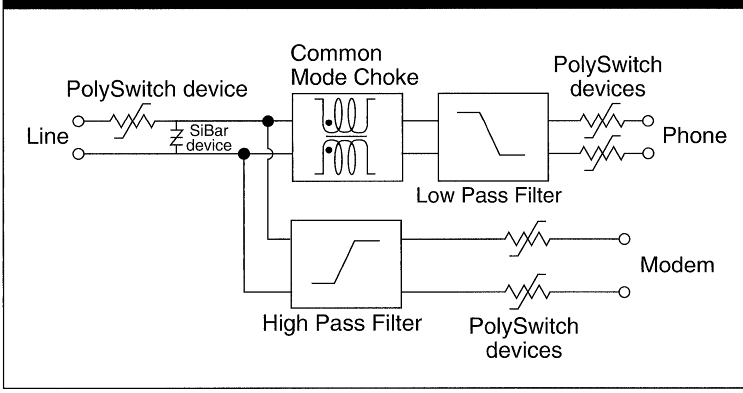


Table 1. Recommended Circuit Protection Devices

Regulatory Standard	PolySwitch Device		SiBar Device
Telcordia GR-1089	TSM600-250-RA	(SMT)	TVB270SC (with TSM600)
	TS600-200-RA	(SMT)	TVB270SB
	TR600-160-RA	(Thru-hole)	
UL1459/UL60950,	TSM600-250-RA	(SMT)	TVB270SC (with TSM600)
TIA-968-A, (formerly	TS600-170	(SMT)	TVB270SA (ungrounded)
FCC Part 68)	TS600-200-RA	(SMT)	TVB270SB (grounded)
	TRF600-150	(Thru-hole)	
	TR600-160	(Thru-hole)	
ITU-T K.20/21	TS250-130	(SMT)	TVB270SA
Telcordia GR-1089	TSV250-130	(SMT)	
Intrabuilding	TR250-145-RA	(Thru-hole)	
	TRF250-180	(Thru-hole)	

HDSL Equipment
Application Overview

Problem/Solution
High-bit-rate Digital Subscriber Line (HDSL) technology is a transparent replacement for a T1 repeatered line in the distribution plant. It allows two-way transmission rates of 1.544Mbps (DS-1) over distances of up to 12,000 feet on copper cable without line repeaters. HDSL can eliminate engineering time and reduce the cost and provisioning time associated with conditioning T1 lines, thereby providing an alternative to traditional T1 equipment for service providers looking to offer high-capacity services. HDSL2 is an upcoming version that delivers the same speed as HDSL using a single copper pair.

Since HDSL equipment connects to the copper infrastructure of the Public Switched Telephone Network (PSTN), it is subject to overcurrent and overvoltage hazards from AC power cross, power induction, and lightning surges. PolySwitch resettable devices and SiBar thyristors provide coordinated resettable protection against these faults, thereby protecting equipment from damage and minimizing field service and warranty costs.

Typical Protection Requirements
Signaling levels for HDSL are +/- 2.5V maximum. Loop powering is typically under 190V. In general, the HDSL transceivers at the central office and the remote site are grounded equipment, thereby requiring longitudinal protection. Figure 2 shows recommended

Figure 1. HDSL Systems Architecture

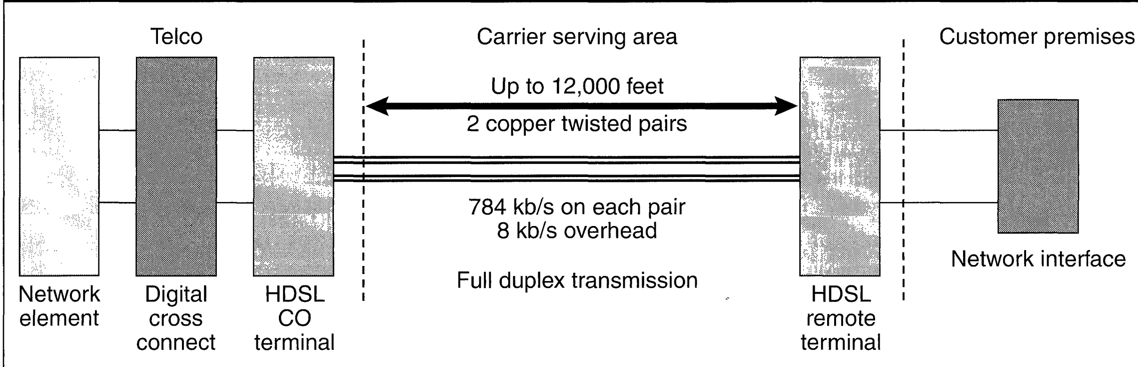
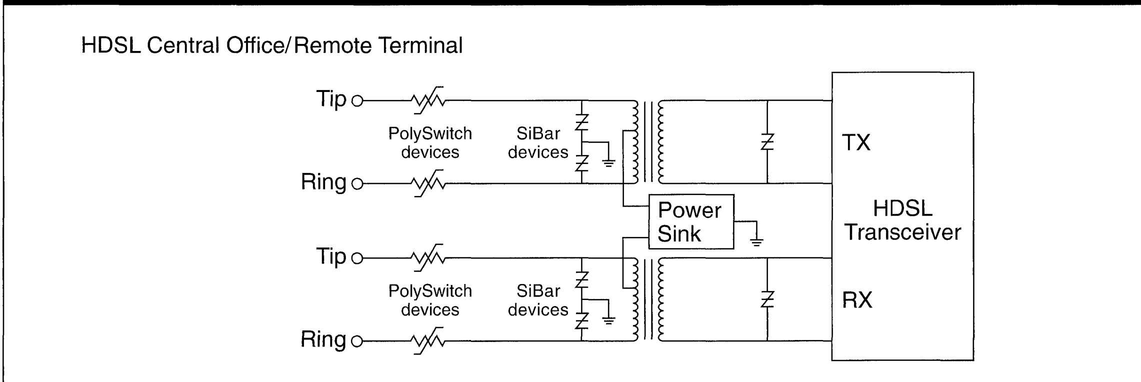


Figure 2. HDSL Protection



protection circuitry for HDSL applications.

Device Selection for Agency Approval Requirements

Protection for telecommunications network equipment is typically designed to meet the requirements of Telcordia GR-1089 for North America installations and of ITU-T K.20 for installations in the rest of the world. Protection for customer premise equipment is typically designed to meet the requirements of UL60950 and TIA-968-A for North American use and of ITU-T K.21 for rest-of-world use. Overviews of the requirements for each of these standards can be found as separate application notes in this Databook.

PolySwitch devices should be selected with voltage ratings based on the regulatory standards for which the equipment is being designed. Surface-mount TS600 or TSM600 and radial-leaded TR600 devices are applicable for North American GR-1089 standards and for UL60950 standards, while surface-mount TS250 and TSV250 and radial-leaded TR250 devices are applicable for ITU-T K.20/21 standards as well as for Telcordia GR-1089 Intrabuilding level protection.

SiBar TVB200SA, TVB200SB, and TVB200SC devices with V_{DM} ratings of 200V are applicable for systems with loop powering up to 190V. For higher or lower loop voltage requirements, designers should consult the SiBar Thyristor product section.

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Table 1. Recommended Circuit Protection Devices for HSDL Applications

Regulatory Standard	PolySwitch Device		SiBar Device
Telcordia GR-1089	TSM600	(SMT)	TVB200SC (with TSM600)
	TS600-200-RA	(SMT)	TVB200SB
	TRF600-150	(Thru-hole)	
	TR600-160-RA	(Thru-hole)	
UL1459/UL60950, TIA-968-A	TSM600	(SMT)	TVB200SC (with TSM600)
	TS600-170	(SMT)	TVB200SA (ungrounded)
	TRF600-150	(Thru-hole)	TVB200SB (grounded)
	TR600-160-RA	(Thru-hole)	
ITU-T K.20/21	TS250-130-RA	(SMT)	TVB200SA
Telcordia GR-1089 Intrabuilding	TSV250-130	(SMT)	
	TR250-145	(Thru-hole)	
	TRF250-180	(Thru-hole)	

MDF Modules/Primary Protection Modules

Application Overview

Problem/Solution

Main distribution frame (MDF) modules and primary protection modules are of critical importance in providing protection for the sensitive components in the central office and on customer premise. These modules protect against AC power cross, power induction, and lightning faults on the telecommunication lines. If not protected against, such hazards can potentially travel into the central office and severely damage sensitive switching and transmission equipment or into the customer premise jeopardizing the safety of residents and their homes. To minimize the effects of such occurrences, PolySwitch resettable devices can be used as overcurrent protection in primary protection applications, such as MDF modules and Network Interface Devices (NID).

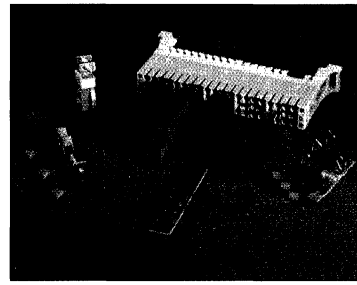
Typical Protection Requirements

The requirements for MDF modules and NID protection vary depending on the local telephone company requirements. Protection specifications are based on collaboration between the local telephone company, the module manufacturer, and the company providing the protection components.

In North America, Telcordia GR-974 is the dominant standard for MDF protection. In the rest of the world, many standards use the ITU-T K.20 specification as a guideline. Most specifications include lightning and power cross surges intended to mimic the worst case electrical faults that can be expected. Typical power cross surges range from 100V to 300V, with current levels from 0.250A to 3A. Lightning surges with open-circuit voltages of 1000V to 2500V and short-circuit currents of 10 to 100A peak are common.

Device Selection for Agency Approval Requirements

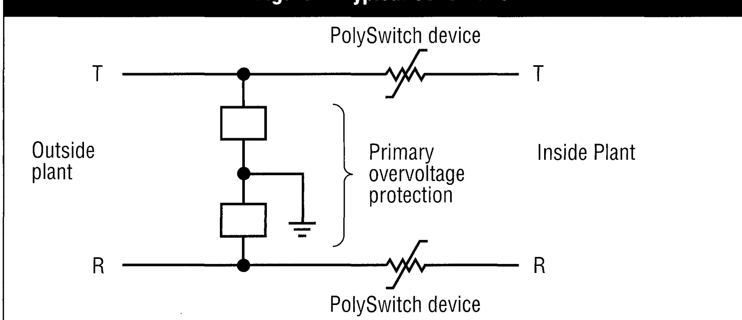
For Telcordia GR-974 applications, the PolySwitch TRF250-180 device is an appropriate overcurrent protection choice.
20Ω and 4Ω heat coils have been used extensively in the past for overcurrent protection. PolySwitch devices will trip faster than 4Ω heat coils, thereby providing a higher level of protection against low level "sneak currents" which can cause significant damage. 20Ω heat coils trip faster and at lower currents than 4Ω heat coils; however, their relatively higher resistance may be a problem for today's DSL services where maximizing loop lengths and minimizing signal attenuation are desirable.



In many parts of the world outside North America, the ITU-T K.20 requirements are used as the basis for primary protection module specifications. The 250V rated PolySwitch devices are commonly used to meet these requirements. To accommodate the variety of protection module form factors, several PolySwitch device form factors have been designed, including radial-leaded (TR250-120), surface-mount (TS250-130), vertical surface-mount (TSV250-130), and chip (e.g., TC250-120T) devices.

Custom devices may be available to meet country-specific requirements. Please contact Raychem Circuit Protection for details.

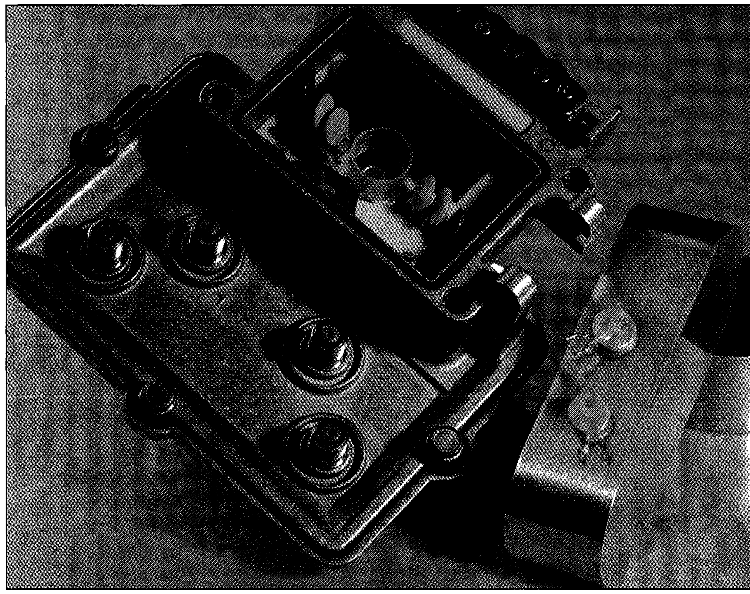
Figure 1. Typical Schematic



Cable Telephony/ Cable Power Passing Tap
Application Overview

Problem/Solution

Various systems are emerging that will bring more bandwidth to the home for the combined demands of fast internet service, traditional telephone service, and television service. One method uses a single coaxial cable to carry these services. The coax cable connects to the input side of a network interface unit (NIU) at the building entrance. At the NIU, telephone, data, and television signals are separated for delivery to respective equipment in the customer premise. The output ports from the NIU may be one or more twisted pair outputs for telephone service, cable outputs for television service, and/or an additional cable output for cable modem service.



3

Power for the NIU electronics may be provided from the cable plant via the coax cable or a twisted pair line.

In order to facilitate provision of such services, cable power tap manufacturers need a way to quickly and easily connect services to and from the home. The PolySwitch BBR product series is designed to plug into power passing taps in series with the powered coax or twisted pair wiring to complete the circuit and enable service to the customer premise. In addition to providing the service connection, the PolySwitch device also serves to limit current in the event of power cross faults on the coax, such as might be generated by phase lags in the multi-phase power distribution system.

At the customer site, the copper telephone lines from the NIU throughout the customer premise are susceptible to faults due to installation errors, such as an errant staple or accidental connection to the home electrical wiring (typically, $120V_{AC}$ or $240V_{AC}$ depending on regional power distribution standards), which can cause damage to the equipment or the home if left unprotected.

PolySwitch resettable devices and SiBar thyristors provide coordinated self-resettable protection against these faults, thereby protecting the NIU electronics from damage and minimizing field service and warranty costs.

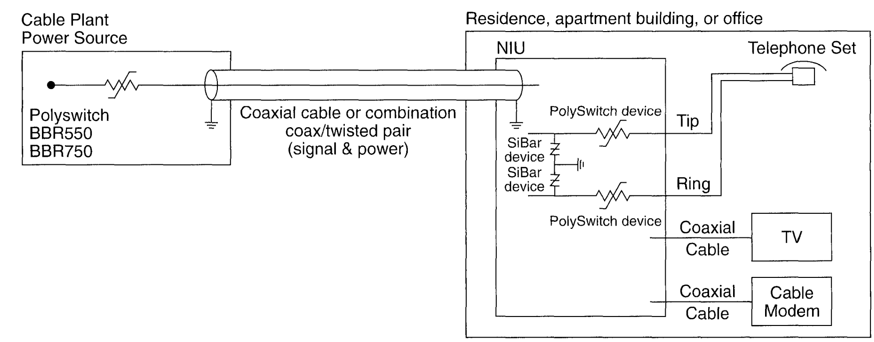
Figure 1 shows the cable power tap and cable telephony NIU applications.

Typical Protection Requirements

Article 830 was added to the 1999 National Electrical Code to dictate requirements for network powered broadband communications systems. Table 830-4 states that maximum power must be limited to 200VA in no greater than 60 seconds. The PolySwitch BBR series of devices can be used as current-limiting devices to meet the maximum current and volt-ampere requirements defined in this table. Typically, power taps for single family residences will supply 350mA through each PTC to the NIU; for apartment buildings, offices and other multi-dwelling units currents of 500mA may be supplied.

At the telecom interface, current systems provide powering either from the network via twisted pair (typically $40\text{-}90V_{AC}$ rms) or from local DC battery power (typically $42\text{-}60V_{DC}$).

Figure 1. Cable Telephony/Cable Power Architecture



Overvoltage protection requirements depend upon the exact powering and ringing configuration used; however, for most applications, standard POTS voltage and current levels are expected.

Device Selection

For residential cable power tap applications, the BBR550 is the recommended PolySwitch device. It has a hold current of 550mA at 20°C and a 90V maximum rating. This radial leaded device can be inserted by a properly trained technician in the field when cable telephony service to a particular customer is to be activated and may be unplugged to terminate service. For larger cable powering systems, such as those for apartment buildings or small office buildings, higher current levels may be supplied. For these applications, the BBR750 with a 750mA hold current at 20°C is recommended.

At the NIU, PolySwitch devices should be selected with voltage ratings based on the regulatory standards for which the equipment is being designed. Many cable telephony equipment manufacturers are choosing to comply with the Intrabuilding recommendations in Telcordia GR-1089, since their NIU devices do not directly connect to the PSTN infrastructure. Surface-mount TS250 and TSV250 and radial-leaded TR250 devices are applicable. For manufacturers who choose to comply with the full Telcordia GR-1089 standard or with UL60950 and TIA-968-A, (formerly FCC Part 68), surface-mount TS600, or TSM600 and radial-leaded TR600 devices are applicable. For ITU-T K.20/21 standards, TR250 and TS250 devices are suitable. TSL250-080 is another alternative for applications requiring GR-1089 intrabuilding protection.

SiBar devices should be selected with surge current ratings based on the regulatory standards for which the equipment is being designed and with off-state voltage ratings based on normal system operation. SiBar TVB270SA, TVB270SB, and TVB270SC devices with off-state voltage V_{DM} ratings of 270V are applicable for most systems.

Table 1 provides recommended PolySwitch and SiBar devices for the phone line interface applications.

Table 1. Recommended Circuit Protection Devices

Regulatory Standard	PolySwitch Device		SiBar Device
ITU-T K.20/21	TS250-130	(SMT)	TVB270SA
Telcordia GR-1089 Intrabuilding	TSV250-130	(SMT)	
	TR250-120	(Thru-hole)	
	TR250-145	(Thru-hole)	
Telcordia GR-1089	TSM600-250	(SMT)	TVB270SC (with TSM600)
	TS600-200	(SMT)	TVB270SB
	TR600-160	(Thru-hole)	
UL 60950 and TIA-968-A, (formerly FCC Part 68)	TSM600-250	(SMT)	TVB270SC (with TSM600)
	TS600-170	(SMT)	TVB270SA (ungrounded)
	TRF600-150	(Thru-hole)	TVB270SB (grounded)
Telcordia GR-1089 Intrabuilding	TSL250-080	(SMT)	TVB270SA

PBX and Key Telephone Systems
Application Overview

Problem/Solution
Both PBX and key telephone systems contain components that may be damaged by overcurrent or overvoltage conditions resulting from installation errors, component failure, or misuse. Some systems use 5V data or control lines in addition to $-48V_{DC}$ tip-and-ring lines. A short circuit of the $-48V_{DC}$ line to the data lines can damage voltage-sensitive electronics components. Also, a short circuit of the $-48V_{DC}$ line to ground may generate excessive current, causing resistors or wiring to overheat or other components to fail. PolySwitch devices may be used to protect against these hazards. Under a fault condition, the PolySwitch device switches to a high-resistance state, protecting the system and its components. When the fault condition and power are removed, the device resets.

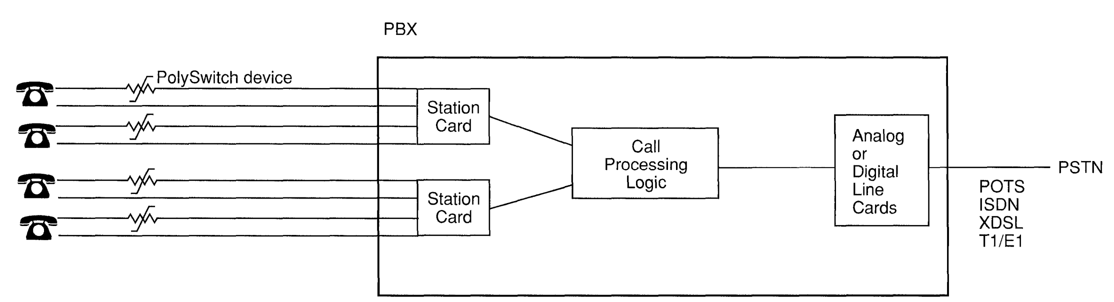
Typical Protection Requirements
Connection of a PBX or key telephone system to the Public Switched Telephone Network (PSTN) may be made via an analog (POTS) or digital (T1/E1, ISDN, XDSL) circuit. For protection of this external interface, please refer to the relevant linecard application notes in this Databook.

Internal station sets are connected from within the business to the station cards of the PBX. Since most of these lines remain within buildings, they are not subject to the severe lightning and power cross hazards which can be present on the outside PSTN lines; instead, they may be prone to short-circuits from miswiring, component failure, or misuse. Power supplies of 48-60V generating loop currents of 10mA on-hook and 40mA off-hook are typical. Short-circuit currents above this level must be protected against.

Device Selection for Agency Approval Requirements
For protection of individual station set lines, both surface-mount and radial-leaded PolySwitch devices are available. For applications with 60V or lower maximum power supply voltage, surface-mount SMD030, SMD030-2018, SMD050, and miniSMDC014 devices or radial-leaded RXE030 and RXE050 devices may be suitable. Consult Section 4 for current and voltage ratings tailored to your application needs.

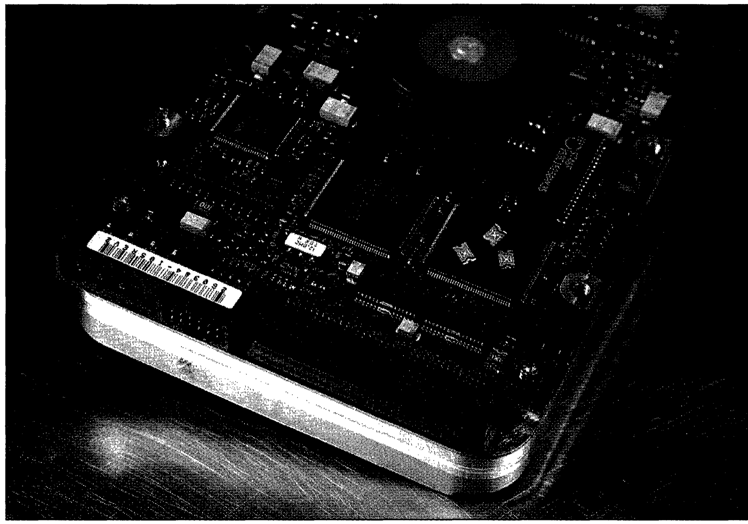
If the PBX is located in a region where fault susceptibility is deemed high and a more robust circuit-protection solution is desired, PolySwitch resettable devices and SiBar thyristors can be selected which will meet the Telcordia GR-1089 Intrabuilding specification. This specification describes faults that may come from accidental connection to $120V_{AC}$ household wiring, as well as lightning surges that are less severe than the surges expected on lines connected to the public switched telephone network. If an even more robust solution is desired, overcurrent and overvoltage protection devices can be chosen which will meet the UL60950 and TIA-968-A or the

Figure 2. PBX and Key Telephone System Protection



Telcordia GR-1089 requirements in North America or the ITU recommendations for other regions of the world. Reference diagrams for protection against UL60950, TIA-968-A, Telcordia GR-1089 Intrabuilding and Extrabuilding, and ITU recommendations can be found as separate application notes in this Databook.

5V/12V Power Line Protection for Hard Disk Drives (CD-ROM, CD-RW, DVD)
Application Overview



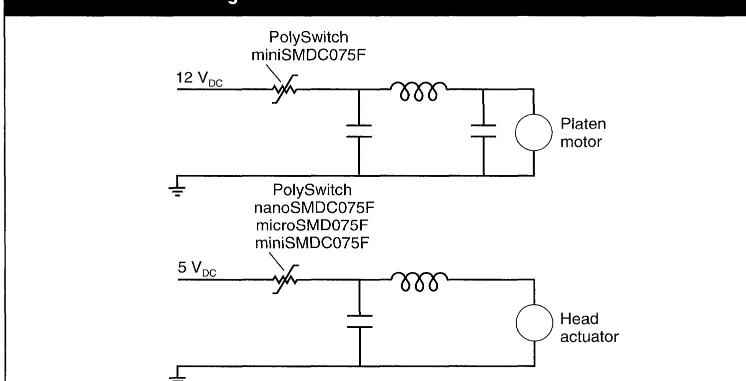
Problem/Solution
With the proliferation of RAID systems and interchangeable hard drives and backup batteries in laptops, hard disk drives (HDDs) can be affected by many external factors that can damage or destroy the storage devices in these hot plug environments. The manufacturers of HDDs must protect their products from incorrect voltages due to misconnection of the 12V, 5V, and/or 3.3V lines. The variations in the host-computer power supplies may also result in AC ripple or incorrect polarity that can damage the tantalum capacitors on the drives. The use of PolySwitch resettable devices on HDDs provides overcurrent protection, minimizing the chances of problems developing. If a fault does occur, permanent damage to circuitry may be avoided. In addition to HDDs, this type of failure can occur on certain floppy disk, CD-ROM, CD-R, CD-RW, and DVD drives.

Typical Protection Requirements
The connection of a 12V line from the computer power supply instead of a 5V line can cause a high-current inrush that can damage the other components in the circuit. Reverse polarity can also cause damage to tantalum capacitors, causing the capacitors to fail in a short-circuit mode.

Technology Comparison
The circuit designer for a hard disk drive has multiple options available when designing the protection of the circuit. An option would be to use fuses for this protection; however, these devices are only good for one use and then must be replaced. Another option is not to use any protection on the circuit, which means that if a fault occurs, repair to the circuit may be extensive and economically unfeasible. PolySwitch devices provide resettable overcurrent protection and should not need replacement or repair after an overcurrent situation.

Device Selection
Devices that meet the storage media protection needs are those of the SMD, miniSMD, and microSMD series. Featuring very small footprints and low height, these devices are well suited to the requirement for small components.

Figure 1. Protection for Disk Drives



Backplane and RAID
Application Overview

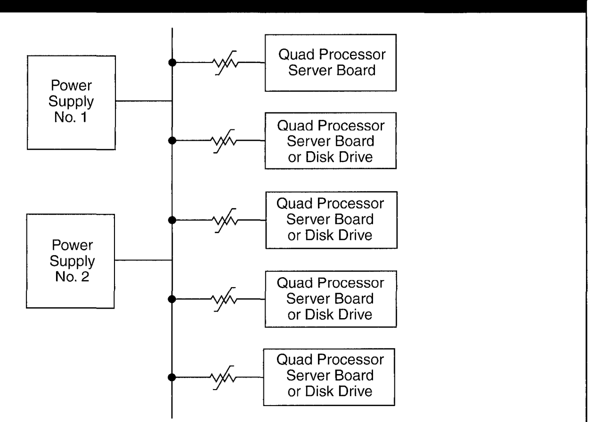
Problem/Solution

In today's plug-and-play architecture, OEMs design their products to be field-serviceable and field-replaceable in order to maximize the "up time" of their products. The drive for reliability also means that in power backplane applications, dual redundant power supplies are often used. Products such as telecommunications circuits for wide area networks, disk drives in Redundant Array of Integrated Discs (RAID) systems, and multiple server platforms are becoming "mission critical" items for businesses.

Typical Protection Requirements

In order to maximize the usage of mission critical systems, it is undesirable to shut down a system in order to make repairs. As such, boards or disk drives that are replaced in the field are often done with live power on the backplane. In order to minimize the safety risks, some sort of circuit protection is often used. Also, since one or more power supplies are used to power several boards or drives, incorrect insertion of a board can result in a short circuit delivering damaging current to a device long before the power supply folds back. Options available to the designer include conventional fuses, protected power switches, or resettable PPTC devices. Conventional fuses operate only once and then must be replaced. Silicon switches are effective, but their cost can be prohibitive. The PPTC device offers resettability for low cost. When the PPTC is tripped, it goes into a high-impedance state, limiting the current. Upon removal of the fault and interruption of current through the PPTC, it will reset, allowing normal operation to resume.

Figure 1. Typical Schematic



Typical Agency Approval Requirements

Most OEMs comply with the "240VA" requirement of IEC60950. The Safety Requirement Clause 1.2.8.7 - "Hazardous Energy Level" states that power must not exceed 240VA. In a 12V system current must be limited to 20A. Clause 2.1.5 - "Energy hazards in operator access areas" states that, "There shall be no energy hazard in OPERATOR ACCESS AREAS." Compliance options include: 1) Provide protection circuit on the power distribution backplane. 2) Declare all inside areas as "Service Access only," although IT people want open access to the equipment. (This method may be difficult to enforce.) 3) Use "Safety Interlocks" as per clause 2.8 which can be expensive, and requires power to be significantly reduced to gain access.

Device Selection

The PolySwitch resettable device for this application depends on the voltage and current requirements. Telecommunication applications typically use TR and TS series devices. Server boards that draw high current at low voltage can select from the RGE series of leaded components; if necessary, these devices can be used in parallel to increase current rating (see fundamentals section). The smaller miniSMD, microSMD, and SMD devices offer surface-mount options.

CPU Protection
Application Overview

In series with the Central Processing Unit (CPU), in some applications, is a Voltage Regulator Module (VRM). A VRM DC-DC converter supplies the required voltage and current to a processor.

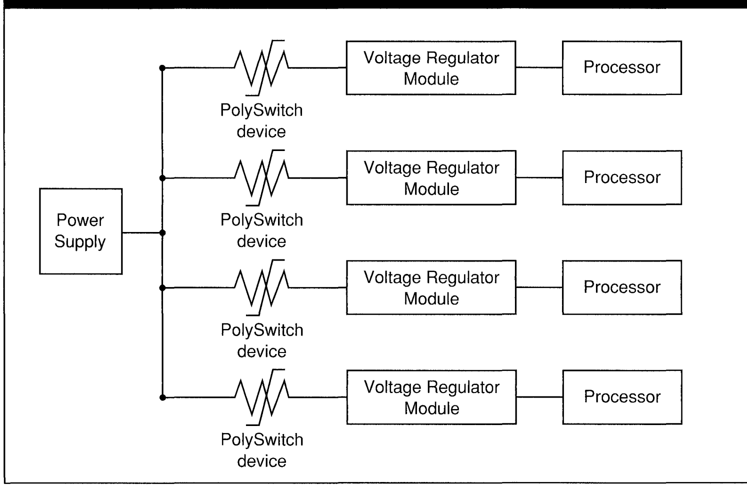
Problem/Solution

The VRM design approach removes cable inductance from the distribution and reduces board inductance. A load-change transient occurs when coming out of or entering a low power mode. For some CPUs this load-change transient can be on the order of 13A. These are not only quick changes in current demand, but also long-lasting average current requirements. Even during normal operation the current demand can still change by as much as 7A as activity levels change within the processor component. Maintaining voltage tolerance during these changes in current requires high-density bulk capacitors with low Effective Series Resistance (ESR). These high-current immediate demands on the circuits can cause components to fail. Circuit protection prevents the VRM from damaging the CPU in the event of a VRM fault. If the VRM fails, the processor tries to pull too much power. A PolySwitch device can be placed on the input pins to the VRMs that supply power to the processors, therefore protecting the processors. If there is a failure, only the VRM needs to be replaced, rather than the more expensive CPU.

Device Selection

Up to 12V and several amps are applied to the circuit. The RGE series, typically the RGE600–RGE 900, is used in this application.

Figure 1. Typical Schematic



Device Bay
Application Overview

The Device Bay system is a standard method of providing a bay which can be utilized for a multitude of applications. Applications for Device Bay include FDD (120MB) and HDD portable storage, network adapters, smart battery, CD-ROM, Smart Card Reader, DVD, PDAs, and USB hubs. Features of the bays include easy access, automatic configuration, and hot swapping.

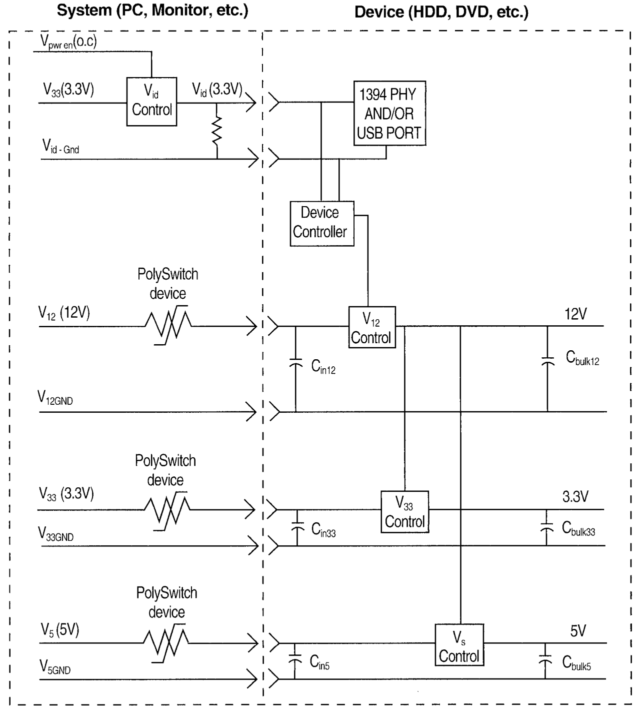
Problem/Solution

The system bay internal system power is analogous to today's 5V/12V 4-pin PC power connector. For safety reasons the receptacle is in the bay. For protection (both mechanical and electrical), the plug connector in a device is recessed (2.0mm for a DB32 form-factor). Per the Device Bay specification, the bay may provide additional overcurrent protection provided it meets all the other bay power requirements (current, voltage, etc). The Device Bay specification cites that this is certainly applicable for high-availability situations (servers, industrial, etc). Overcurrent protection should also be considered because devices can provide an externally accessible (IEEE 1394 and/or USB) native bus connector.

Device Selection

Maximum continuous operating currents range from 0.8A to 3.5A depending on implementation and bus voltage. Devices in the miniSMD, SMD, RGE, RHE, and RUE series are typically used for these applications.

Figure 1. Typical Schematic



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Fibre Channel
Application Overview

Problem/Solution
A Fibre Channel network can be connected through copper cabling or optical fibre cables. Fibre optic transceivers provide a high-speed serial electrical interface for connecting processors, switches, and peripherals through an optical fibre cable. A Gigabit Interface Converter (GBIC) is used to convert signals to light. The GBICs use lasers that enable cost-effective data transmission over optical fibres at distances of up to 10 kilometers. These compact, hot-pluggable modules are designed to connect easily to a system card through an industry-standard connector.

Typical GBIC features include short-wavelength (SW) or long-wavelength (LW) lasers, hot-pluggable capability, and compact design. The GBIC runs at a voltage of +5V ± 5% and a current of 300mA maximum. A typical Fibre Channel PCI Card has PCB power of 9W max, 6W typical at 5V ± 5% which results in approximately 1.8A maximum.

Typical Protection Requirements
A fault, such as a short-circuit during testing or hot-swapping a PCI card, can cause significant damage. Furthermore, on an optical fibre application, incorrect insertion of the GBIC or a foreign object placed into the connector can also cause permanent damage to the system. Protection on the PCI bus input is typically used as well as a secondary protector for the GBIC I/O.

Device Selection
miniSMDC260 devices are typically used for PCI bus protection. miniSMDC110 devices are typically used for GBIC protection.

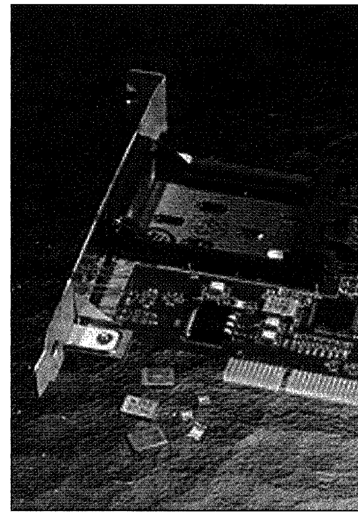
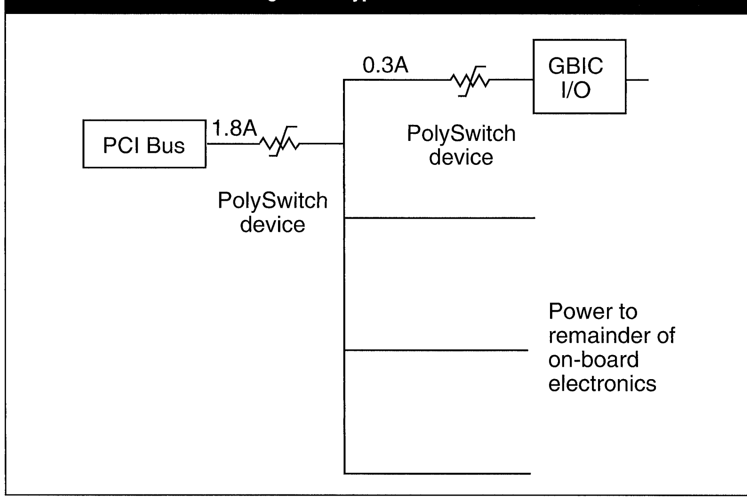


Figure 1. Typical Schematic



IEEE 1284 Parallel Data Bus
Application Overview

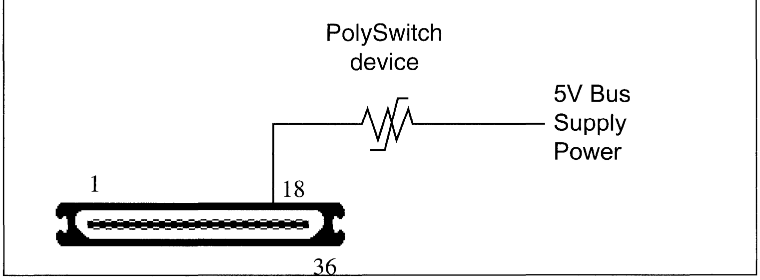
The IEEE1284 standard defines a signaling method for asynchronous, fully interlocked, bidirectional parallel communications between hosts and printers or other peripherals. The IEEE 1284 interface is designed to be interoperable with an older interface called "Centronics." The "Centronics-compatible" printer interface is widely used today. Its standard external interface connector is a 36-pin AMP 555119-1 or equivalent connector and is by definition the same as the IEEE 1284-B connector. An example of this type of interface is the print server whereby a pocket-sized print server device connects printers directly to a network allowing users of different operating systems to share printer resources.

Problem/Solution
Pin #18 of the connector can source up to 350mA at 5V. A misconnection of the connectors or a foreign metal object placed into the connector can cause a large overcurrent which could damage internal electronics. Placing a PolySwitch device in series with the connector will help to protect the system circuitry when a fault occurs.

Typical Agency Approval Requirements
IEC60950 and UL1950 agency approvals apply to all Information Technology equipment.

Device Selection
Devices from the microSMD and miniSMD series are typically used for this application.

Figure 1. Typical Schematic



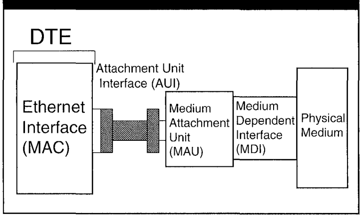
IEEE 802.3 Ethernet LAN (incl. Powered Ethernet)

Application Overview

3

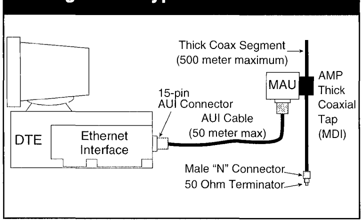
Ethernet is a local area network (LAN) technology that transmits information between computers at speeds of 10, 100, and 1000 (draft as of February 2000) million bits per second (Mbps).

Figure 1. DTE



Data Terminal Equipment includes a terminal and computer ports that use the RS-232 interface standard to communicate with data communications equipment, such as a computer or a remote access server.

Figure 2. Typical Schematic



The AUI consists of signal circuits, power, and ground. The interface provides for power transfer from the DTE to the MAU. Per the IEEE 802.3 standard, the Voltage Plus (VP) circuit shall be capable of operating at 12-15V_{DC} for all currents from 0 to 500mA. In addition, per section 7.5.2.5, the source shall provide protection for this circuit against an overload condition.

In addition to this traditional use of a LAN, a new use of the standard 8 conductor cable is for powering devices in addition to transferring signal. The concept is to use existing ethernet network also to carry power. Power is supplied from a backplane or standalone power supply to power peripherals such as IP phones, POS systems, and security cameras/alarms. Power travels on unused copper pair(s) (typically 4 of 8 conductors in the RJ45 are used for the ethernet data transmission). Normal operating current is 150mA max. Protection is typically required against short-circuit and/or FET failure. Typical power requirements for devices targeted at this application are: EtherPhones (5W), Wireless Access Points (8W), EtherCams (10W). Current and voltage levels have not been standardized but are typically 60V and 1.75A.

Typical Protection Requirements

Per IEEE 802.3 - Local and Metro. area networks, “The DTE (Data Terminal Equipment) shall be capable of: Operating voltage: 12–15V and Operating current: <500mA. The source shall provide protection for this circuit against an overload condition.”

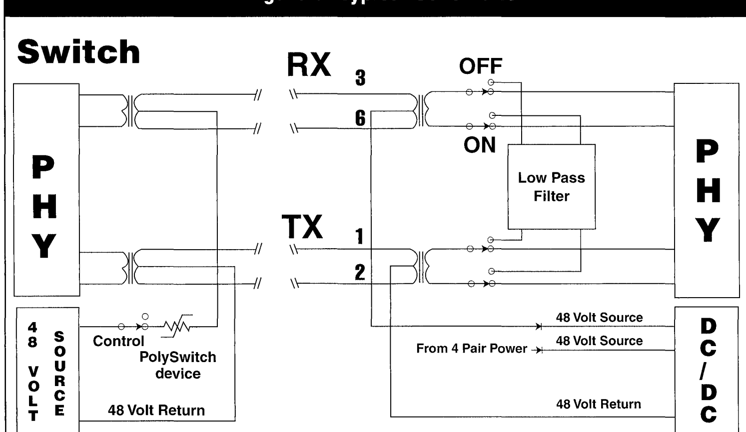
Typical Agency Requirements

IEC60950 and UL1950 requirements apply.

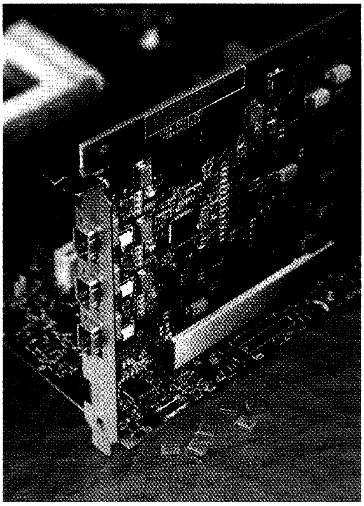
Device Selection

Devices from the miniSMD series are typically used for AUI protection. The most commonly used devices are miniSMDC110F/16 and miniSMDC075.

Figure 3. Typical Schematic



IEEE 1394 FireWire, i.Link Application Note



1394 Technology

The IEEE 1394 multimedia connection commonly known as FireWire and i.Link enables simple, low-cost, high-bandwidth data interfacing between computers, peripherals, and consumer electronics products such as camcorders, VCRs, printers, TVs, and digital cameras. With IEEE 1394 compatible products and systems, users can transfer data without a PC. The end user experience is greatly simplified and enhanced by the fact that the IEEE 1394 standard provides the opportunity to provide power down the cable.

Cable Power

Offering cable power is a major asset to simplifying and enhancing the end user experience. There are many purposes for the use of cable power. Three major uses are: 1) PHY layer keep-alive, 2) peripheral power, and 3) optical transceiver power.

PHY keep-alive is a method to use cable power to keep the physical layer in a device running even though its internal power may be off. As an example, the PC is powered off, but the PHY stays on by utilizing cable power. In this way, it can continue to identify its status on the network and minimize user complaints.

In IEEE 1394 peripheral power can be provided on the cable. This simplifies peripheral design in that a power supply does not need to be built into the device. It simplifies the user experience in that it creates a true plug-and-play environment with no additional cables crowding the work area.

Sample peripherals include:

- Still cameras
- Hard drives
- Camcorder
- Hubs
- Zip drives

The final use of cable power is to power 1394 optical transceiver modules at both ends of a fibre cable. Long optical cables cannot directly connect to IEEE 1394-1995 copper interface. Therefore, a small copper-optical transceiver at each end of the cable is used to make the "connection" between copper and optical cable. The transceiver can be cable-powered (-3W) with power needed at both ends (6-pin connectors).

When providing cable power, PolySwitch device integration offers a way to meet the requirements of the IEEE 1394 specification as well as those of UL and other regulatory agencies.

Figure 1, on the following page, shows a possible IEEE 1394 network as well as recommendations for the use of PolySwitch devices in different IEEE 1394 device configurations.

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Figure 1. Example of a IEEE 1394 Network

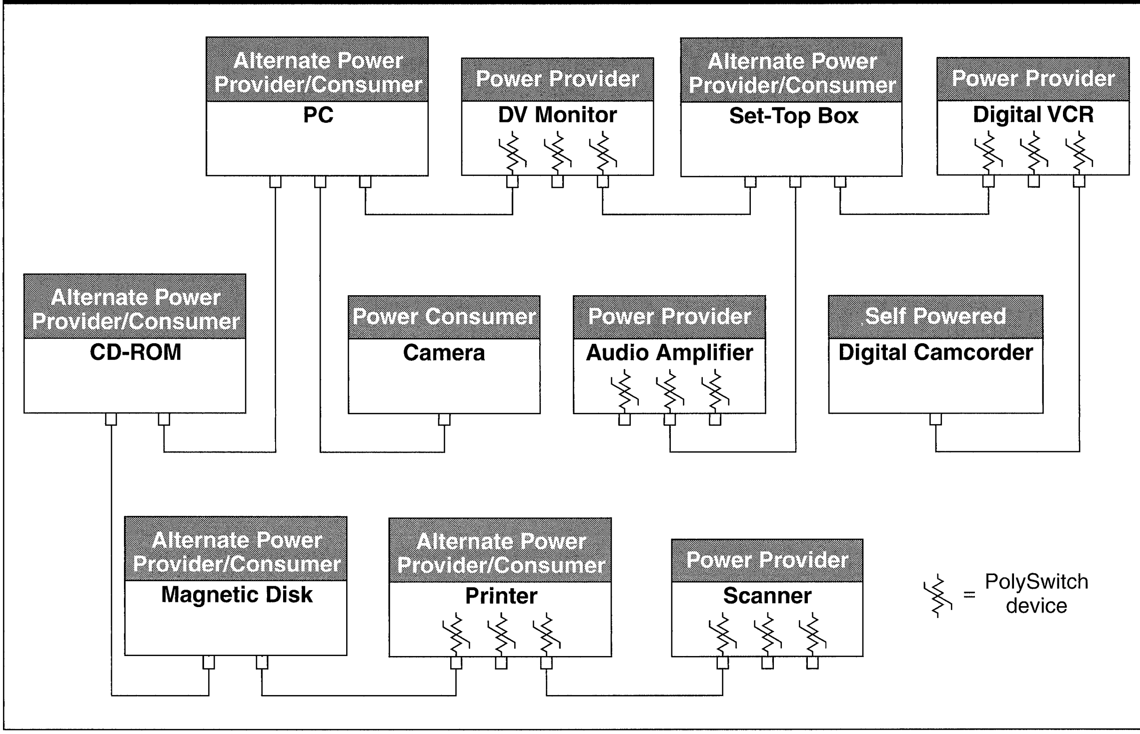


Figure 2. Power Provider

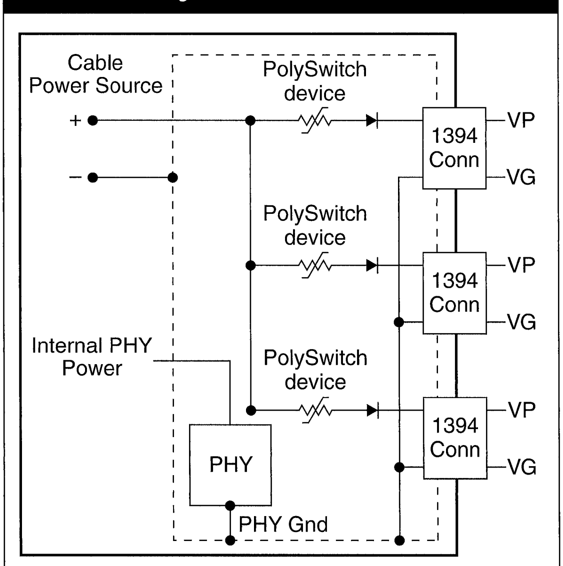


Figure 3. Alternate Power Provider (self-powered PHY)

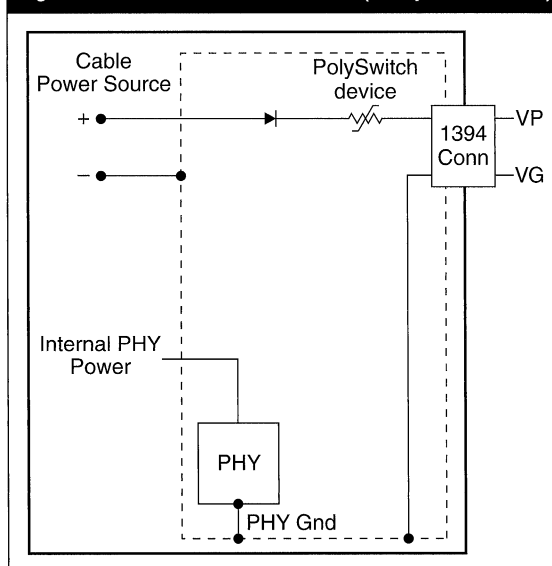


Figure 4. Alternate Power Provider (cable-powered PHY)

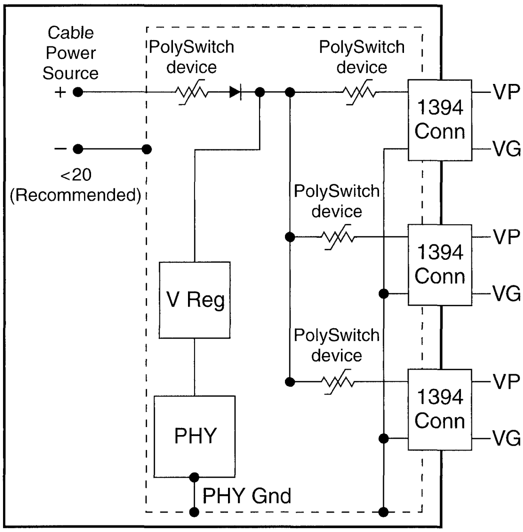
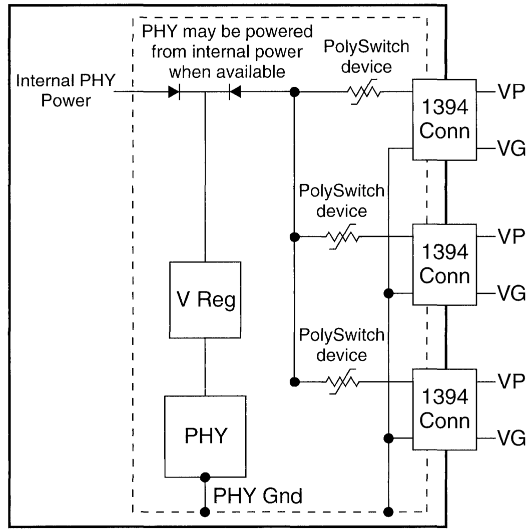


Figure 5. Self-Powered Hub (SelfID)



PolySwitch Device Selection

Devices suitable for the IEEE 1394 applications must support 33V (the maximum allowable continuous bus voltage) and up to 1.5A of continuous current. PolySwitch PPTC devices typically used in IEEE 1394 applications include the SMD, RTE, and RXE series, specifically those rated for 33V and above.

I/O Ports (PS2, MIDI, Gameport, etc) –Motherboards
Application Overview

Problem/Solution
Manufacturers are faced with providing a safe and reliable product for their customers, and protecting the I/O ports is an important consideration. To meet regulatory agency requirements, these ports must have some way of interrupting or limiting current in the event of an overload or a short-circuit. Using a PolySwitch resettable device in series between the connector and the host power supply can provide an effective solution while simultaneously lowering manufacturers' warranty costs.

3

Typical Agency Approval Requirements
If the manufacturer is required to meet UL1950 or IEC60950 specifications, the current at the connector must be limited to 5A in less than 60 seconds. By limiting current during a short-circuit situation, a PolySwitch device will help the manufacturer meet this requirement.

Technology Comparison
The circuit designer has many options available, including fuses and power management circuits. Fuses provide current interruption; however, the device can provide protection only once, and then it must be replaced. The designer can also choose to use a power management circuit, but the cost can be prohibitive.

PolySwitch resettable devices offer a low-cost solution because, once the fault and power to the circuit are removed, the device automatically resets and is ready for normal operation.

Device Selection
The most commonly used PolySwitch resettable devices for these applications are the microSMD, miniSMD, RUE, and RUSB series.

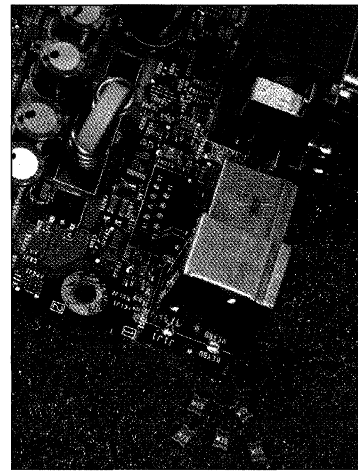
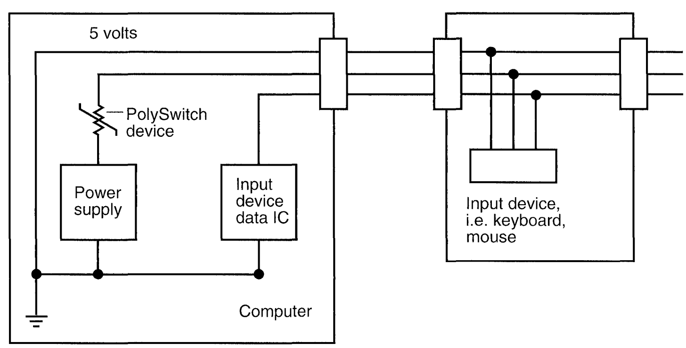


Figure 1. I/O Port Circuit



LCD Monitor Controller/Inverter
Application Overview

Large flat panel displays designed to replace CRTs make for extremely space and power efficient displays, attractive to both consumers and businesses. At the same time, the cost of large flat panel displays is high, resulting in high customer expectations for reliability and repair. The cost of large displays is driven by the expense of the liquid crystal displays (LCD) panel, making this a key component to protect from overcurrent damage.

Current generation portable computers use backlit LCDs to take full advantage of power and size efficiency.

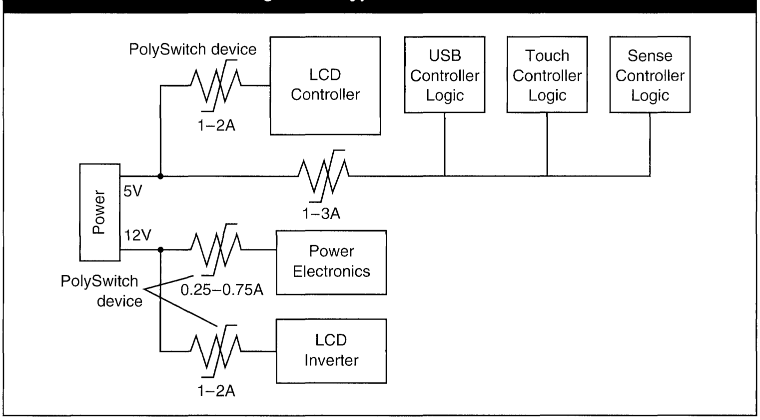
Cold-cathode fluorescent lamps (CCFLs) provide the highest available efficiency for backlighting the display. The lamp requires high voltage AC to operate, mandating an efficient, high voltage DC/AC converter. The LCD also requires a bias supply for contrast control. The supply's output must regulate and provide adjustment over a wide range. A wide array of monochrome and color displays are available. These displays vary in size, lamp drive current, contrast voltage polarity, operating voltage range, and power consumption. The small size and battery-powered operation often associated with LCD-equipped apparatus dictate low component count and high efficiency. Size constraints place limitations on circuit architecture and often long battery life is a priority. For laptops, all components, including PC board and hardware, must fit within the LCD enclosure with a height restriction less than 10mm.

Problem/Solution
Power for LCDs is derived from 5V and 12V buses. The LCD controller itself and the surrounding controller logic are powered from the 5V bus. The LCD inverter and other electronics on the board are powered from the 12V bus. Misconnections and mishandling either during assembly or during use of a wake-up port can cause large overloads and short-circuits to the system. In addition, component failures on the board can destroy the entire board. Isolating critical circuits with separate PolySwitch devices (as shown in Figure 1) helps prevent expensive components from being damaged during this type of fault.

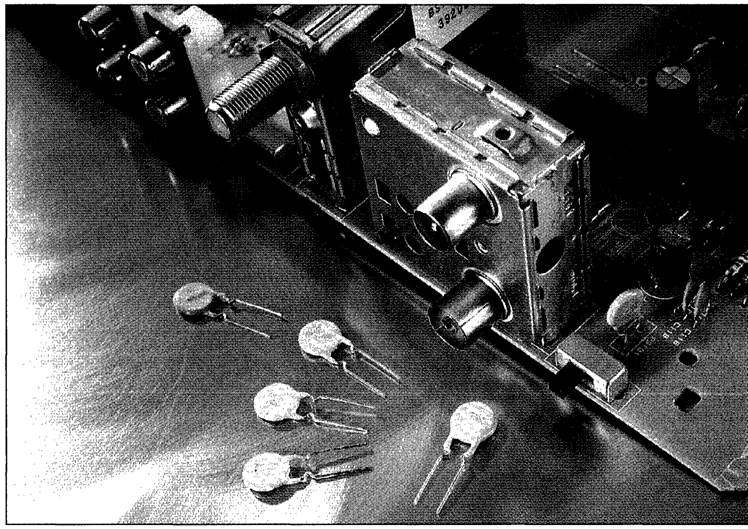
Device Selection
The microSMD and miniSMD series are typically used for surface-mount applications, whereas the RXE and RUE devices are typically for thru-hole applications.

3

Figure 1. Typical Schematic



LNB (Low Noise Block) Satellite Set-tops
Application Overview

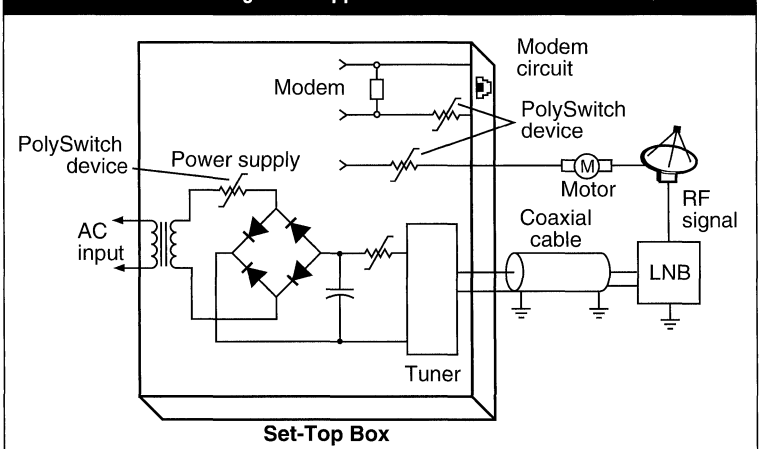


Problem/Solution

DBS-1 and DBS-2 satellites transmit Left-Hand Circular Polarization (LHCP) and Right-Hand Circular Polarization (RHCP) respectively. Although using both LHCP and RHCP increases the complexity of the home receiving antennas, it allows more channels to be broadcast in the same frequency band without interference. Even numbered channels are transmitted using LHCP, and odd numbered channels with RHCP. The LNB is an electronic unit mounted on the satellite dish. It receives the signals reflected by the dish and converts them to signals that can be used by the receiver. The power supply in the receiver provides +13V at the RHCP and +18V at the LHCP input for the LNB. Typical specifications for the dual LNB are 13V ± 5%,18V ± 5% maximum, both at 400mA operating current.

Coaxial cable is used to carry both signals from the satellite dish LNB to the receiver unit, and DC power from the receiver's power supply to the LNB. A short-circuit overload to the power supply can occur if the central pin in the coaxial cable connection to the receiver is bent or crushed against the connector during installation; it can also occur any time the user disconnects the antenna from the receiver. Thus, the LNB circuit should be protected.

Figure 1. Application Schematic



Technology Comparison

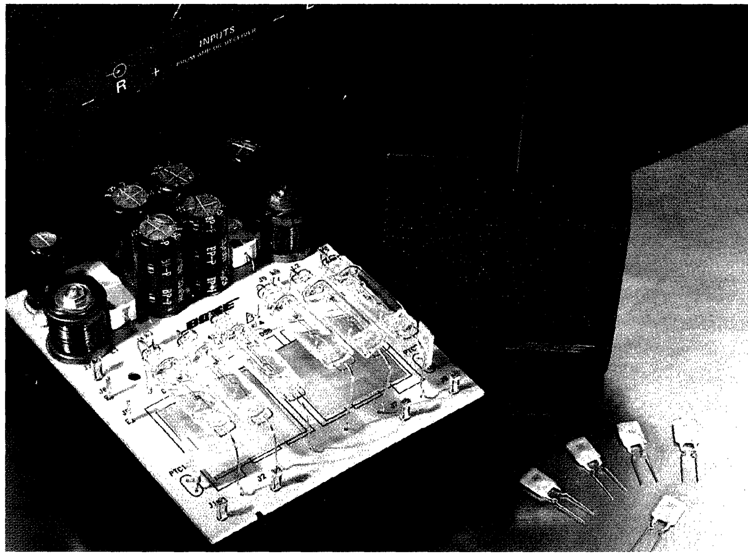
Fuses have been used in these applications. But fuses need to be replaced when blown, frequently leading to expensive service calls. Fuses that are user accessible can be incorrectly replaced, leading to nuisance blowing if too small a fuse is used, or to system damage if too large a fuse is used. PolySwitch resettable devices latch into a high-resistance state when a fault occurs. Once the fault and power to the circuit are removed, the device automatically resets and is ready for normal operation.

Device Selection

Devices typically used in this application are the miniSMD, SMD, RXE, and RUE series.

Loudspeakers
Application Note

Many loudspeaker systems incorporate PolySwitch devices for overcurrent protection. By tripping during high-current conditions and resetting when no longer needed, PolySwitch devices provide reliable protection without the nuisance and replacement costs associated with fuses.



The Problem

Today's speakers are generally designed and sold independently of amplifiers. Thus, mismatches may occur, which can lead to damage. Also, the advent of digital recordings and compact discs places extra burdens on sound systems. Speaker damage can result from a number of factors, including the following situations:

- High-power amplifiers used with low-power speakers may simply overdrive the speaker coils with excessive power during sustained high volume.
- Low-power amplifiers may be overdriven so that clipping occurs. This causes an upward frequency shift of power that can overload the tweeter. This problem is especially common with the wide dynamic ranges found on compact discs.
- Digital recordings, including compact discs, with their ability to reproduce high-frequency material, place extra strain on tweeters.

The protection choices for loudspeaker systems are fairly limited. Fuses will protect the speaker, but a blown fuse will be a source of frustration for the user and may result in field returns for the manufacturer. Also, the addition of a fuse holder and wire so that the fuse is accessible will increase material costs. Because the fuse must be accessible, it can be defeated or replaced with the wrong fuse. Circuit breakers are an alternative method. However, they can arc as they start to open and cause disturbing noise until they are fully open. PolySwitch resettable devices are typically used to solve these problems.

The Solution

PolySwitch resettable devices provide soft switching into a high-resistance tripped state, and automatically reset to a low-resistance state when power is removed. At normal operating temperatures, these devices have very low resistances (from 30mΩ to 800mΩ for the RXE devices typically used in speakers). Therefore, their insertion loss is usually less than 0.1dB. They have essentially no capacitive or inductive reactance and cause no measurable distortion over the audio range of frequencies.

When excessive currents are flowing, the temperature of the PolySwitch device increases and the crystalline structure of the polymer begins to change to an amorphous state and expand. Conductive paths within the polymer mass separate, causing a dramatic increase in the device's resistance. This increased resistance reduces the amount of current that can flow to a minimal level. The time it takes for a particular device to trip depends on the amount of current flowing.

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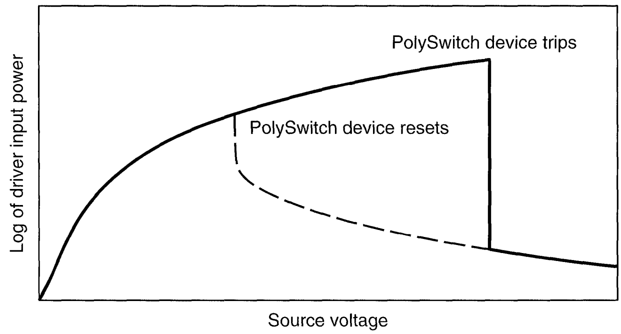
Figure 1. Effect on Load Power



The resistance of the PolySwitch device in the tripped state (R_{PS}) is typically three to four decades higher than the untripped resistance. Tripped state resistance is determined from the square of the PolySwitch devices voltage (V_{PS}) and the power dissipation of the device (P_D). P_D is essentially constant for a particular PolySwitch device in the tripped state. It can be affected by heat transfer conditions, such as the way the part is mounted or connected, air currents, and other factors. The formula for Rps when the device is in the tripped state is as follows:

$$Rps = \frac{V_{PS}^{\ 2}}{P_D}$$

$$Rps \cong \frac{V^2}{P_D}$$

(V is the drive voltage and V_{PS} is the voltage across the PolySwitch device. They can be assumed to be approximately equal for this equation.) As long as the drive voltage is sufficient, the PolySwitch device will stay in the tripped state and protect the system. Figure 1 shows how the load power is reduced by 20 to 30dB after the device trips. The formula for dB power attenuation in the tripped state is:

$$\text{Atten.} = 20 \log \frac{V - V_{PS}}{V}$$

where:

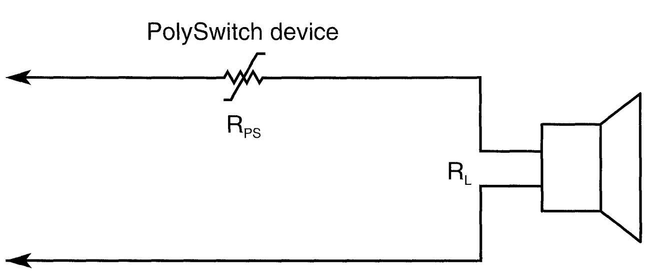
$$V_{PS} = \frac{V + \sqrt{V^2 - 4R_LP_D}}{2}$$

When the drive voltage is increased, the PolySwitch device resistance increases, causing the power output to decrease. When the drive voltage is reduced, the power increases along the dotted line in Figure 1. When the drive voltage is reduced so that the PolySwitch device can no longer draw sufficient power to keep itself in the tripped state, the device resets. Since PolySwitch devices reset themselves, they do not have to be accessible or replaceable by the user. The drive voltage at which the PolySwitch device will reset is approximately:

$$V \leq 2\sqrt{R_LP_D}$$

where R_L is the load resistance.

Figure 2. Typical Circuit



Applications

Figure 2 shows the most simple installation, which consists of a PolySwitch device in series with the driver. The PolySwitch device should be sized so that its time-to-trip at any particular current is less than the time required to damage the driver at that current. The circuit in Figure 2 will have the power characteristics shown in Figure 1.

PolySwitch device with shunting resistor

Some designers would like to reduce the drive power by a smaller fixed amount in case of a fault, rather than the large amount.

Figure 3. Shunt Resistor Circuit

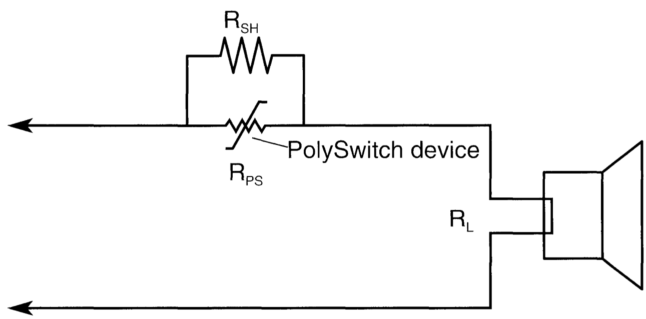


Figure 4. Effect on Load Power—Shunt Resistor

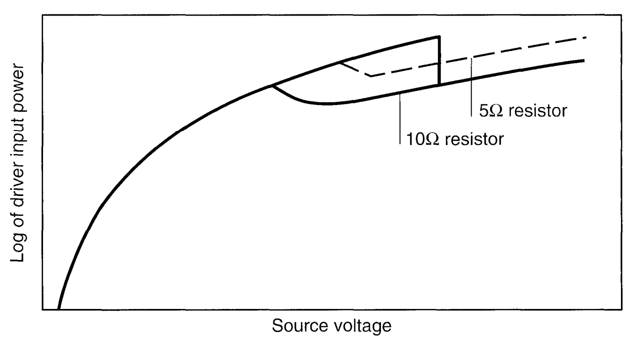


Figure 5. Shunt Lightbulb Circuit

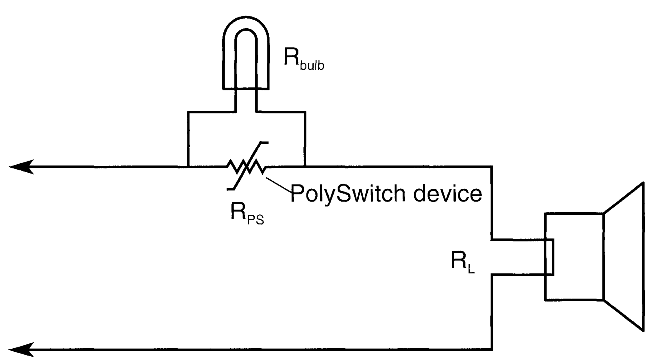


Figure 3 shows a sample circuit with a shunt resistor in parallel with the PolySwitch device. Figure 4 shows the load power characteristics for a 5Ω and 10Ω shunt resistor.

Now, the dB power attenuation when the PolySwitch device trips is approximately:

$$\text{Atten.} \cong 20 \log \frac{R_L}{R_L + R_{SH}}$$

where R_{SH} is the value of shunt resistance. The approximate source voltage at which the PolySwitch device resets in this case is:

$$V \leq 2R_L \sqrt{P_D \left\langle \frac{1}{R_L} + \frac{1}{R_{SH}} \right\rangle}$$

PolySwitch Device with Shunting Lightbulb

A third method is to use a shunting lightbulb in parallel with the PolySwitch device as shown in Figure 5. Figure 6 shows the load power characteristics for a 0.5Ω and 1.5Ω lightbulb.

As with the shunting resistor, the PolySwitch device normally carries most of the current. When the PolySwitch device trips, most of the current now passes through the lightbulb. As the bulb filament lights and heats it exhibits a PTC effect (about 1 decade of resistance increase). As with the fixed-shunt resistor, increases in drive voltage will increase load power. However, the PTC effect of the lightbulb causes this increase to be much flatter than the increase seen with the fixed-shunt resistor. The result is less of an increase in speaker power as the volume is increased as shown in Figure 1.

The same equations for dB attenuation and reset drive voltage for the fixed-shunt resistor apply for the shunt lightbulb. The value for shunt resistance now depends on a complex balance between the PolySwitch device resistance and lightbulb resistance.

The lightbulb is typically used only for its PTC effect, but it can also be used as an overload indication to the user. An LED in series with a resistor can also be used as an overload indication, but it does not have any PTC effect.

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The choice between a shunt resistor and a lightbulb resistor, or the choice to use nothing at all in parallel with the PolySwitch device, depends on the protection philosophy of the speaker designer. Components can be chosen so that the user immediately hears the attenuation when the PolySwitch device trips. Alternatively, components can be chosen so that the user never hears an attenuation, just a reduced volume increase as he or she turns up the volume control after the PolySwitch device has tripped.

Device Selection

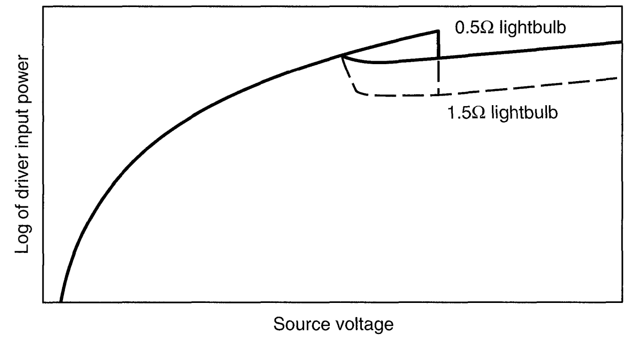
Deciding which part to use must be based on a knowledge of the specific protection needs of the driver. An analysis of the time it takes to cause damage for various drive currents would be very useful.

For effective protection, the PolySwitch device's time-to-trip curve at the lowest expected ambient temperature should lie below the driver's time-to-damage curve. If a complete time-to-damage curve for the driver is not available, the designer can choose a PolySwitch device with a trip current just below the maximum safe steady-state current for the driver. In either case, the designer should conduct an empirical investigation to verify performance.

The RXE series of PolySwitch devices is rated from 60-72V.

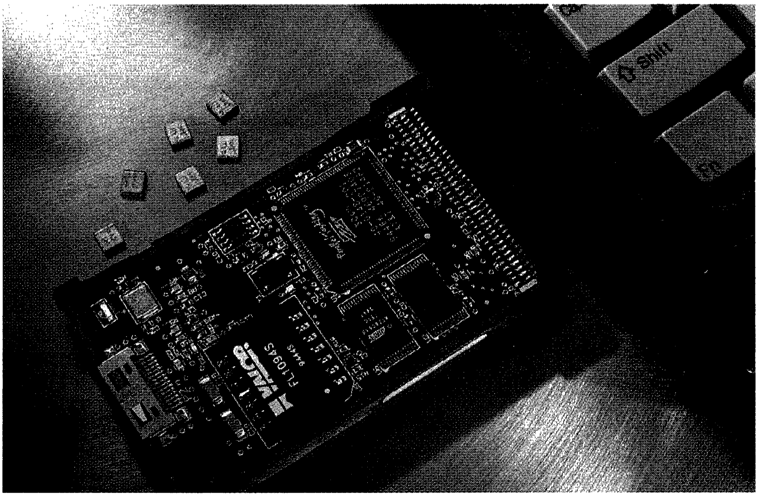
The SPK series may also be used where connectors are needed rather than mounting to a PCB. For more information on this product line contact your local Raychem Circuit Protection representative.

Figure 6. Effect on Load Power—Shunt Lightbulb



PC Cards and Sockets
Application Overview

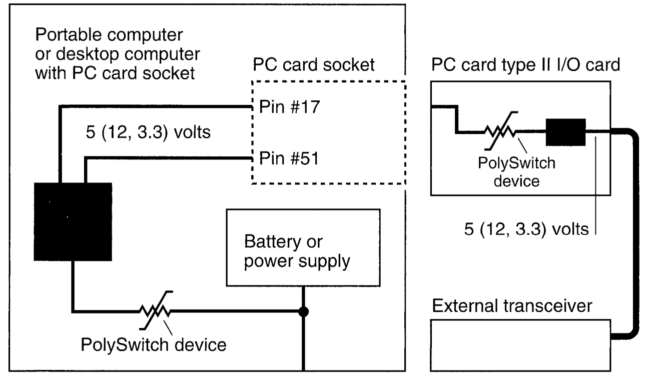
Problem/Solution
PC cards are the standard method for adding capabilities to portable computers. The cards have low operating currents of 70mA to 100mA. Threats to the PC cards and the PC card bus come from sources external to the cards and bus—damaged cables or incompatible cards, for example—not from failure of the PC cards themselves. Use of PolySwitch resettable devices on the PC card itself or in the host computer provides overcurrent protection, which minimizes the chances of permanent damage should a fault occur.



Typical Protection Requirements
Short-circuits from external sources are the primary hazards for PC cards. The cards need protection from large current inrushes that can damage the PC card or the PC card bus.

Technology Comparison
The circuit designer has many options available, including fuses and power management circuits. Fuses provide current interruption; however, the fuse can provide protection only once and then it must be replaced, which may not be possible on a PC card. The designer can also choose to use a power management circuit, but the cost can be prohibitive or the space unavailable. PolySwitch resettable devices latch into a high-resistance state when a fault occurs. Once the fault and power to the circuit are removed, the device automatically resets and is ready for normal operation.

Figure 1. Type II PC Card and Socket



Device Selection
Devices that are typically used in this application are miniSMD, microSMD, nanoSMD and SMDxxx-2018 series.

SCSI
Application Overview

The Small Computer Systems Interface (SCSI) is a local I/O bus that is used to connect several peripherals to a host computer. The number of addressable devices per system is determined by the width of the data path, i.e. wide SCSI can have 16 devices.

Termination and TERMPWR
Proper termination of the SCSI bus is very important to maintain signal integrity. Since the cable environment is not controlled, the termination impedance may not match the cable impedance resulting in signal reflections. Reflections contribute to improper bus performance. The terminator circuitry absorbs reflected signals and improves data integrity. The function of a SCSI terminator is to source current when the line is active, and to maintain the proper open circuit voltage when the line is not active. All terminators independent of location shall be powered from the TERMPWR lines. Per the SCSI standards, provisions shall be made to provide power to the TERMPWR lines of the SCSI bus. The power shall be supplied through a low forward drop diode or similarly behaving circuit that prevents backflow of power if one of the sources of TERMPWR is powered-off.

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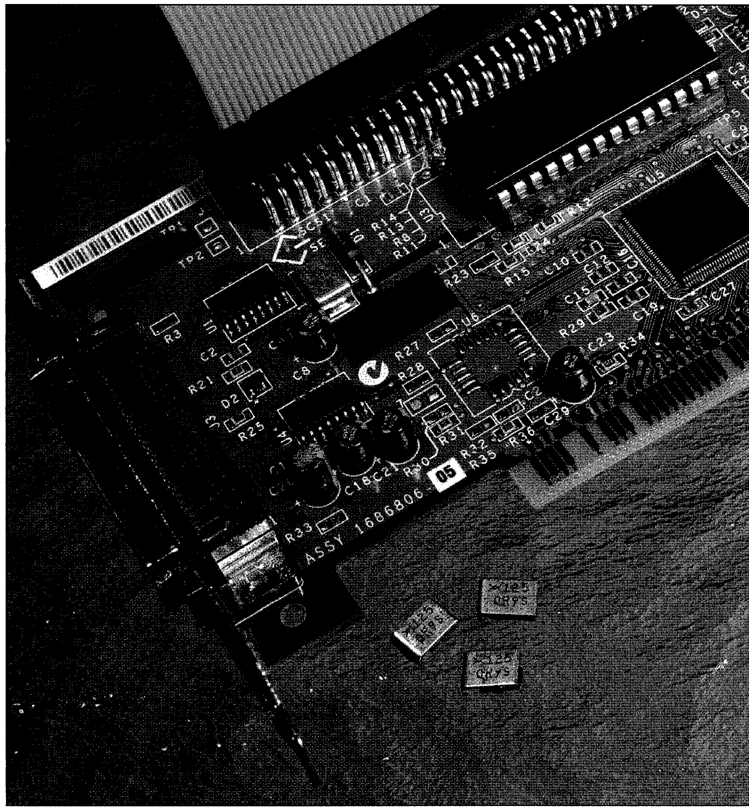


Problem/Solution
The TERMPWR line on a SCSI port provides termination power for peripherals on the SCSI bus. A short-circuit anywhere on the bus can cause the entire bus and host to crash. A PolySwitch device can be used for circuit protection on the SCSI controller circuit and on each individual peripheral that is connected to the SCSI bus.

Typical Agency Approval Requirements
UL1950 and IEC60950 are the primary agency specifications that govern the output of power sources.

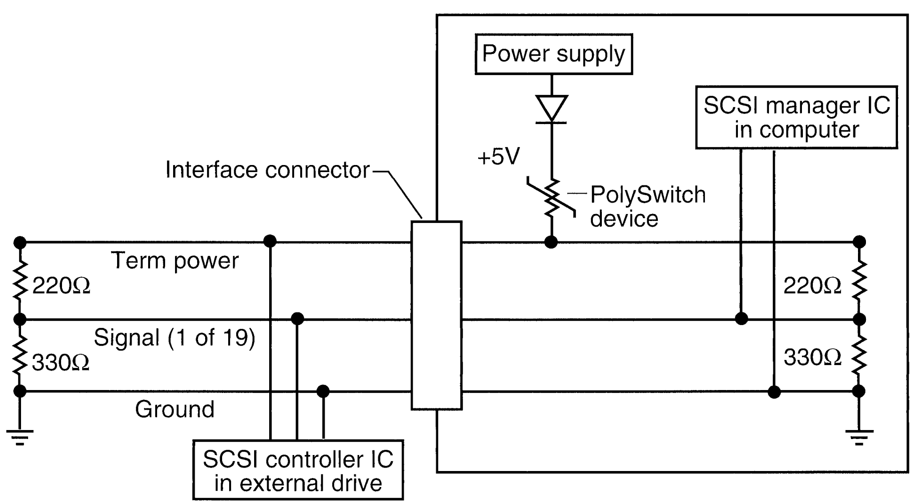
Typical Protection Requirements

The SCSI bus TERMPWR line can draw up to 1.5A in certain conditions. When a short-circuit occurs, that current can increase well beyond safe levels thus requiring protection. Also, resettability is important because the frequency with which peripherals will be connected and disconnected from the bus increases the likelihood of a short-circuit caused by a damaged cable or a misconnection.

Device Selection

The most commonly used PolySwitch resettable devices in SCSI applications are the microSMD, miniSMD, and SMD series devices ranging in hold current from 0.75 to 3.0A.

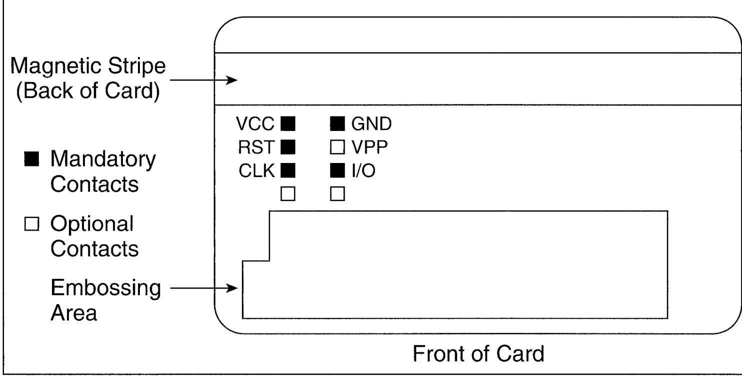
Figure 1. Typical Schematic



Smart Card Reader
Application Overview

Problem/Solution
Called by various names—Integrated Circuit Cards, Smart Cards, Chip Cards—these wallet-size cards with an IC chip inside are used to deliver information, store data, and/or modify data content. The card is powered from the card reader's Vcc. Defective cards or foreign objects placed into the reader can cause a short-circuit and permanently damage the reader. Placing a PolySwitch device in the power source circuit can provide protection against such faults.

Figure 1. Smart Card



Typical Protection Requirements
The EMV '96 – Integrated Circuit Card Specification for Payment Systems (Version 3.1.1, May 31, 1998) states that terminals do require circuit protection; VPP is not used by the terminals, Vcc is covered by section 1.4.6 listing the following operating characteristics:

$V_{OP} = 5V \pm 0.4V$

I_{OP} max = 55 mA

T_{OP} = 0-50 C

Resettable overcurrent protection is required per sections 1.4.6 and 1.4.8 of the EMV:

1.4.6 Supply Voltage (Vcc)

The spec states:

> "The terminal shall generate a Vcc of 5V ± 0.4VDC and shall be capable of delivering steady state output current in the range 0 to 55 mA while maintaining Vcc within these tolerances.... The terminal shall contain protection circuitry to prevent damage occurring to it in the event of fault conditions such as a short-circuit to GND or Vcc."

1.4.8 Short-Circuit Resilience

The spec states:

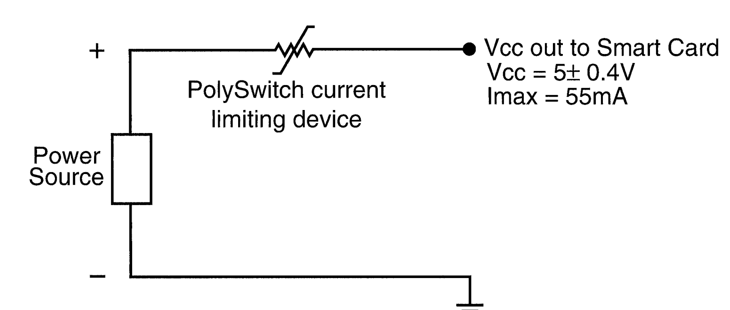
> "The terminal shall be capable of sustaining a short-circuit of any duration between any or all contacts without suffering damage or malfunction, for example, if a metal plate or an ICC with a metallic surface is inserted."

Typical Agency Approval Requirements
ISO/IEC 7816-3 covers the requirements for these cards.

Type	Voltage (max.)	Current (max.)	Ambient Temp.
A	5.5V	60mA	0-50C
B	3.3V	50mA	0-50C

Device Selection
For Vcc protection, products typically used are from the nanoSMD and microSMD series.

Figure 2. Smart Card Reader Schematic



USB (Universal Serial Bus)
Silicon & PolySwitch Solutions Application Note

Overcurrent Protection and Power Switch Design Criteria

The Universal Serial Bus connection offers a standard interface for attaching computer peripherals to a host system. USB is a bus-powered interface on which circuit protection is a requirement. Per the 1.1 and 2.0 USB specifications, high-power devices can source up to 0.5A current, while low-power devices can source up to 0.1A current. Circuit protection minimum requirements stem from UL, IEC, CSA, and other regulatory agencies. As an example, UL60950 states that current must be limited to 5A within 60 seconds if a short is applied across the bus. These requirements can easily be met with the appropriate application of PolySwitch devices. However, tighter requirements can be driven by system limitations. Raychem Circuit Protection offers both PolySwitch and protected power switch devices to meet all design requirements.

USB Hub Design

The first criterion is meeting the USB Specification where the following is given in Table 1.

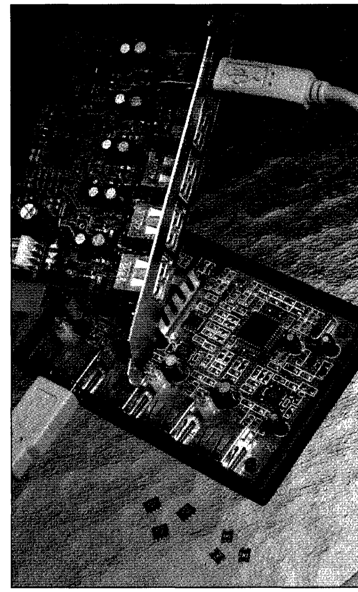
Additional design considerations include:

- Cost
- System Functionality
- Ganged/Individual Protection or Switching
- Component Long-Term Reliability

PolySwitch Protection

The most important design requirements for Hosts/Self-powered Hubs are low cost, high system reliability, and overcurrent protection implementation; power switching is optional. The low-cost, reliable, resettable overcurrent protection is achieved with a PolySwitch PPTC device.

Raychem Circuit Protection's PolySwitch devices offer designers the broadest range of products to select from, including the lowest resistance and smallest size packages. Depending on the design criteria, Raychem Circuit Protection has a device which fits the specific requirements. Table 2 is a selection guide for PolySwitch devices for USB.



Implementation examples are offered in Figures 1 and 2.

Protected Power Switch Protection

With the advent of portable PCs and energy conservation, some USB system implementations have become extremely power sensitive. In low-power designs, voltage droop on the main system bus can disable a system. Therefore, for reliable system operation, extremely fast and accurate fault correction on the USB bus is required. In addition, voltage drop between the system Vcc and the USB port must be minimized. Finally, these requirements must be met at a reasonable cost.

Table 1. Protection Criteria

Host	Overcurrent Protection*	Power Switching*
Self-powered hub	Required	Optional
Bus-powered hub	Optional	Required

Note: *Overcurrent protection and power switching may be designed in either a ganged or individual port format.

Table 2. Selection Guide for PolySwitch Devices for USB

	Device Selection Criteria		
	Small Size	Low Resistance	Fast Time-to-Trip
1 port (individ.)	nanoSMDC075	microSMD150	nanoSMDC075
2-port ganged	nanoSMDC150	microSMD150	nanoSMDC100
3-port ganged	miniSMDC200	miniSMD200	miniSMDC200
4-port ganged	miniSMDC260	miniSMDC260	miniSMDC200

Figure 1. Ganged Port Protection (two-port example)

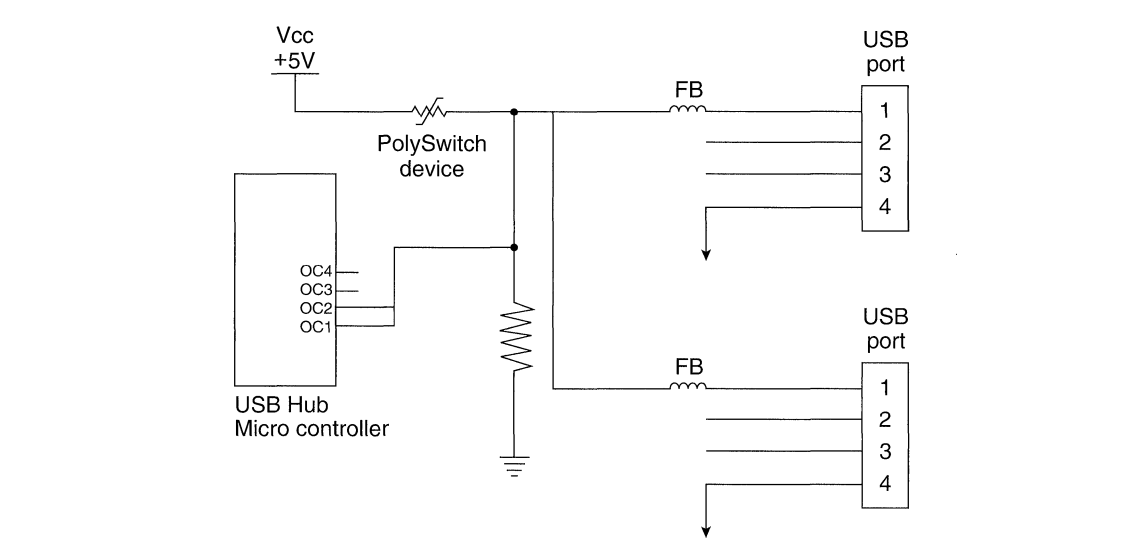
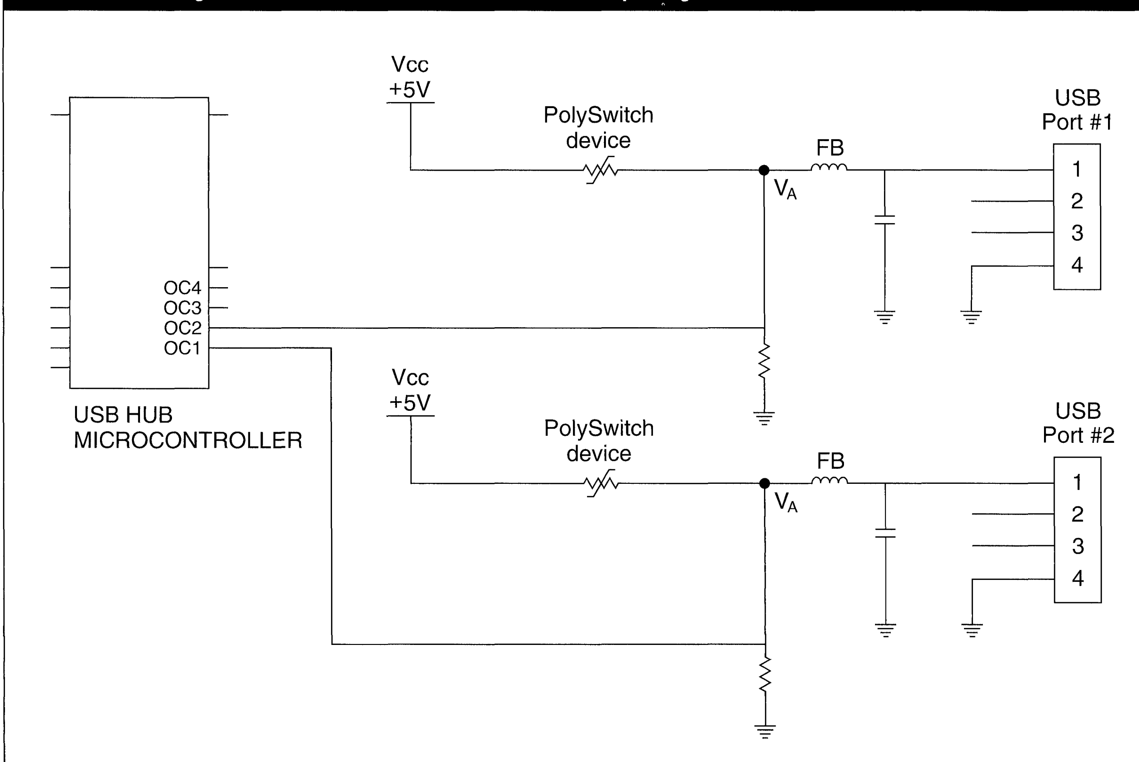


Figure 2. Low-active Overcurrent Pin Fault Reporting for Individual Port Protection



Raychem Circuit Protection has developed a line of active silicon protected power switches to meet these requirements. These power switches offer:

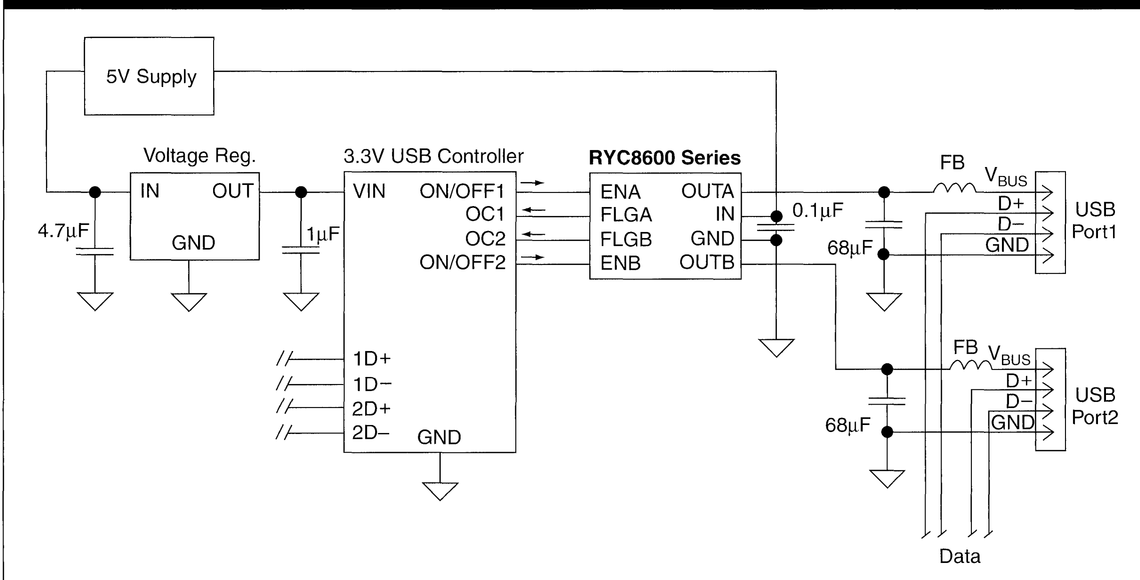
- Extremely fast trip time
- Extremely sensitive overcurrent sensing
- Low series resistance that drops with input voltage
- Individual port control
- Integrated anti-nuisance tripping circuitry
- Integrated off-board components
- UL recognition

A selection guide for Raychem Circuit Protection's protected power switches is offered in Table 3. Implementation examples are offered in Figures 3 and 4.

Table 3. Selection Guide to Protected Power Switches

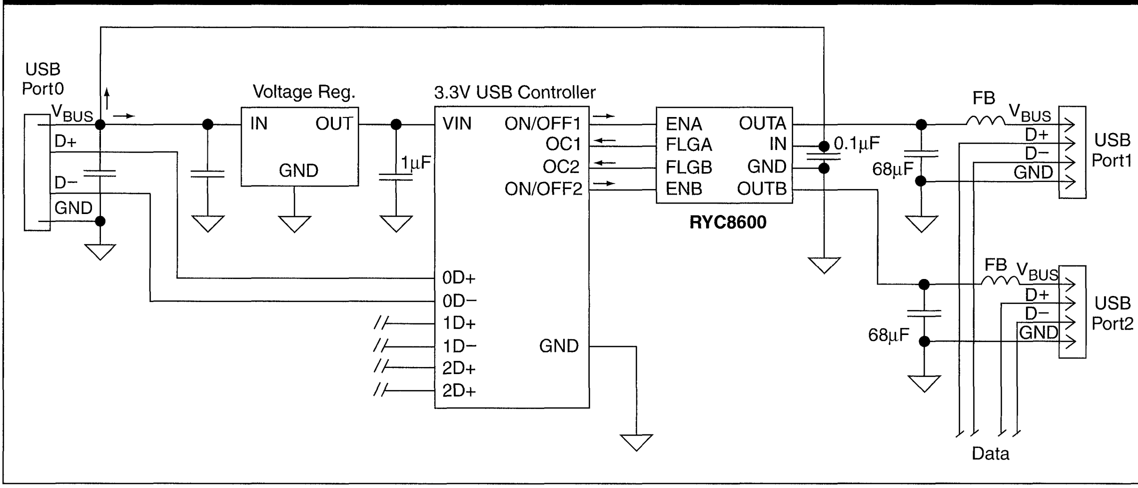
Host	No. of ports	Device
Self-Powered Hub	1 / 2	RYC8600 Series
	2	RYC8600 Series
Bus-Powered Hub	2	RYC8600 Series
Peripheral Devices	1	RYC8600 Series

Figure 3. Dual Port Power Switch in a Self-powered Hub*



*This design is popular in Desktop PCs and Notebook PCs with two ports.

Figure 4. Dual Port Power Switch in a Bus-powered Hub



USB Peripherals: In-Rush Limiting

Per the USB Specification 1.1, the maximum load that can be placed at the downstream end of a cable is 10µF in parallel with 44Ω. The 10µF capacitance represents any bypass capacitor directly connected across the V_{BUS} lines in the function plus any capacitive effects visible through the regulator in the device. The 44Ω resistance represents one unit load of current drawn by the device during connect. If more bypass capacitance is required in the device, then the device must incorporate some form of V_{BUS} surge current limiting, such that it matches the characteristics of the above load. The soft-start circuit below can be utilized to meet USB transient regulation specifications with large load capacitances (C_{BULK} >10µF). The RYC8600 series devices are typically used to provide in-rush current limiting for these applications.

Video Ports: DDC, DVI, M1, VGA
Application Overview

Problem/Solution
More and more software and hardware standards are specifying configurations that support the plug-and-play concept and energy-saving features such as those outlined in the EnergyStar program. The Display Data Channel Standard (DDC) promoted by the Video Electronics Standards Association is one such standard. To meet regulatory requirements, video interfaces must have some method of interrupting or limiting current in the event of an overload or a short-circuit. Using a PolySwitch resettable device in series between the connector and host power supply can provide an effective solution, while simultaneously lowering manufacturers' warranty costs.

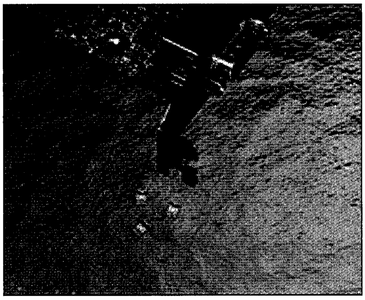
The Digital Visual Interface (DVI) specification incorporates a subset of the DDC for operation between a DDC compliant host and DDC compliant monitor. The DDC level support required in the DVI specification is DDC2B, which means that support of the 5V signal pin is required.

The M1 standard is a modification of DVI. M1 incorporates a USB connection to the display device as well as the addition of a power pin on the display side connector.

Typical Protection Requirements
Devices that comply with the DDC host system standard typically provide supply voltage on pin #9 of the standard 15-pin VGA connector. The voltage is 5V ±5% and supplies a minimum of 300mA to a maximum of 1A.

For DVI compliant systems, pin #14 carries the 5V power at a maximum of 50mA. In a short-circuit condition, the current draw can be many times that specified by the standard and the port should be protected.

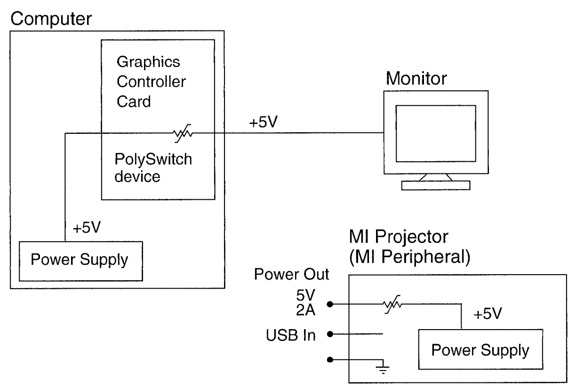
For M1 compliant devices the M1 peripheral has an additional power pin imbedded in its connector assembly. This pin is a 5V pin that can support up to 2A of current. Circuit protection is required if this pin is active. USB protection may also be required for M1 peripherals. (See the USB application note for details.)



Typical Agency Approval Requirements
If the manufacturer is required to meet UL60950 or IEC60950 specifications, the current at the connector must be limited to 5A in less than 60 seconds. By limiting current during a short-circuit situation, a PolySwitch device will help the manufacturer meet this requirement.

Device Selection
The devices that are typically used in this application are from the microSMD, miniSMD, nanoSMD, SMD, and RUSB series.

Figure 1. Video Card & M1 Peripherals Circuit Protection



POS Equipment
Application Overview

Problem/Solution
Credit card verification units transmit information over telephone lines and are subject to overcurrent and overvoltage threats, primarily from power cross, lightning surge, and low-frequency induction. A PolySwitch device, in conjunction with a SiBar device, helps to protect against these faults.

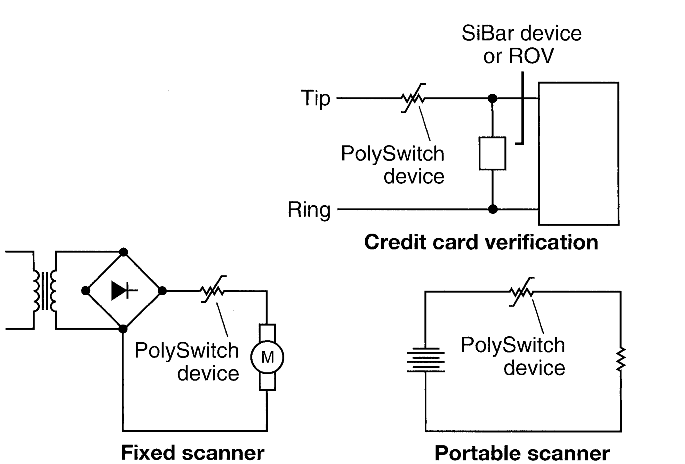
Bar code scanners, fixed and portable, are driven by motors and ditherers, respectively. PolySwitch devices installed in series with the load can protect the scanners from stalls, jamming, and overheating of the motors and ditherers.

Typical Protection Requirements
Telecommunication equipment typically requires overcurrent and overvoltage protection. For a more specific discussion of Telecommunication requirements, see Application Note entitled Customer Premise Equipment. For motors, voltage is typically less than 30V and currents are less than 1A.

Typical Agency Approval Requirements
UL1950 and FCC Part 68 may apply in this application.

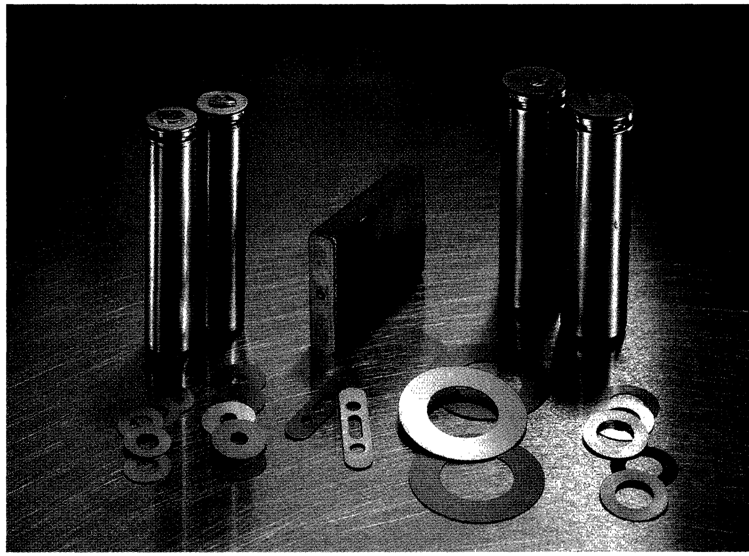
Technology Comparison
Bimetallic thermostatic switches, fuses, and ceramic positive temperature coefficient (CPTC) devices have been used to protect motors. The limitations of bimetallic switches include cycling and the potential for contacts to weld shut. The CPTC device has a relatively high resistance and power dissipation, which may be a concern in a portable system. In addition, CPTC devices are relatively large and can exhibit thermal behavior where undesirable high temperatures can be reached. Moreover, being a ceramic material, they may be vulnerable to cracking as a result of shock or vibration. CPTCs also have a relatively slower time-to-trip compared to polymeric PTC devices. Fuses can fatigue as well, but most significantly they are one-use devices that must be replaced after a fault has occurred. PolySwitch resettable devices latch into a high-resistance state when a fault occurs. Once the fault and power to the circuit are removed, the device automatically resets and is ready for normal operation.

Figure 1. Typical Circuits



Device Selection
For phone line protection see the SiBar, ROV, and Telecom Product sections of this Databook. For motor protection, small RXE devices, usually in the range of RXE017– RXE050, are typically used, as well as ROV devices.

Lithium Cells and Battery Packs
Application Overview



Problem/Solution
Primary lithium cells (such as AA and 2/3A) and rechargeable lithium cells (such as 18650, 17500, and prismatic) are sensitive to faults that cause overcurrent/ overtemperature conditions, such as the accidental shorting of the cell terminals and (for rechargeable lithium) abusive charging or charger failure. For these reasons, these cells usually need to be individually protected. Because of their electrical characteristics as well as their thin, flat form factor, PolySwitch devices internal to each cell help provide effective protection.

Typical Protection Requirements
Lithium cells typically require a protection device with a rating of 15V and 40A minimum.

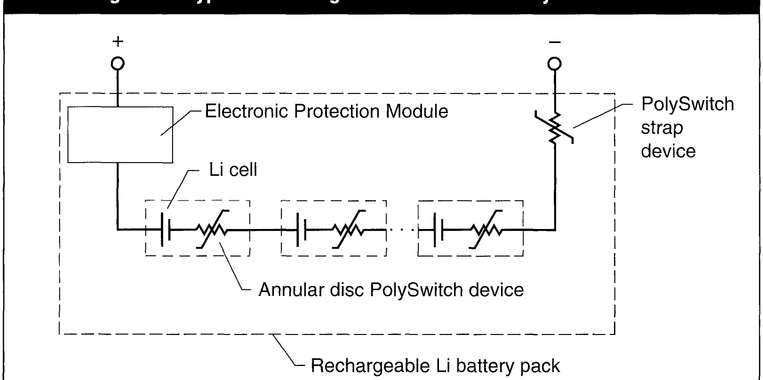
Typical Agency Approval Requirements
Primary and rechargeable lithium cells/packs are covered under the UL1642 Standard for lithium batteries and UL2054 Standard for household and commercial batteries.

Technology Comparison
The industry standard for the protection of lithium cells for consumer applications (such as cameras, laptop/notebook computers, cellular phones, and camcorders) is the use of PPTC devices in the form of PPTC annular discs inside the lid assembly of each cell. These disc devices work in conjunction with other cell safety devices, such as separators, pressure vents, and others.

PolySwitch PPTC devices latch into a high-resistance state when a fault occurs. Once the fault and power to the circuit are removed, the device automatically resets and is ready for normal operation.

Device Selection
Because the design of lid assemblies of lithium cells varies from manufacturer to manufacturer, PolySwitch annular discs are usually custom devices. Different disc sizes can be accommodated for the various cell configurations. For rechargeable lithium battery packs, VLR, VTP, LTP, LR4, SRP, VLP series are typically used with other special application strap devices for coordinated protection with our disc products.

Figure 1. Typical Rechargeable Lithium Battery Pack Circuit



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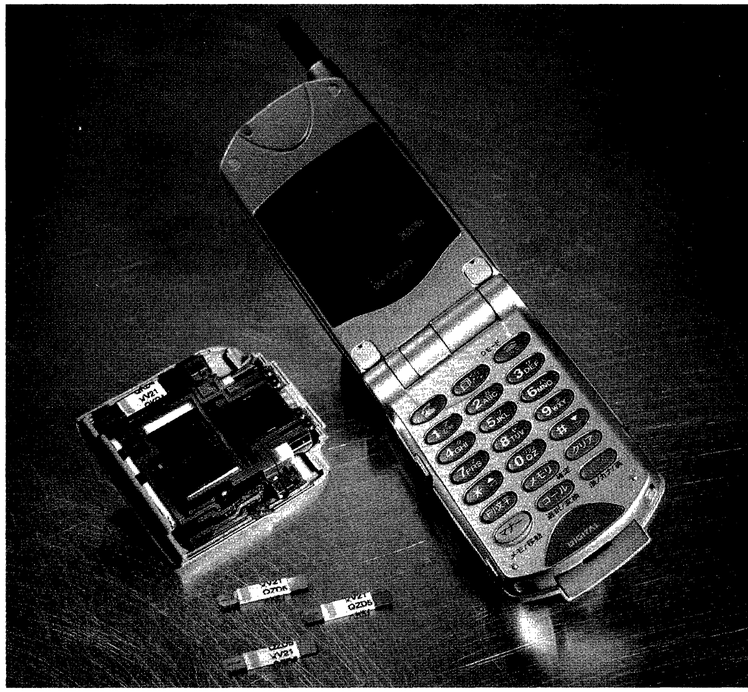
Rechargeable Battery Pack Protection
Application Note

Battery packs for the power supply of portable electronics equipment such as cellular phones, PDAs and laptop computers have particular protection requirements. Pack protection is required to provide continuing pack performance and consumer safety following misuse. In the last few years many different battery cell technologies have evolved and each of them requires its own specific protection solution.

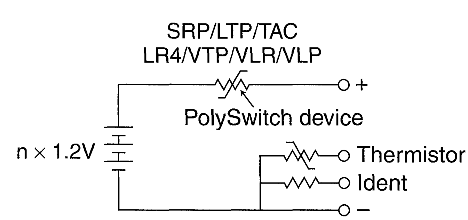


Problem
The principal electrical hazards faced by battery packs are the result of external terminal short-circuits during discharge and overcharge due to a faulty or incorrect charger. Internal pack faults are less common but if complex electronics for features such as fuel gauging or charge control are incorporated then there is an increased risk of internal faults. Any of the above conditions can result in a significant overtemperature event either inside or outside the pack.

Short-Circuits During Discharge
An unprotected battery pack typically can deliver up to 100A of short-circuit current when “hard” shorted by a low resistance element. Power dissipated in the battery cell’s internal impedance leads to a rise in cell temperature, the severity of which will depend on the pack’s thermal characteristics and the battery cell chemistry.

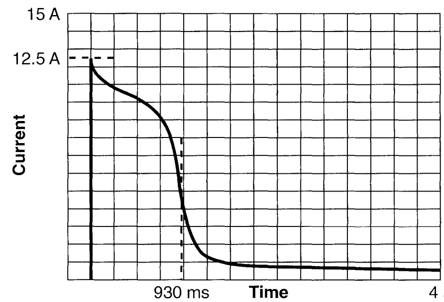
At a minimum the pack’s performance will deteriorate, and with some packs thermal runaway may take place resulting in venting, smoke or flame. If an unprotected pack is “soft” shorted by an element with some resistance, for example a few hundred milliohms, then the hazard changes from being power dissipated in the cell to power dissipated in the shorting element. Tests have shown that the resistive shorting element can reach temperatures in excess of 600°C in this situation and may result in ignition of adjacent combustible materials.

Figure 1. NiMH/NiCd Battery Pack Circuit Diagram



Battery Pack Overcharge
Each cell chemistry requires a specific charging profile to

Figure 2. NiMH Battery Pack Short-Circuit Interrupted by PolySwitch Strap Device



produce maximum performance and to minimize hazards. If this profile is not adhered to then overcharge can occur. A battery pack overcharge condition may be due to:

- A runaway charging condition, in which the charger fails to stop supplying current to the pack once it is fully charged. This is typically caused by a charger fault.
- Abusive charging occurs when the pack is charged under the wrong conditions by an incorrect or faulty charger. This is especially likely to happen when aftermarket chargers are used. To cope with the proliferation of battery chemistries, capacities and end-user products, a wide range of charger products has become available with limited standardization. Product reliability and/or safety issues may arise in some aftermarket products due to the proprietary nature of cell chemistry and charger designs.

Battery cell overcharge can result from an overcurrent or overvoltage condition or a combination of both. Nickel chemistries (NiCd, NiMH) tend to use a constant-current charge profile with charge termination determined by voltage, temperature, or time detection. Li-ion cells are charged with a constant current followed by charge completion with constant voltage. In both cases if current or voltage is allowed to exceed the prescribed values, then a significant rise in cell temperature may result, potentially resulting in venting, smoke or flame.

UL and IEC have set tests for battery pack resilience to both short-circuit and overcharge events (UL1950/IEC 6950). The characteristics of a series PolySwitch device to interrupt charging or discharging current during an unexpected short-circuit or overtemperature are very important.

NiMH & NiCd Pack Design & Device Selection

Figure 1 shows a schematic of a typical NiMH or NiCd battery pack. The pack contains n x 1.2V cells, depending on the application, in series with a PolySwitch strap as the sole circuit protection component. A thermistor is often incorporated to allow adaptation of charging depending on pack temperature. Depending on the required pack resistance and degree of overtemperature protection required, SRP, LTP, LR4, VTP, and VLR series may all be used. If the cells were AAA form factor then a TAC part could also be considered. Figure 2 shows how a 100mΩ short-circuit of a three cell NiMH pack is interrupted within one second by a VTP210 device.

The primary result of NiMH battery overcharging is the electrolytic generation of gas inside the battery. As this gas is generated, both internal cell pressure and temperature increase. In some cases, the internal heating can raise the temperature high enough to damage the battery's internal structure permanently or even result in venting. Figure 3 shows the combined overtemperature and overcurrent protection of a VTP210 device during an over-

Figure 3. NiMH Battery Pack Overtemperature due to Overcharge Interrupted by VTP Strap Device

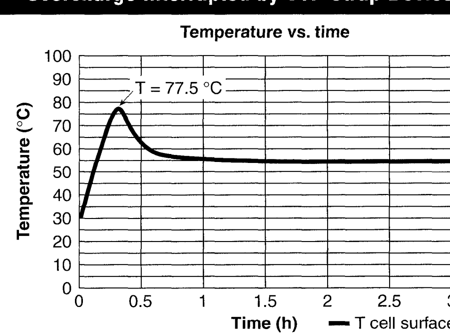
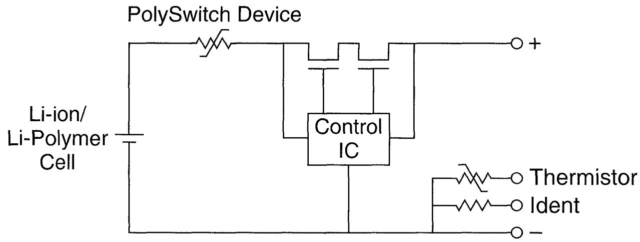


Figure 4. Single Cell Li-ion/Li-Polymer Battery Pack Circuit Diagram



charge event. In this case a 1.5C (825mA) overcharging current was interrupted once the cell surface temperature exceeded 77°C.

Li-ion & Li-Polymer Pack Design and Device Selection

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Figure 4 shows a schematic of a typical single-cell Li-ion battery pack for cellular phone or PDA applications. Similar principles apply for multicell applications, such as those for notebook PCs. In addition to a thermistor, packs including Li-ion cells with cobalt-based cathodes typically include two redundant series protection schemes as shown in Figure 4. Two series MOSFETs and a control IC provide overvoltage, undervoltage, and overcurrent protection while a PolySwitch device provides cell overtemperature protection on charge, discharge, and redundant overcurrent protection. Some Li-Polymer cell manufacturers and Li-ion cell manufacturers with manganese-based cathodes may recommend using only a PolySwitch device (perhaps in conjunction with a thermal fuse) without over/undervoltage protection from MOSFETs and a control IC. The precise protection requirement is cell chemistry-dependent and advice should be sought from the cell manufacturer on the exact protection required.

For Li-ion & Li-Polymer based packs, a low temperature/low resistance PolySwitch strap is required, such as devices from the VTP or VLR series. The device's low resistance overcomes the additional series resistance introduced by the MOSFETs and low temperature can provide optimum protection of the cell against thermal runaway in the case of an abusive overcharge. Figure 5 shows how a VTP170 will interrupt a 2.5C overcharge current when the cell temperature reaches 75°C. Welding to the cell body improves heat transfer from an overheating cell into the PolySwitch device.

Regardless of the pack chemistry device hold current is selected on the basis of the maximum average charge or discharge current taking into account maximum operating temperature. Form factor depends on the available space within the pack. A full range of PolySwitch strap devices is available to meet individual pack requirements.

Standards

There are various international standards for battery packs most based on original UL and IEC specifications. Both standards bodies specify short-circuit protection and overcharge tests. For example, UL specifies short-circuits of 8A or greater must be interrupted in 1 minute or less and packs must be capable of withstanding a 2.5C high rate charge. Further details and exact test conditions can be found in UL and IEC specifications.

Technology Comparison

PolySwitch PPTC devices are often used to replace bi-metal or thermal fuse protectors. Bi-metals are often bulky, high cost protectors which frequently do not latch in the protected position in a fault condition. This can result in a cycling battery pack fault and battery cell damage.
Conventional thermal fuses are not resettable and are therefore limited in their ability to match the low temperature protection of PolySwitch devices. The selection of minimum fusing temperature of conventional thermal fuses is limited by the need to avoid nuisance tripping in temporary high ambient temperature environments (such as car dashboards on a hot day or high storage temperatures). Even thermal fuses with 94°C or higher fusing temperatures often nuisance trip during normal operation or pack assembly.

Table 1. Device Selection Summary

Temperature Protection	Resistance	Strap Series*
Low	Low	VLR, VTP
Med	Med	LTP
High	Low	LR4, TAC
High	High	SRP, TAC

*For a full description of suitable part numbers, see the Protection Application Selection Table for Strap Battery Devices in Section 4.

Linear AC/DC Adapters
Application Overview

Problem/Solution

Linear AC/DC adapters, or "wall warts", have applications in both battery charging applications and as low-cost DC power supplies for a variety of consumer equipment. In using a separate AC/DC adapter, the end equipment design is often simplified and regulatory approval is more straightforward. A typical circuit diagram of an unregulated supply is shown in Figure 1 with its equivalent circuit in Figure 2.

Adapters have their own safety and reliability requirements. Principally these are associated with short-circuit current-limiting and overtemperature protection as a result of excessive heating in the transformer windings. If the windings reach a temperature in excess of that specified for the insulation, the resulting insulation breakdown may result in short-circuits within the transformer and a corresponding fire hazard. Winding overtemperature can occur as a result of high ambient temperatures, external short-circuits, or fluctuating input power conditions.

While the benefits of overcurrent protection with a PolySwitch device are easily understood, it may be less clear that the inherent thermal derating characteristic of PolySwitch devices is capable of providing protection during an overtemperature fault as described above.

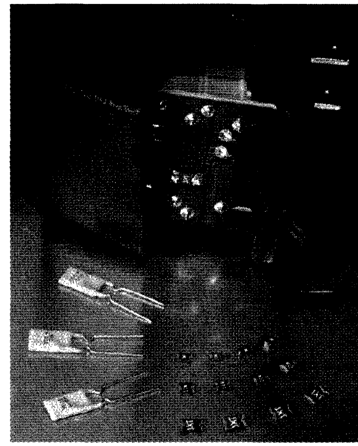


Figure 1. Example of an Unregulated Linear Adapter Protected by a PolySwitch Device

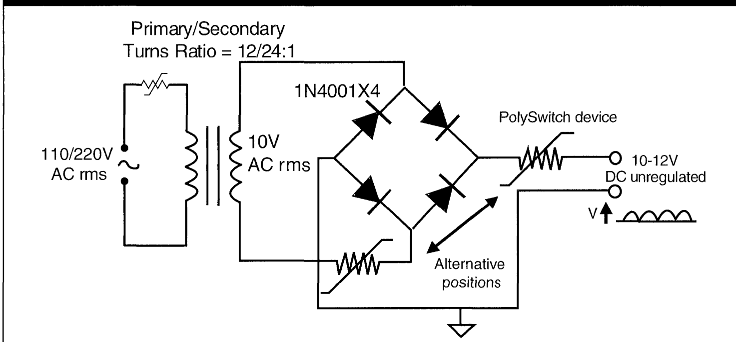
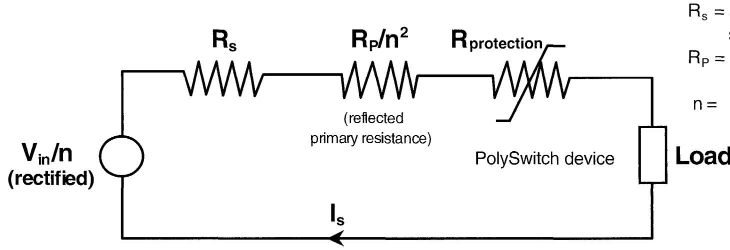


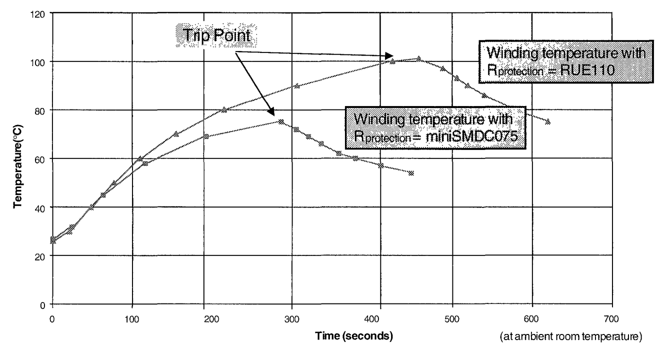
Figure 2. Transformer Equivalent Circuit



R_s = secondary winding series resistance
R_P = primary winding reflected resistance
n = turns ratio

- **Source impedance =** $R_s + R_P/n^2 + R_{protection}$
  – optimized to the load by adjusting resistance seen in the secondary side (winding gauge and number of turns)
- **Power dissipation =** $I_s^2R_P/n^2 + I_s^2R_s + I_s^2R_{protection}$
  – minimized by reducing winding and protection resistance

Figure 3. PolySwitch devices can limit transformer winding temperatures to well below UL/IEC specifications



Protection Requirements

Regulatory requirements for AC adapters are defined by UL. They are classified as a Listed Device and are subject to the Class 2 UL1310 specifications. UL1310 further specifies whether the adapters are inherently limited or not inherently limited. For 0-20V adapters the maximum specified output current in any condition is 8A and the maximum specified winding temperature is defined as a function of the insulation class. Typically, for the majority of low-cost consumer adapters, the choice of winding insulation is classed as Type A by UL with a maximum permitted temperature of 65°C above ambient in normal operation and an overall maximum of 150°C in fault conditions.

Technology Comparison

A thermal fuse embedded in the transformer winding is sometimes used but has the disadvantage that it is a one-shot device and is therefore less suitable for transient fault conditions such as output short-circuit or a fluctuation in input voltage. Ceramic PTC devices have the disadvantage of a higher impedance in the nontripped state, resulting in excessive power dissipation during normal operation. A higher class of insulation may also be considered for the transformer winding to avoid the need for further protection, but this generally results in a significantly more expensive transformer.

PolySwitch Device Selection

The PolySwitch device is selected by considering the maximum load current to be delivered, the highest ambient temperature, and the minimum time to trip with rise in transformer temperature. New Polyswitch LVR devices are capable of operating at line voltages of 85 V_{AC} to 265 V_{AC}, making them suitable for protection on the primary side of linear transformers. These devices help protect against excessive voltage on the primary side and short circuits on the secondary side. In addition to their current limiting ability, their ability to sense and respond to elevated temperatures makes them ideal for protecting the primary windings. Depending on these parameters, either a radial-leaded or surface-mount device can be considered. For designs of about 5W, devices typically used might include a miniSMDC075 or RUE110. For 10W adapters, an RUE185 device is commonly used. For primary side protection, LVR devices are available in hold currents from 50mA to 400mA.

An example of the overtemperature protection characteristics of a PolySwitch device in this application is shown in Figure 3. The linear adapter output is intentionally shorted and the output current is limited by the winding resistance to about 1A. The secondary winding temperature starts to increase and when it reaches 100°C the combined thermal and electrical energy trips the PolySwitch device, limiting the secondary winding current further and reversing the winding temperature rise. The PolySwitch device is included in the secondary circuit and also protects the primary winding, as limiting the secondary winding current automatically reduces the primary current.

Table 1. Secondary Side Device Selection Summary

Adapter Power	Form Factor	Typical Device Series
<5W	Radial-leaded	RUE, RXE
	SMT	nanoSMD, microSMD, miniSMD
5–10W	Radial-leaded	RUE, RXE
	SMT	nanoSMD, microSMD, miniSMD
>10W	Radial-leaded	RGE
	SMT	miniSMD, SMD
<60W	**Primary Side**	
	Radial-leaded	LVR

Portable Electronics Input Power Protection
Application Overview

Problem/Solution
Portable electronics equipment, such as mobile phones or PDAs, is powered and/or recharged by AC/DC adapters that convert a line voltage or unregulated DC to a suitable low DC voltage for the equipment. With the growth in aftermarket adapters and universal chargers there is a growing risk of an unsuitable or faulty adapter being applied to the portable electronics equipment. The adapter applied voltage, polarity and permitted current may exceed the specifications of the power regulation circuits within the equipment, resulting in equipment damage and possibly even safety concerns.

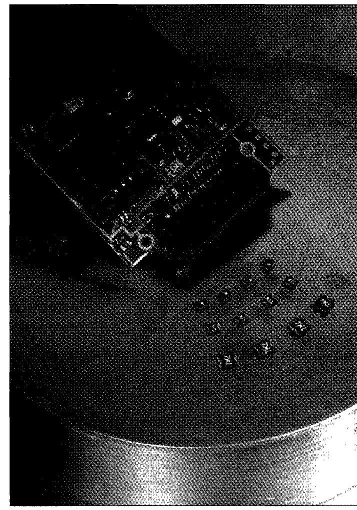
A PolySwitch microSMD or nanoSMD device, in series with the power connector combined with a parallel voltage limiting device such as a Zener or transient suppression diode, helps provide effective protection against the use of nonapproved adapters.

Protection Requirements
Figure 1 illustrates the typical battery charging circuit in portable electronics equipment together with protection components. Unregulated DC power applied by the adapter is conditioned and converted to a suitable profile for charging the battery pack. In the case of a Li-ion pack, the final charging profile is constant current-constant voltage while NiMH packs require a constant current source. The coordinated action of the overvoltage and PolySwitch protection components is capable of:

- Protecting against reverse polarity where the diode will forward conduct and the PolySwitch device will trip and limit the current.
- Protecting against excessive applied voltage where the overvoltage device will break down and the PolySwitch device will trip and limit the current.
- Limiting excessive current draw as a result of an equipment or battery pack fault.

A PolySwitch device may also be used at the battery pack connector input where it helps provide additional equipment overcurrent protection from the application of faulty or inappropriate aftermarket packs. Accessory connector output power protection is also desirable if the equipment is required to supply limited power to an accessory such as a hands-free car kit or active headset.

Technology Comparison
A one-shot fuse is often considered for this application because of its small size. However, with the new generation of smaller microSMD and nanoSMD series, size is no longer a barrier to using resettable protection. The majority of faults experienced by the equipment are temporary in nature, and resettable protection would avoid costly warranty returns for isolated fault events.



Necked down traces combine the disadvantages of one-shot operation with poor tolerance fusing current.

Keyed adapter input plugs are often common but it is generally only a matter of days before aftermarket adapter manufacturers copy a keyed plug and present a quite different electrical interface to the product than originally intended, potentially with damaging consequences. Fortifying the downstream converter, for example by employing a higher breakdown regulating element, is generally more expensive and can lead to excessive power dissipation in the equipment.

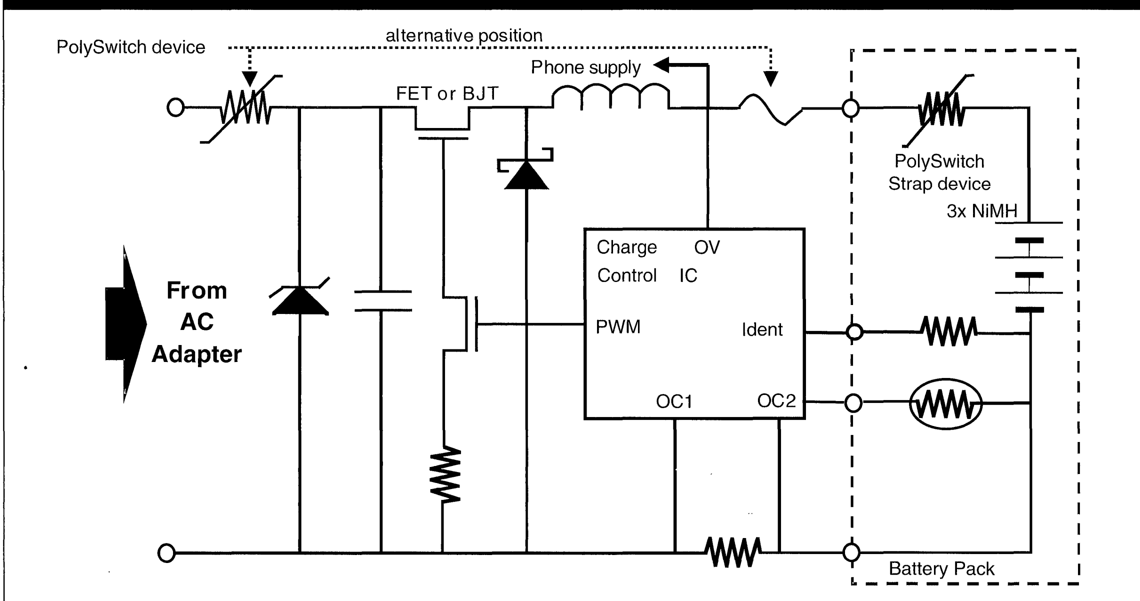
Device Selection

Battery packs are typically charged at an initial 1C rate which, for packs of up to 1000mAH, corresponds to 1A current. Charging of NiMH packs can take place up to 60°C without significant degradation. Devices such as the microSMD075, microSMD150, nanoSMD100, or nanoSMD150 are typically used in these applications.

Table 1. Device Selection Table

Charging Current @60°C	Voltage Rating	Device
<0.5A	6 to 13.2V	microSMD075
		miniSMDC075
		nanoSMDC075
		miniSMDC075
0.5Ato1A	6 to 8V	miniSMDC110
		miniSMDC110
		microSMD110
		nanoSMDC100
>=1A	6 to 8V	miniSMDC150
		miniSMDC160
		nanoSMDC150

Figure 1. Typical Portable Electronics Charging Circuit with Protection



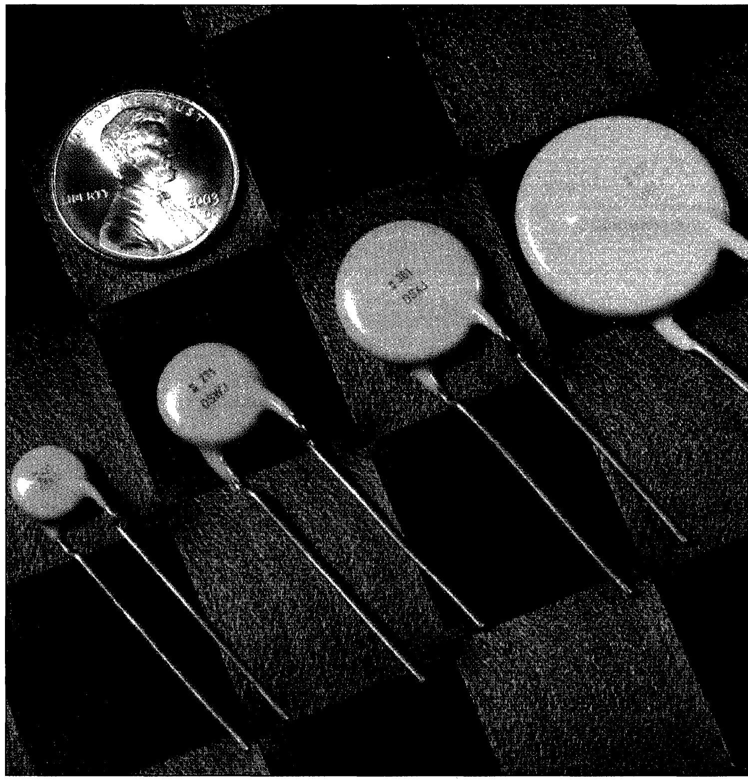
LVR and ROV Devices Help Designers Meet IEC 61000-4-5 Requirements for AC Mains Applications

Application Note

Design engineers are continuously challenged to increase the reliability of their products and ensure survivability under harsh environmental conditions. Electrical equipment can be put at risk from large voltage or power transients on the AC Mains inputs due to lightning strikes or power station load switching transients. IEC 61000-4-5 is the global standard for voltage and current test conditions for equipment connected to AC Mains.

Combining overcurrent and overvoltage protection at the AC Mains input can allow engineers to help meet their circuit protection requirements while minimizing component count and cost. Tyco Electronics now provides AC Line voltage rated PolySwitch devices and Metal Oxide Varistor (ROV) products to help meet these circuit protection needs.

This application note will provide information to help design engineers meet IEC Standard IEC 61000-4-5, "Electromagnetic Compatibility; Testing and Measurement Techniques – Surge Immunity Test" for AC Mains applications



The Problem

Overcurrent and overvoltage protection are often considered as two separate elements during the design process. As a result, protection strategies can result in multiple component solutions that can be costly. Additionally, synergies between protection devices can be overlooked as overvoltage and overcurrent protection are often viewed as completely unrelated conditions. With PolySwitch LVR devices and Raychem Metal Oxide Varistors (ROV), Raychem Circuit Protection offers designers a complete solution that helps enhance product protection and reliability.

IEC 61000-4-5 Test Conditions

The standard specifies voltage and current surge waveforms for five installation classes of equipment. An overview of the classes is as follows:

Class 1 – Partly Protected Electrical Environment, surge may not exceed 500V.

Class 2 – Electrical Environment, where the cables are well separated, even at short distances, surge may not exceed 1kV.

Class 3 – Electrical Environment, where power and signal cables run in parallel, surge may not exceed 2kV.

Class 4 – Electrical Environment, where the interconnections are running as outdoor cables along with power cables, and cables

Table 1. Selection of Test Levels (Depending Upon Installation Conditions)

Test Levels		
Installation class	Power Supply Coupling mode	
	Line to Line kV	LIne to Earth kV
0	NA	NA
1	NA	0.5
2	0.5	1.0
3	1.0	2.0
4	2.0	4.0
5	[1]	[1]

[1] Depends on the class of the local power supply system.
The surges (and test generators) related to the different classes are as in the following:
Class 1 to 5: 1.2/50µs open circuit (8/20µs short circuit)

are used for both electronic and electric circuits, surge may not exceed 4kV.

Class 5 – Electrical Environment, for electronic equipment connected to overhead power lines in a non-densely populated area, without a widespread earthing system, surge may not exceed 4kV.

Equipment for AC Mains applications is tested for surge immunity using a combination wave having a voltage waveform with 1.2usec rise and 50usec fall times and a current waveform having 8usec rise and 20usec fall times for all installation classes. Different rise and fall times exist for some telecom/datacom applications but all AC Mains applications are tested to the combination wave described above. Table 1 defines the test conditions for each class.

The Solution

Circuit Design

Raychem Circuit Protection's PolySwitch LVR overcurrent and ROV overvoltage devices offer a unique solution to help electronic equipment survive the harsh AC Mains environments and pass the tests specified in IEC 61000-4-5. Because the LVR devices are rated for operation up to 265V_{AC}, they can be combined directly with the ROV overvoltage protection devices in the AC Mains input lines. A typical installation is shown in Figure 1.

Layout Considerations

Placement of the LVR and ROV devices is not critical to their performance if there are significant layout constraints and the devices are chosen correctly. However, if the geometry allows, placing the LVR device adjacent to the ROV device can help protect the ROV device in extended overload conditions by transferring heat to the LVR device and causing it to trip faster.

Conditions which would cause any ROV device to remain clamped and conducting current can eventually result in overtemperature failure of the ROV. While not directly applicable to passing IEC 61000-4-5 tests, placing the LVR device in thermal proximity to the ROV device can cause the LVR device to trip faster, limit the current through the ROV and thus helping to protect it in continuous overload conditions. Taping the devices together may be required to achieve sufficient thermal transfer.

Device Selection

The LVR and ROV devices chosen for a particular application will depend on the IEC 61000-4-5 class rating for the equipment as well as the operating conditions of the equipment itself.

When selecting an LVR device, the primary consideration will be to match the hold current rating of the LVR device to the primary current drawn by the electrical equipment under normal operating conditions. The installation class will not affect the selection of an LVR device as all devices are rated to 265V_{AC}. LVR devices are not recommended in applications where they will be operated beyond their maximum ratings. Therefore, when using an LVR device in a Class 5 application, it should be protected by a series resistance or an ROV device in parallel.

Figure 1. Typical AC Mains Protection Circuit

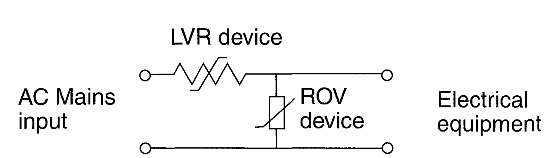


Table 2. LVR and ROV Device Selection Guidelines

IEC 61000-4-5 Installation Class	AC Mains Voltage	ROV Device* Line-to-Line	ROV Device* Line-to-Ground
1	120V	N/A	ROV05H201K
1	240V	N/A	ROV05-391K
2	120V	ROV07-201K	ROV07-201K
2	240V	ROV07-391K	ROV05-391K
3	120V	ROV07H201K	ROV07H201K
3	240V	ROV07H391K	ROV05H391K
4	120V	ROV10H201K	ROV10H201K
4	240V	ROV10H391K	ROV07H391K
5	120V	ROV10H201K	ROV10H201K
5	240V	ROV10H391K	ROV07H391K

* Table 2 presents a guideline. Any part should be thoroughly tested in the application to ensure proper operation before the design is finalized.

When selecting an ROV device, the nominal AC mains voltage rating for the equipment as well as the IEC 61000-4-5 installation class should be considered. The nominal AC Mains voltage will define the ROV device's voltage rating and the installation class will determine the ROV device's diameter.

Table 2 provides a guideline for ROV devices that can help equipment pass the IEC 61000-4-5 testing.

Electromagnetic Loads
Application Note

The ability to open a valve, lock a door, or extend an actuator relies on the use of electromechanical forces. These types of applications are executed by electromagnetic devices that turn electrical signals into mechanical movement. Solenoids, valves and motors are some of the devices that are used to accomplish these tasks.

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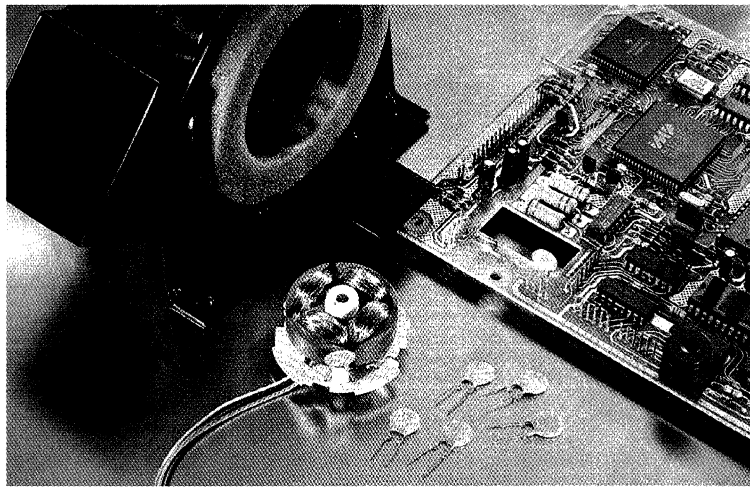
Since these devices are inherently mechanical, reliability and product life are critical design considerations. The environments where these devices are used can be harsh and unforgiving. Installation problems, stalls in the field, and short-circuits can permanently damage these systems if not protected properly.

The reliability of these electromechanical systems can be enhanced in several ways, one of which is with the use of a PolySwitch device.



The Problem: Construction of Electromagnetic Devices

Solenoids, valves, relays, and motors are examples of electromechanical devices that generate mechanical force by converting electrical energy into mechanical energy. Typically, a magnetic core piece (commonly referred to as a plunger or armature) moves as a result of being part of a magnetic circuit. Depending on the type of electromagnetic device, this movement can be linear or rotational.

When an electromagnetic device is required to act, current passing through a coil generates a magnetic field the strength of which is measured in ampere-turns (NI). This magnetomotive force causes the core piece to move as a result of the magnetic attraction between it and its magnetic counterpart. Different types of movements, magnitudes of forces, etc., are controlled by the device construction and the magnetomotive force generated by the coil.

Failure Modes

Failures in electromechanical devices can result from binding of the armature or actuator or miswiring of the connections when the device is installed. In the case of a mechanical failure, elevated currents can exist in the device for extended periods. Electrical miswiring during installation can also result in higher than normal currents through the device.

Since design engineers choose components based on normal operating conditions, such elevated currents can lead to overheating and eventual failure. Such failures can have secondary effects such as short circuits at the electrical inputs.

Mechanical or electrical problems in electromechanical devices can affect not only the device itself but also the control electronics that power them. The high currents that exist when a motor stalls, an actuator jams or a device is miswired can cause failures in both the electromechanical device and the control electronics. This means that not only does the electromechanical device need to be replaced, but the control electronics must also be serviced or replaced. The results are higher service and repair costs.

The Solution

A PolySwitch device used in the drive circuit can save both the electromechanical device and the electronic control circuitry. By limiting the current when a problem occurs, a PolySwitch device can prevent overheating of the magnetic coil in the electromechanical device. This can save the electronics portion of the device from damage and allows it to be serviced and repaired instead of replaced. For example, if a solenoid actuator protected with a PolySwitch device was jammed because a piece of scrap had fallen into the contacts area, then once the scrap was removed, the solenoid could operate normally without having to be replaced. Additionally, the drive circuitry on the control board would not have been exposed to the high currents and it would not require any service. Even if the solenoid was permanently mechanically damaged, the control board would likely remain operational.

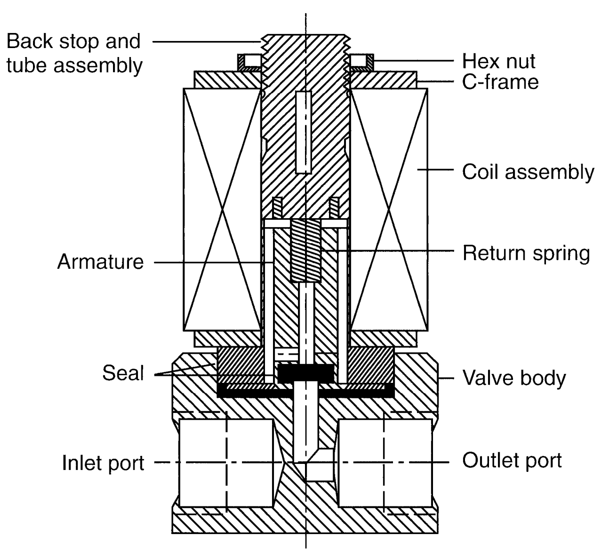
PolySwitch Resettable Devices

The PolySwitch resettable device is made from a conductive polymer blend of a crystalline polymer and carbon black that provides conductive chains through out the device. PolySwitch devices exhibit low-resistance charachteristics under normal operating conditions, but when excessive current flows through the device its temperature increases and the crystalline polymer changes to an amorphous state.

This transition causes the device to expand, breaking the conductive paths inside the conductive polymer. The change causes a dramatic increase in the device's resistance. This increase in resistance reduces the amount of current that can flow through the the device to minimal levels.

The PolySwitch device will remain in this state until the circuit is opened. Once this occurs the device cools, the carbon chains reconnect and the device returns to a low-resistance state.

Figure 1. Pressure Valve



Examples: Design Issues

Design engineers are continually trying to optimize the ampere turns equation by maximizing the amount of current and the number of turns on a given coil. Theoretically, as the amount of current that passes through a given number of turns in a coil increases, the force generated on the armature also increases. However, the electromagnetic device can be only a finite size; thus, the number of turns and the wire diameter become constrained. Also, materials used to manufacture these devices have temperature limitations.

Designers must, therefore, be careful that the current that flows through the device keeps the I^2R heating below the temperature rating of the device. In other words, the heat rise generated by the current flow in addition to the ambient temperature must stay below the temperature rating of the device. The materials that designers use can vary greatly with respect to temperature limitations. Temperature ratings of standard materials range from 105°C to over 200°C. Typically, designers will attempt to approach these limitations but not exceed them. Generally, the closer one can get to the maximum temperatures, the more efficient the electromagnetic device becomes. If the temperature of the coil exceeds the device rating, the wire insulation can burn away, causing the coil to short to adjacent windings or even burn through the magnet wire itself, creating an open circuit.

Example 1 (AC Applications)

Solenoid and valve products are susceptible to problems in the field. Devices designed for AC

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applications have inherent problems. Figure 2 displays the normal characteristic for an AC solenoid. Upon energizing an AC solenoid, a high inrush current is generated due to low inductive reactance since the plunger (armature) is in the extended position. This oscilloscope trace shows that the inrush current through the solenoid is approximately 5A. When the solenoid is energized, the plunger begins to travel through the solenoid body, causing the inductive reactance to increase, thus lowering the current until a steady state is reached. This occurs when the plunger inside the solenoid is fully retracted or seated.

As indicated in Figure 2, it takes approximately 250ms for the plunger to fully seat. At this time, the steady-state current is less than 0.4A. If the plunger is obstructed or bound during operation, the higher current will persist, causing the solenoid to generate excessive heat. Under this condition, the solenoid temperature will begin to rise until it exceeds the thermal rating of the materials used in the solenoid construction. Typically, the magnet wire will fail or the other materials will break down. In addition, the bobbin, tapes, and other insulating materials are all thermally constrained so excessive temperatures could lead to shorted coils, open coils, bobbins collapsing, and other undesirable situations. All of these conditions can lead to permanent device failure.

Figure 2. Normal Characteristic for an AC Solenoid

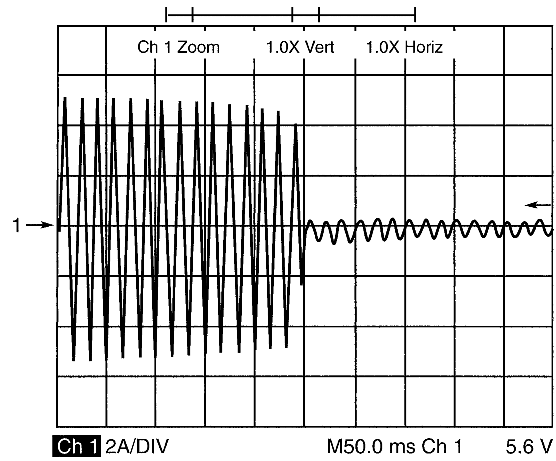
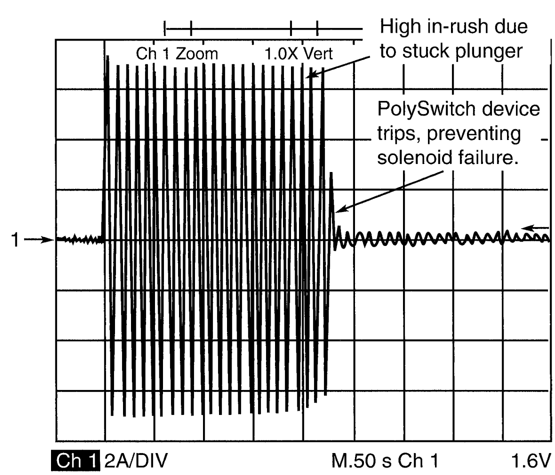


Figure 3. Protected Oscilloscope Trace



Solution

The oscilloscope trace in Figure 3 depicts a hypothetical situation where the AC solenoid is prohibited from seating. As shown, a large inrush current in excess of 6A persists. In this scenario, the steady-state condition is never realized. If this situation continues for an extended period of time, the heat generated by the current draw would exceed the ratings of the solenoid and cause premature failure. But in this case, a PolySwitch device is placed in series with the coil. After approximately 2.5 seconds, the PolySwitch device has changed from its original low-resistance state to a high-resistance state, reducing the current draw to a level where the solinoid was not damaged.

A stalled AC solenoid can easily generate three to ten times the normal steady-state current. This type of stall scenario is not only detrimental to the electromagnetic device but also can be problematic for the entire circuit. For example, driver circuits controlling the electromagnetic device can be damaged. Usually, drivers are not rated for much more than the worse case steady-state condition. When higher than expected currents exist for extended periods of time, the switching circuit may fail along with the electromagnetic device. Also, traces on the printed circuit board can open if they are not designed to handle this type of situation. This also can be true for the wiring.

The PolySwitch device provides several advantages in this case. The circuit in Figure 4 places the PolySwitch device in series between the FET driver and the load. This load can be a damper, a valve, a solenoid, a motor, or any other electromagnetic device.

If the system is installed incorrectly and the load is shorted, the PolySwitch device will trip, thus helping to protect the control circuits. Once this situation is recognized, the power to the circuit is removed, allowing the PolySwitch device to reset. Then, the installation can be rewired correctly and normal operation can ensue without any damage to the control circuits.

If a stall occurs, the PolySwitch device can trip before any of the components in the control electronics fail or before the electromagnetic device itself fails. Once the stall is eliminated, the PolySwitch device can reset and normal operation can resume. If the system fails because of the electromagnetic device's life limitation (usually determined under ideal conditions and measured in cycles or number of operations), the excessive current will then disable the control circuits. If the PolySwitch device is used as portrayed in Figure 4, it can isolate these control circuits from the electromagnetic device. In this case, the electromagnetic device is thought of as a field output. Most maintenance/repair professionals can change field outputs, but changing control circuits is usually a problem that only the OEM can address.

Example 2 (DC Applications)

Precautions must also be taken in DC applications. Electromagnetic devices are rated in terms of duty cycle (continuous duty, intermittent duty, and pulse duty). The duty cycle is determined by the ratio of the time the device is energized to the time of one complete cycle [time on/(time on + time off)]. In some cases, an electromagnetic device can be driven with a large amount of current for a short period of time, resulting in higher force during this time period. Because the device is energized intermittently, the heat rises but stays within an acceptable level. However, if a device with an intermittent or pulse duty is used continuously, the temperature increase will quickly exceed the limitations of the device and cause the device to fail.

Solution

There are a number of scenarios that can lead to the situation discussed above. In the security market, for example, an intermittent-duty solenoid can be used with a sensing mechanism. After the solenoid is energized, the end of travel is detected by the sensor. This sensor can then feed back the position of the armature (status of the lock) to the electronics, thus turning the power to the solenoid off. If the sensor fails or if the armature fails to pull in, the intermittent solenoid will generate excessive heat and fail. This will result in system downtime and maintenance attention. A PolySwitch device in the circuit can react to this situation and help to protect the circuit from damage.

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Figure 4. PolySwitch Device between the FET Driver and the Load

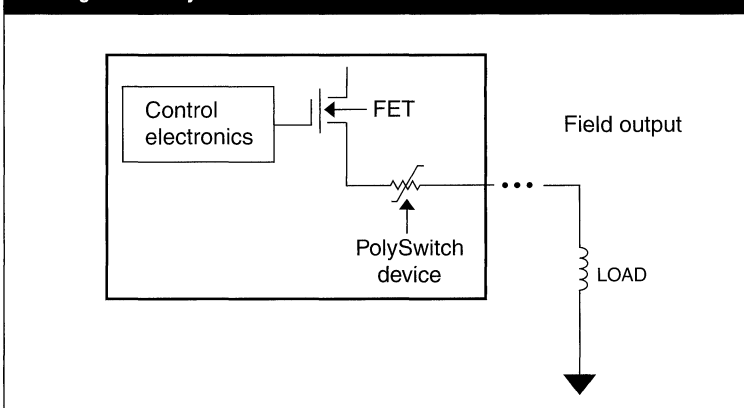


Figure 5. Dual-Coil

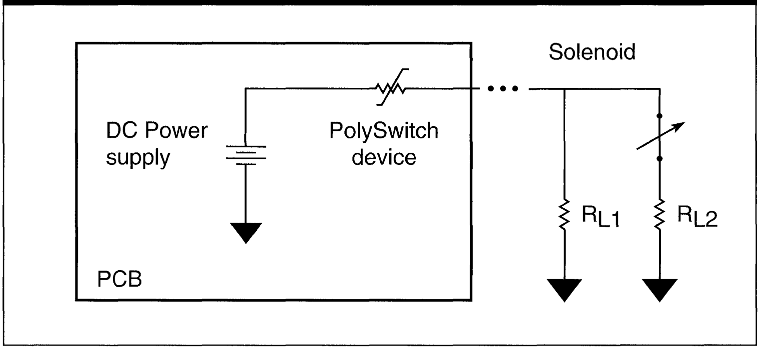
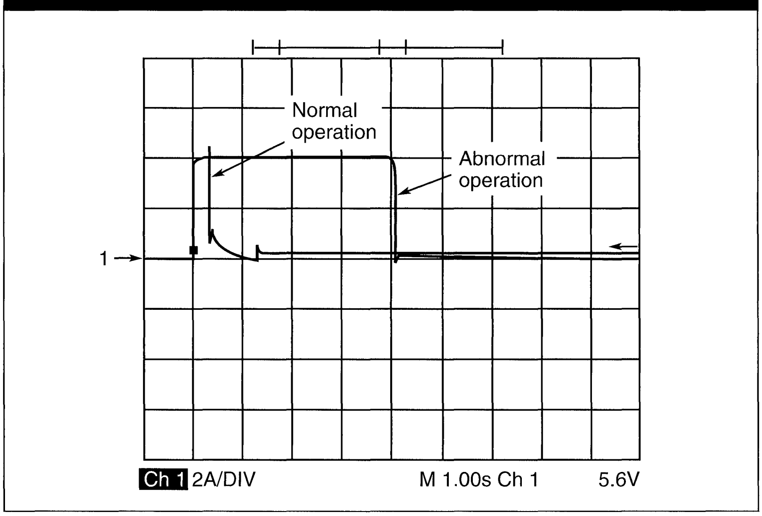


Figure 6. Oscilloscope Waveform



In the automotive market, a designer may use an intermittent-duty solenoid in a trunk-release application. In most cases, the lock will only be energized once or twice within a couple of seconds. However, if the lock is continuously operated, the solenoid will eventually exceed its thermal rating and fail. A PolySwitch device in series with the coil can help eliminate this problem.

Example 3 (DC Applications)

Another direct-current situation includes a dual-coil arrangement, Figure 5. This configuration is necessary if a load is unusually heavy or if a large "breaking force" is required. In a dual coil situation, two coils are wound one over the other on a bobbin. One coil includes a low-resistance path, the other is wound to a higher resistance. These coils are wired in parallel with each other, yielding a low total resistance. Next, a normally closed switch is placed in the circuit as shown. Once the assembly is energized, current flows through the parallel combination, taking advantage of the low-resistance (high-current), high-turns path. This generates a large amount of force.

As the plunger completes its travel, it physically hits the switch arm, opening up the closed contacts. The switch opens up the "pull-in" coil, leaving only the higher resistive coil in series with the load. This high-impedance path limits the heat rise and allows operation with continuous holding force.

The oscilloscope waveform (Figure 6) shows this type of operation. The first waveform shows the current flow that is expected under normal operation. When the device is first energized, the current generated is above 4A. Once the armature seats, the switch is opened and current flows only through the series coil. The current at this point is dramatically reduced and, in this case, is approximately 0.25A. However, if the armature is prohibited, it will not switch the circuit to high resistance.

Solution

The second waveform shows that if the armature is not allowed to move, the higher current will persist. At this point, it is only a matter of time before the solenoid wire ratings are exceeded. A PolySwitch device in series with the parallel coil combination helps protect the system. In this example, the PolySwitch device trips to its high-resistance state after about 4 seconds and system damage is avoided.

Example 4 (Motors)

Due to its inherent properties, a motor will require higher currents during start-up. When the motor is first energized, the armature resistance is usually quite low. Therefore on start-up, the in-rush currents can be very high, several times greater than its steady-state run current. When the motor begins to rotate, a counter electromotive force (EMF) begins to build. As the motor builds up its speed, the counter EMF builds inside the motor. The counter EMF opposes the drive voltage and causes the current to decrease, eventually reaching its steady state. If a motor is stopped or if a stall occurs during operation, the motor ceases to rotate, eliminating the counter EMF.

If this happens while the motor is energized or operating, little voltage remains to oppose the drive voltage and dangerously high currents will flow.These currents will flow through the motor, heating up the windings inside the motor until the temperature is exceeded. At this point the coil will open or short, creating premature motor failure.

As is true with other electromechanical devices, motors will eventually fail. The materials used in the construction of a motor will determine its life. For example, as the motor armature rotates, the current in the armature windings routinely reverse. Due to the inductance of the windings, the current does not instantaneously reverse, and this results in sparking at the commutator brushes. This eventually leads to device failure. Side loading and other forms of improper use also contribute to device failure. While the failure of an electromechanical device is accepted, one can certainly limit the damage that can be done to the entire circuit.

Solution

If stalls are created during normal operation, higher currents will persist. In many applications, such as this one, the PolySwitch device can be placed in series with the motor. If a stall is encountered, the PolySwitch device will rapidly heat up and change to its high-resistance state before the temperature extreme of the wire is exceeded. The PolySwitch device will remain in its high-resistance state until the stall is removed, thus helping to protect the motor from premature device failure. Once the voltage is removed and the fault cleared, the PolySwitch device will return to its low-impedance state. The system can then resume normal operation without intervention.

Technology Comparison

In some motor protection circuits (see Figure 7), a bimetal alternative is placed in series with the motor. If the motor stalls, the bimetallic contacts heat up and open. When contacts open a circuit in this fashion, arcing occurs between the contacts, causing the plating of the contacts to deteriorate. As the plating deteriorates, the bare metal becomes exposed and oxidation begins to occur. This eventually causes the contacts to stick together, resulting in a short-circuit. This problem can be solved by placing a snubber circuit across the contacts. As the contacts open, the capacitor shunts the arc away from the contacts providing a level of protection for the bimetal breaker.

The PolySwitch device has advantages over the bimetal alternative. Because the PolySwitch device is a solid-state solution, arcing between contacts is not an issue. Therefore, one does not need the extra RC network defined above. The PolySwitch device replaces the bimetal breaker, the resistor, and the capacitor (Figure 8). This design can enhance reliability, save space, and reduce cost. The PolySwitch device also is not as susceptible to vibration as is the bimetal breaker.

Motors are usually controlled by relays or switches. Typically, these components are part of the control circuitry found in a panel or on a printed circuit board. Wiring is then used to connect the control circuitry out to the motors in the field. A PolySwitch

Figure 7. Bimetal Alternative

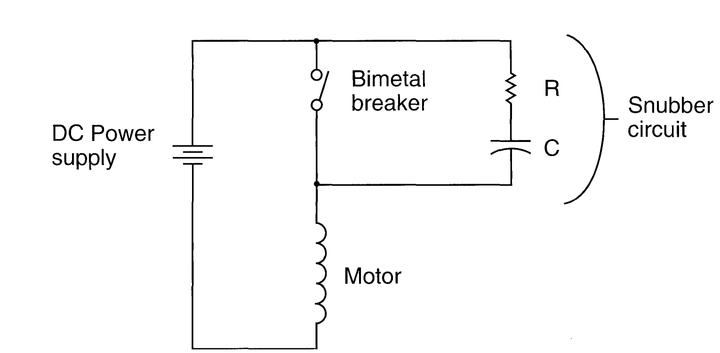


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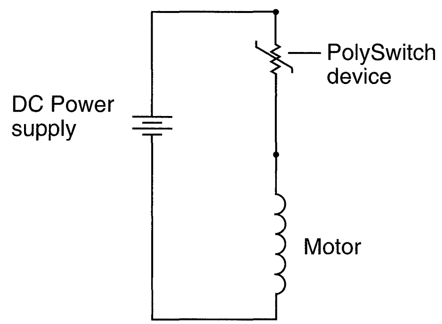
Figure 8. PolySwitch Device Solution



device can contain the fault to the load, electrically isolating the control circuitry. If an electromagnetic device should fail due to its designed end-of-life, the PolySwitch device can protect the contacts, FETs, etc., that drive these devices. Many times it is easy to replace a motor in the field but difficult to replace a component on a PCB. Replacing a component may require the user to remove the entire control board and send it back to the OEM, a costly solution.

Conclusion

Electromagnetic devices are found in numerous markets, such as automotive, medical, security, industrial and consumer. The PolySwitch device can help avoid damage that can occur when using an electromagnetic device. The resettability of the PolySwitch device allows the user to enhance the reliability of the system and to provide the OEM with a more robust solution. Including the PolySwitch product solution can lead to such benefits as lower field returns, better warranties, and greater customer satisfaction.

Device Selection

The PolySwitch device is selected by considering the maximum load current to be delivered, the highest ambient temperature, and the maximum permissible time to trip to prevent damage to other components. Depending on these parameters, either a radial-leaded (RUE, RXE, RTE, RHE series) or surface-mount device (SMD, miniSMD series) is typically used.

**Special thanks to Brian Cahill, Deltrol Controls, Inc., for his assistance on this application note.*

Solenoid Protection

Application Overview

Problem/Solution

A solenoid is an electromagnetic device with four basic parts: a coil assembly, frame, armature, and backstop. The coil assembly is constructed by winding magnet wire around a bobbin. The coil assembly, along with the backstop, are placed into a frame and mechanically secured together. The armature is then inserted into the completed solenoid assembly. When the coil is excited with current, a magnetomotive force is created, causing the plunger to be pulled into the coil and to seat on the backstop.

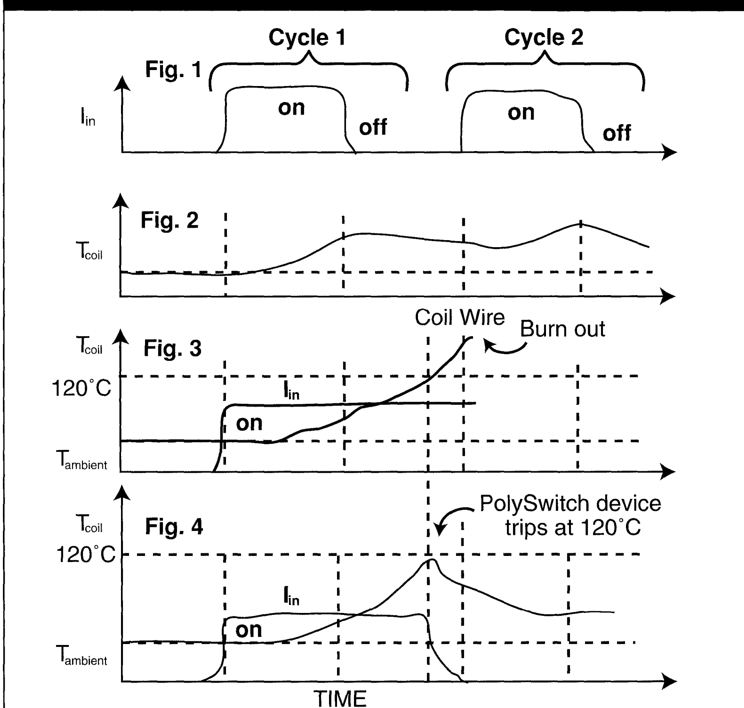
Once the solenoid is energized, the end of travel is detected by the sensor. This sensor can then feed back the position of the armature (status of the lock) to the electronics, thus turning the power to the solenoid off. If the sensor fails or if the armature fails to pull in, the intermittent solenoid will generate excessive heat and fail. This will result in system down-time and maintenance. A PolySwitch device in the circuit can react to this situation and help to protect the circuit from damage.

During normal conditions, (Figures 1 and 2), the coil temperature increases each time the solenoid is cycled. Several actions can cause abnormal operation, such as an object leaning against a PC CD-ROM tray ejector button, causing constant current to be applied (Figure 3). The coil temperature can continue to increase and can eventually burn out the coil wire. As shown in Figure 4, when a PolySwitch device is inserted in the circuit, the PolySwitch device trips at about 120°C, limiting I_{IN} such that the coil temperature gradually drops such that damage to the coil wire is undamaged.

Device Selection

The PolySwitch device is selected by considering the maximum load current to be delivered, the highest ambient temperature, and the maximum permissible time to trip to prevent damage to other components. Depending on these parameters, either a radial-leaded (RUE, RXE, RTE, RHE series) or surface-mount device (SMD, miniSMD series) is typically used.

Figures 1-4



Process and Industrial Controls
Application Note

With the continuing automation of industrial processes, remote monitoring and control is becoming increasingly important in industrial-control arenas. Modern installations need control systems that guarantee accurate communications between different decision centers and machines and throughout an installation.

Many designers provide the means to monitor the environment in factories, schools, and office buildings and communicate the resulting information back to a central processor. This feedback is used to control the surrounding environment. However, because these systems can be damaged by faults that result in excessive current, monitor and industrial-control manufacturers are increasingly turning to PolySwitch resettable devices to limit fault currents to safe levels.

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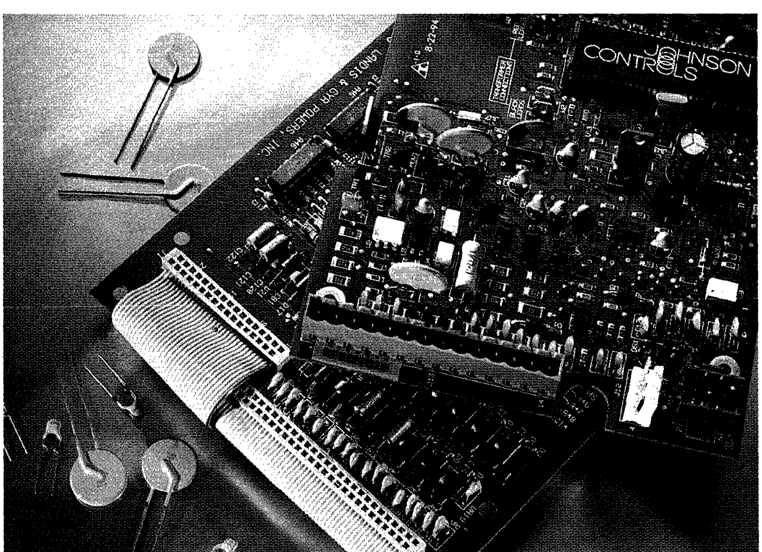
The Problem
Remote monitoring and control systems are inherently complex and present designers with several potential problem areas. Installers, for example, can inadvertently short-circuit power lines, or a cable can be pinched when it is installed in a conduit. A fault condition can also arise from the installation of an incorrectly wired cable that connects the wrong power source to the load.

If the current that results from these kinds of faults is high enough, wiring can overheat, components can fail, and circuit board traces can burn. The consequences of such faults can be extensive damage to expensive equipment and the loss of a critical system for an extended period. Because of these consequences, critical circuits must be protected against overcurrent conditions.



The Solution
PolySwitch resettable devices can react to the faults that are caused by overcurrent and overtemperature conditions and can help to protect monitoring, sensing, and control systems.

Monitoring and Sensing Applications
Many process control architectures exist. In a closed-loop system, such as the one shown in Figure 1, numerous serial drops with a range of several thousand feet can be connected together. In these kinds of multidrop systems, the state of the process variable affects the control system. Remote monitors extract data regarding such parameters as temperature, pressure, and velocity. If any of the process parameters exceed preset limits, the host computer can issue instructions to the appropriate units to alter the environment to bring the process back under control.

When communications over several hundreds or thousands of feet are required, they are often handled through a serial RS-485 twisted-pair transmission link that can connect the host to several monitor sites. The RS-485 drive includes a differential voltage of +5V. Since the distance covered can be quite long, miswiring and short-circuits are not unusual. To prevent damage, overload protection is essential. As shown in Figure 2, the proper protection scheme can come from a Zener diode and a small PolySwitch resettable device such as an RXE010 device. Circuit protection would be placed immediately after the interface to the printed circuit board before the transceiver for the twisted pair.

An additional benefit to using a PolySwitch device in this configuration is the ability to downsize other protection devices, such as the Zener diode in this case. A transorb or Zener diode acting as a voltage clamp on a 5V signal line protects the circuit by creating a very low resistance path to ground if the voltage on the protected line exceeds its breakdown voltage. However, since significant current can flow through the device, it must be large enough to handle the maximum anticipated current flow under worst-case conditions. If a PolySwitch resettable device is used to limit the current that flows through the clamping device, the device will not have to dissipate as much power and therefore can be much smaller and less expensive.

Figure 1. Closed Loop Monitoring Circuitry

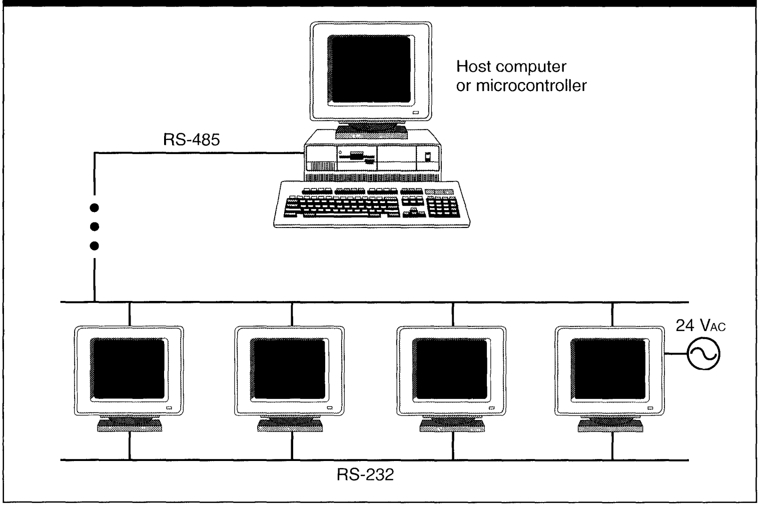
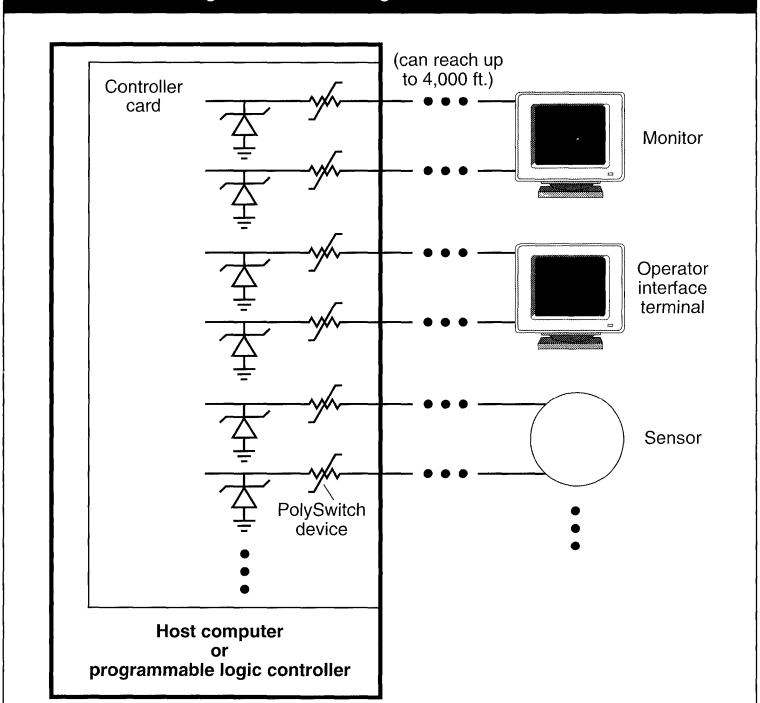


Figure 2. RS-485 Signal with Protection



In other types of industrial monitoring applications, such as environmental control, many times it is necessary to provide communication between sensors and a microcontroller. A typical block diagram, Figure 3, describes this data acquisition architecture. Numerous sensors can be located throughout the building.

These sensors can be of three types: voltage, current, and temperature. The devices will feed back information through an operational amplifier, then to an analog-to-digital converter, where the microcontroller will read the input. If the input is not within a specified or acceptable range, the microcontroller can instruct the control circuitry as required. Should an overcurrent condition occur, damage could result to the op-amp, the analog-to-digital converter, the circuit traces, or even the microcontroller itself.

Figure 3. Data Acquisition Architecture

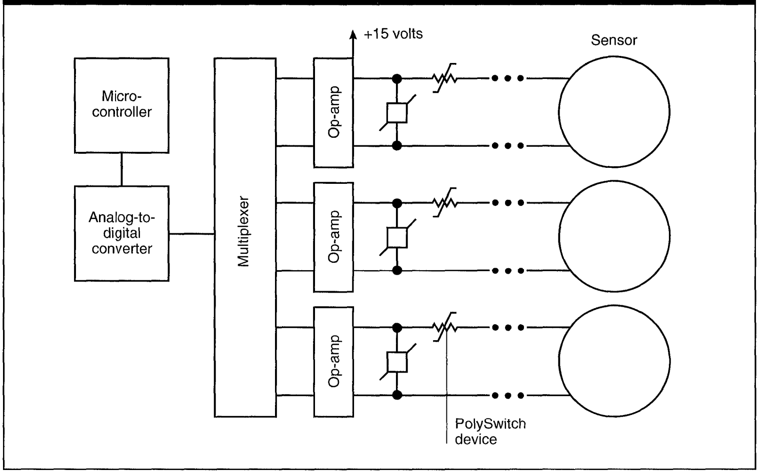


Figure 4. RS-232 Signal with Protection

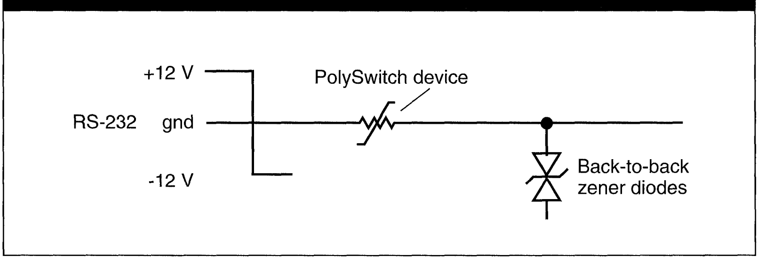
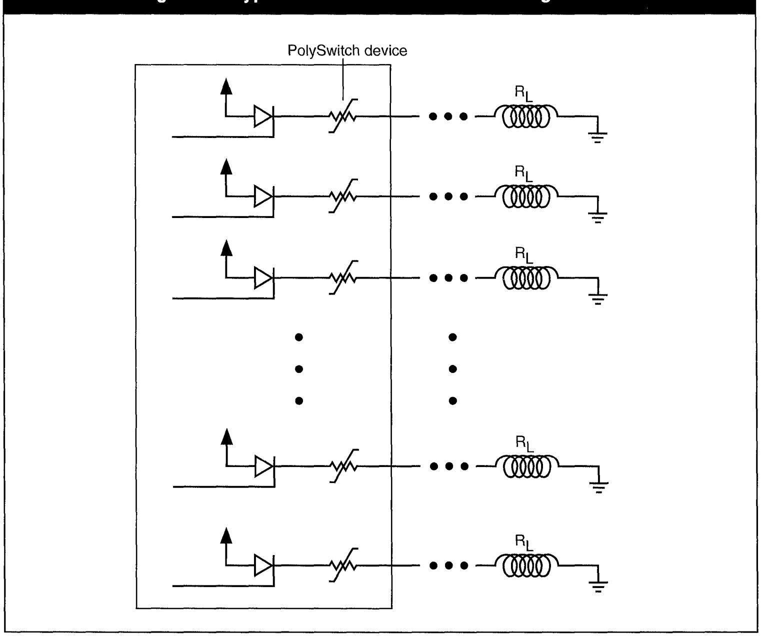


Figure 5. Typical SCR Master-Slave Configuration



A protection scheme is also noted in Figure 4. Since these sensor lines can cover long distances, they are typically found in the same conduit with other voltages. If an overvoltage situation should occur, and the rail voltage of the op-amp is exceeded, the overvoltage device will immediately break down. The PolySwitch device will then trip if the fault is prolonged, helping to protect the circuitry, including the overvoltage device.

Other types of microcontroller/sensor configurations are popular. In a second example, the sensor feedback is read by the change in voltage across a 250 to 300Ω series resistor. In this system, the microcontroller will monitor this change in voltage, and if the range is exceeded in any way, the microcontroller will instruct the control circuitry to make appropriate adjustments.

The use of the resistor is one potential solution to protect against damage from these faults. Since the microcontroller has to read small changes in voltage, the resistor has to be very precise. The power rating of the resistor must also be robust enough to sink any anticipated fault that may occur. Whether the designer chooses a thick-film or wire-wound resistor, the size will be quite large. A ceramic resistor can typically dissipate about 4W per square inch. If a resistor is used to dissipate the energy from a fault, the result is a much larger protection device when compared to a PolySwitch resettable device. The designer is also faced with constant power dissipation. The cost of such a resistor may also be an issue.

If the microcontroller is required to scan numerous sensors in this design, scan time and resolution become critical. In some applications, a complete scan may take nearly 1.0 second to run a complete check. If a fault occurs and the microcontroller does not see it in time, damage will occur to the circuit. A PolySwitch device in this application can react to the fault and help to protect the circuit from damage. This also frees up the channel of the microcontroller to perform more useful operations in the system.

It is not uncommon in a given process control architecture to change the range for the process variables. This can be accomplished by downloading the parameters to the monitors through the RS-232 connection. The RS-232 link is also used to verify calibration between the monitor and the host. Either application requires the use of external equipment to the host's RS-232 port. The RS-232 drive includes a low-current ±12V signal. If an incorrectly wired cable is used or pins are accidentally shorted, damage can quickly occur. A strategy similar to that used for the RS-485 port can also be used for the RS-232 port, but it requires the use of back-to-back Zener diodes to accommodate the drive voltage, as shown in Figure 4.

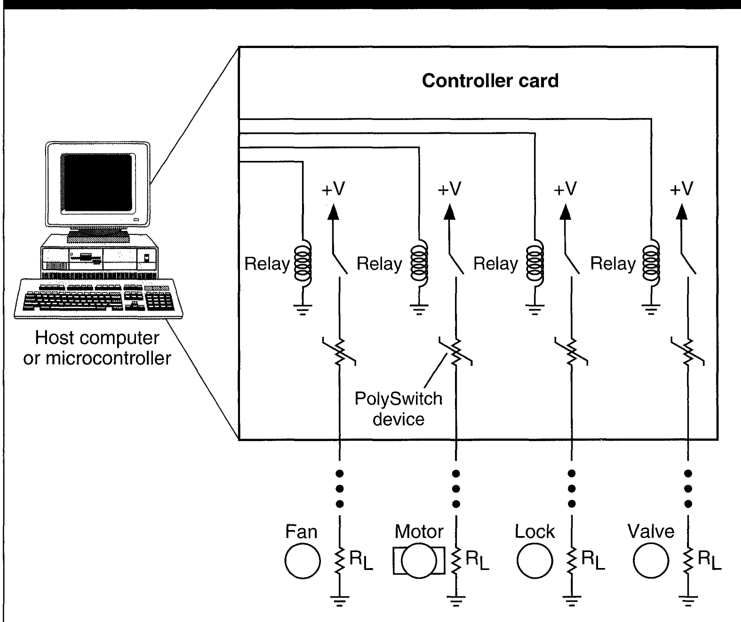
The monitors themselves also pose potential problems. Many are powered by a 24V source, as shown in Figure 1. Should the power connections be miswired and inadvertently directed onto low-voltage signal lines, significant damage can result. A PolySwitch resettable device in series with the secondary side of the power supply can help to protect against this damage.

Control Circuits

When a process variable is out of its specified range, the host can instruct control circuits to correct the problem. The host does this by turning a motor on, energizing a solenoid, closing a valve, or taking some other appropriate action. Each action, however, requires some type of switching. Today, most switching is solid-state and often performed by a silicon-controlled rectifier (SCR). An SCR is a diode that normally does not conduct in either direction, but can be turned on in the forward direction by the application of a low-voltage control signal to its gate (Figure 5 is a typical SCR master-slave configuration). Although a robust device, if the SCR is incorrectly wired or if connected to a malfunctioning load, it can overheat and fail. A Poly-Switch device which trips before the SCR on the board fails eliminates the need to replace the SCR. Now, only service of the load is required and the control card can stay functional.

Electromechanical relays are still used in some process control equipment but they are not immune from potentially damaging overcurrent faults. For example, if the load out in the field fails or shorts, excessive current will flow through the contacts causing them to weld shut and fail short. This relay failure will result in significant system down-time until the relay on the card, along with any other damaged components, are replaced. A PolySwitch device in series with the relay contacts helps protect against the damage that can occur, Figure 6. The PolySwitch in its high-resistance state helps protect the contacts until the load is repaired.

Figure 6. Controller Protection



A long-standing tradition that contributes to miswiring is that both power (less than 100 V_{DC}) and signal lines are often run in the same conduit. At the remote end, which can be thousands of feet away from the host, it is not difficult to connect the wires incorrectly, wire the hot lines to ground, or superimpose powered lines on low-voltage data lines.

Technology Comparison

Traditionally, fuses and ceramic positive temperature coefficient (CPTC) resistors have been used to limit current in remote monitoring and control systems. However, both technologies present some disadvantages.

While fuses can reliably prevent damage or fire due to a short-circuit or low resistance fault, they are one-use devices that must be replaced when they blow. If the circuit experiences a transient current, a fuse can nuisance blow and will make the circuit inoperable. PolySwitch devices will typically not trip during a transient current, since the power is too small to sufficiently heat the device. If the device does trip due to an overcurrent fault, it can reset without replacement once the circuit power and fault are removed. With the continuing miniaturization of components and the use of surface-mount technology, the replacement of most fuses may require a service technician.

CPTC resistors also function by increasing their internal resistance as their temperature rises. As their resistance increases, the current flowing through them and the protected load decreases. Eventually, a thermal equilibrium is established that maintains the current at a level low enough to ensure the load is not damaged. However, CPTC resistors have a relatively high resistance under normal operating conditions and can dissipate noticeable power. PolySwitch devices typically switch to high resistance at lower temperatures and dissipate significantly less power under normal operating conditions.

To have a sufficiently low resistance, CPTC resistors are relatively large, which may be a concern in applications where space is at a premium. Also, being a ceramic material, they may be vulnerable to cracking as a result of mechanical shock or vibration.

Device Selection

RXE010-RXE030, miniSMDC014, miniSMDC020, SMD030, or SMD050 devices are typically used in this application.

Special thanks to Mike Schuler, Landis & Staefa, Inc., for his assistance on this application note.

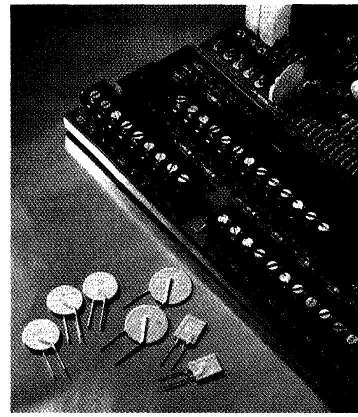
Security and Fire Alarm Systems
Application Overview

Problem/Solution
Security and fire alarm systems have multiple applications for circuit protection. The systems can be damaged by high fault currents caused by a short-circuit or overload condition. Power supply and circuit traces need protection because faults can occur if the installer inadvertently shorts out a pair of wires carrying power to remote components, installs the system backwards, or if the back-up battery is accidentally shorted. Modems are often included in alarm systems to automatically call the fire or police department in an emergency. Telephone lines need protection from the faults that lightning strikes, power-line crosses, or AC power induction on the telephone line can cause. PolySwitch devices—one installed on each extension of the power bus and used in combination with SiBar devices on the tip-and-ring circuit—can help provide protection against these fault conditions.

Typical Protection Requirements
Telecommunication equipment typically requires overcurrent and overvoltage protection. Overcurrent protection requires the ability to survive 600V or 250V with low current. Power supply and trace protection typically require a capability for currents from 1A to 4A.

Typical Agency Approval Requirements
Alarm systems must comply with UL864. This standard states that nonuser-replaceable fuses (soldered-in) are not allowed to qualify a power supply as inherently limited (UL864 Para. 24A.3). The test requires that current be reduced to 8A in less than 5 seconds. If the product has provisions for connection to a tele- phone line, it must comply with UL1950 (UL864 Para. 43.9), in North America, and ITUK.21 elsewhere.

Technology Comparison
Fuses have typically been used in these applications. However, UL864 and UL1950 pose difficult challenges for fuses to meet. Fuses can fatigue under certain UL1950 test conditions, but more



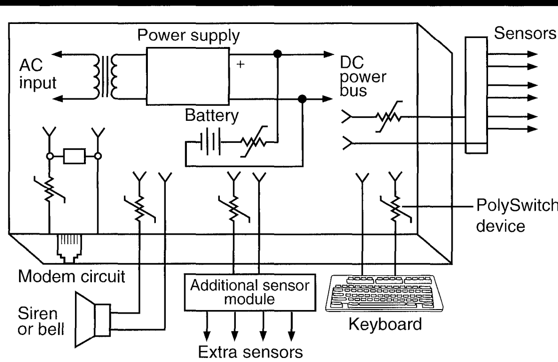
significant is that they are one-use devices that must be replaced after a fault has occurred. PolySwitch resettable devices latch into a high-resistance state when a fault occurs. Once the fault and power to the circuit are removed, the device automatically resets and is ready for normal operation.

Device Selection
TR600, TS600, and TVB device series are typically used in UL1950 applications. TS250, TC250, TVB device series are typically used in ITUK.21 applications. RUE250U*, RUE300U*, or RGE300 are typically used in UL864 applications for power supply systems not inherently limited.

For non-UL864 or inherently limited power supply applications, use RXE110–RXE160 or RUE250–RUE400 devices, depending on the voltage.

*Contact your local Raychem Circuit Representative for more information.

Figure 1. Typical System Power Distribution



Test and Measurement Equipment
Application Overview

Problem/Solution
A typical test and measurement instrument can experience overcurrent conditions in the secondary side of its internal power transformer, in one of its communication ports (modem, SCSI, ethernet, mouse/keyboard), and through its probes and voltage/current input terminals. A portable unit can also experience overcurrent conditions in its battery packs. Installing PolySwitch devices in series with the variety of loads will help protect each specific load.

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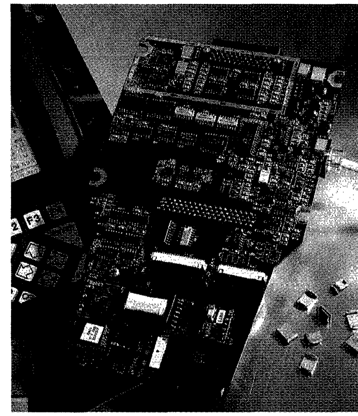
Typical Protection Requirements
Telecommunication equipment typically requires overcurrent and overvoltage protection. Overcurrent protection requires the capability to survive 600V or 250V with low current. For the power supply, communication ports, and probes, voltage is typically less than 30V and currents are less than 3A.

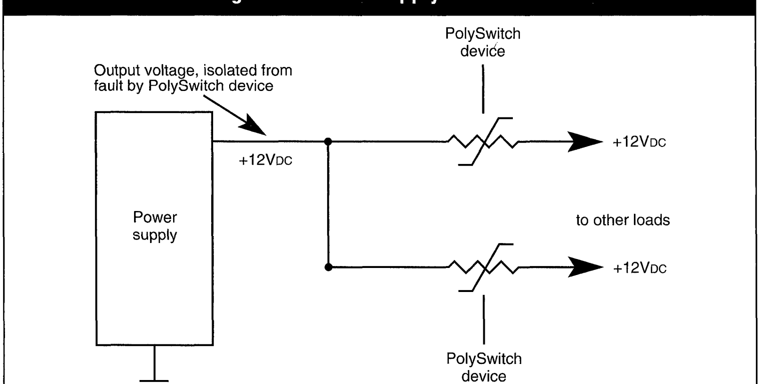
Typical Agency Approval Requirements
Power supplies generally fall under UL1012 and/or UL1310, depending on their classification. These standards describe the overcurrent limiting required by the power supply—8A in 60 seconds and 8A in 5 seconds respectively. UL1950 and FCC Part 68, in North America, and ITUK.21 elsewhere, specifically apply to telecommunication customer premise equipment; these also specify overcurrent and overvoltage safety standards applicable to telecommunication equipment.

Technology Comparison
Bimetallic thermostatic switches, fuses, and ceramic positive temperature coefficient (CPTC) devices have been used to protect motors. The limitations of bimetallic switches include cycling and the potential for contacts to weld shut. The CPTC has a relatively high resistance and power dissipation, which may be of concern in a portable system. In addition, CPTCs are relatively large and can exhibit thermal behavior where undesirable high tempera-



tures can be reached. Moreover, being a ceramic material, they may be vulnerable to cracking as a result of shock or vibration. CPTCs also have a relatively slower time-to-trip, compared to polymeric PTC devices. Fuses can fatigue as well, but most significant is that they are one-use devices that must be replaced after a fault has occurred. PolySwitch devices latch into a high-resistance state when a fault occurs. Once the fault and power to the circuit are removed, the device automatically resets and is ready for normal operation.

Figure 1. Power Supply Protection



Device Selection
For telecommunication applications, the TR600, TS600, and TVB series devices are typically used. The TR250 and TS250 series devices are typically used for telecommunication applications elsewhere. For power supply, port, and probe protection, products from radial-leaded and surface-mount families are typically used.

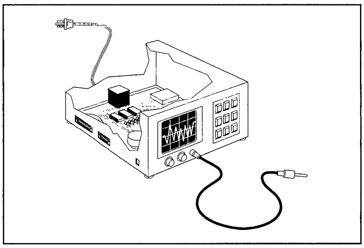
Medical Electronics
Application Overview

Problem/Solution
An electromedical device can experience overcurrent conditions in the secondary side of its internal power transformer, in one of its communication ports (modem, SCSI, ethernet, mouse/keyboard), and through its probe and voltage/current input terminals. A portable unit can also experience overcurrent conditions in its battery packs.

Typical Protection Requirements
The modem circuit typically requires overcurrent and overvoltage requirements. For overcurrent protection, 600V or 250V with low current is needed. For the power supply, communication ports, and probes, voltage is typically less than 30V, with currents less than 3A.

Typical Agency Approval Requirements
Power supplies generally fall under UL1012 and/or UL1310, depending on their classification. These standards describe the overcurrent limiting required by the power supply—8A in 60 seconds and 8A in 5 seconds respectively. UL1950 and FCC Part 68 in North America, and ITUK.21 elsewhere, specifically apply to telecommunication customer premise equipment; these also specify overcurrent and overvoltage safety standards applicable to telecommunication equipment.

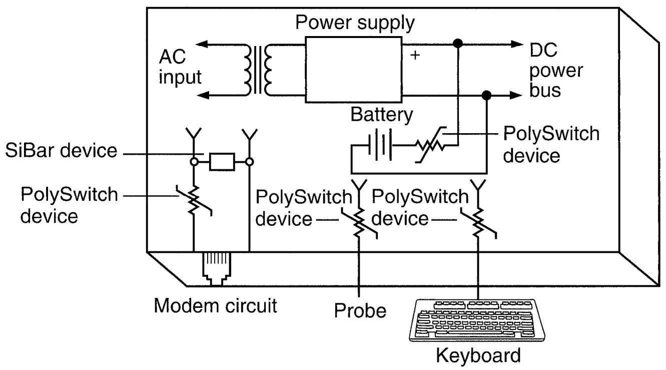
Technology Comparison
Bimetallic thermostatic switches, fuses, and ceramic positive temperature coefficient (CPTC) devices have been used to protect motors. The limitations of bimetallic switches include cycling and the potential for contacts to weld shut. The CPTC has a relatively high resistance and power dissipation, which may be of concern in a portable system. In addition, CPTCs are relatively large and can exhibit thermal behavior where undesirable high temperatures can be reached. Moreover, being a ceramic material, they may



be vulnerable to cracking as a result of shock or vibration. CPTCs also have a relatively slower time-to-trip compared to Polymeric PTC devices. Fuses can fatigue as well, but most significant is that they are one-use devices that must be replaced after a fault has occurred. PolySwitch devices latch into a high-resistance state when a fault occurs. Once the fault and power to the circuit are removed, the device automatically resets and is ready for normal operation.

Device Selection
For telecommunication applications, the TR600, TS600, or TVB series devices are typically used. The TR250 and TS250 series devices are typically used for telecommunication applications elsewhere. For power supply, port, and probe protection, products from radial-leaded and surface-mount families are typically used.

Figure 1. Base Unit Circuit



Raychem Circuit Protection products should not be used as components in critical life support systems or devices where the failure of the product in the application may be reasonably expected to cause the failure or malfunction of the system or device or to affect its safety or effectiveness. Tyco Electronics does not authorize the use of its products in applications involving permanent surgical implants into the body.

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Transformers
Application Overview

The Problem
Equipment that uses a transformer is subject to failures from two main causes: overcurrent and overvoltage. Overcurrent is typically the result of a short circuit within the equipment, a substantial increase in load or miswiring of the equipment during installation. Overcurrent can cause overheating in the transformer itself and can lead to smoke, fire and damaged wires and connectors.

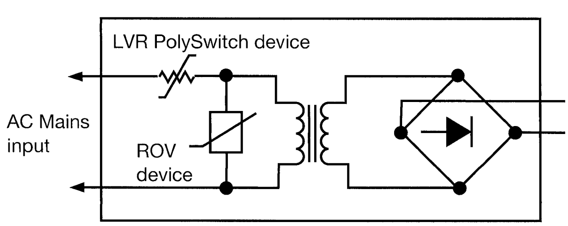
Overvoltage is typically the result of power line surges caused by lightning or load switching at local power stations. These voltage surges travel through the power lines and are imposed upon the AC power input of the equipment. They can be devastating to semiconductor devices and damage the equipment if not properly suppressed.

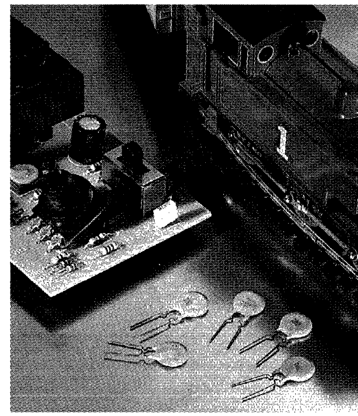
The Solution
Using an LVR PolySwitch device in combination with a Raychem Metal Oxide Varistor (ROV) device on the primary side of the AC Mains input can help protect electronic equipment from damage due to overcurrent and overvoltage faults (See Figure 1).

The LVR device helps provide overcurrent protection for the equipment against shorts, increased loads or miswiring of the equipment's outputs. The protection mechanism that the LVR device uses is the same as other PolySwitch devices. Using the LVR device in the AC Mains primary can provide additional protection when $120V_{AC}$ equipment is inappropriately connected to $240V_{AC}$ power. The LVR device will limit current and drop additional voltage when this problem occurs. This can help protect both the power transformer and the electronics.

The ROV device clamps voltage surges that may not trip the LVR device but might still damage the transformer or the equipment's electronic components. An example would be fast transients due to lightning strikes.

Figure 1. Transformer Circuit





This protection strategy can be applied to a variety of applications including lighting ballasts, toys, portable electronics and battery chargers.

Adding Thermal Protection
Clever use of the LVR device can help provide a level of thermal protection for transformers as well. Because the LVR device is a positive temperature coefficient device, thermally linking it to the transformer can help provide protection under conditions in which the LVR device might not trip due to current alone. Such conditions might exist when the AC Mains voltage droops and equipment becomes less efficient creating increased power dissipation in the electronics. Combining the temperature increase from an overheating transformer with current induced heating in an LVR device can cause it to trip faster and protect the transformer under such "soft fault" conditions. Thermally

coupling the LVR device to the transformer can be accomplished either by making physical contact with the transformer or specifying that the transformer supplier design the LVR device into the transformer itself.

Care should be taken to account for both normal current and temperature effects when choosing an LVR device for this application.

Device Selection

Table 1 provides a guideline for selecting an LVR device based on the power drawn by the primary. This guideline assumes 40°C ambient temperature and does not take into account thermal coupling to the transformer or any other device.

Table 2 provides a guideline for selecting an ROV device based on the AC Mains voltage and the power quality.

Technology Comparison

Bimetal thermostatic switches, fuses, and ceramic positive temperature coefficient (CPTC) devices have been used to protect transformers. The limitations of bimetal switches include cycling and the potential for contacts to weld shut. CPTC devices have a relatively high resistance and are relatively large; their temperature rises significantly, making them vulnerable to cracking as a result of shock or vibration. CPTCs also have a relatively slower time-to-trip compared to Polymeric PTC devices, resulting in a smaller protection envelope. Fuses can fatigue as well, but most significantly they are one-use devices that must be replaced after a fault has occurred. PolySwitch resettable devices latch into a high-resistance state when a fault occurs. Once the fault and power to the circuit are removed, the device automatically resets and is ready for normal operation.

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Table 1. LVR Device Selection Guideline at 40°C*

Power Rating	AC Mains Voltage	Recommended LVR Device
5W	$120V_{AC}$	LVR008
5W	$240V_{AC}$	LVR005
10W	$120V_{AC}$	LVR012
10W	$240V_{AC}$	LVR008
20W	$120V_{AC}$	LVR025
20W	$240V_{AC}$	LVR012
30W	$120V_{AC}$	LVR040
30W	$240V_{AC}$	LVR016
40W	$120V_{AC}$	LVR040
40W	$240V_{AC}$	LVR025

*Table 1 is a guideline. Check the specific requirements defined by your application or any regulatory standards that your equipment must meet for any special conditions when using these protection devices. Additionally, any part should be thoroughly tested in the application to ensure proper operation.

Table 2. ROV Device Selection Guideline†

Rated AC Mains Voltage	Recommended ROV Device‡	Power Quality
$120V_{AC}$	ROVxx-201K	Stable, minimal voltage variation, regular sinusoidal shape
$120V_{AC}$	ROVxx-241K	Unstable, large unpredictable voltage variations
$240V_{AC}$	ROVxx-391K	Stable, minimal voltage variation, regular sinusoidal shape
$240V_{AC}$	ROVxx-471K	Unstable, large unpredictable voltage variations

‡ "xx" indicates device diameter. Proper diameter depends on the surge current, wattage and energy ratings defined by the application or standards requirements.

† Table 2 is a guideline. Check the specific requirements defined by your application or any regulatory standards that your equipment must meet for any special conditions when using these protection devices. Additionally, any part should be thoroughly tested in the application to ensure proper operation.

Automotive Actuators and Medium-size Motors
Application Overview

Problem/Solution

System designers must protect automobile electric motors against overheating that can damage temperature sensitive components. These fault conditions are usually temporary so devices with a reset capability that allow the circuit to return to normal operation once the power is removed and the fault is cleared are preferred over fuses. However, some resettable devices such as bimetallic and magnetic circuit breakers, as well as ceramic positive coefficient devices have disadvantages.

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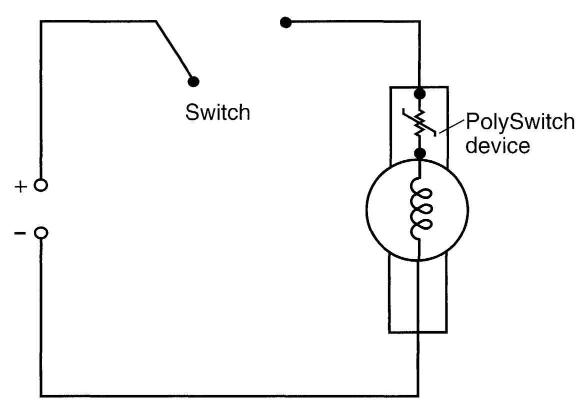
PolySwitch devices, generically know as Polymer Positive Temperature Coefficient (PPTC) resistors, offer several advantages over other resettable protection products and have been used for several years in automotive applications. These advantages include, but are not limited to:

- PPTC devices do not cycle on and off during the fault condition. Unlike Type I circuit-breakers, which cycle at about a 50% duty-cycle and therefore still deliver about 50% of the fault energy to the motor, PPTC devices latch in the tripped state, reducing the fault energy by several orders of magnitude.
- PPTC devices do not have mechanical contacts that can go out of calibration as a result of the effects of shock or vibration.
- PPTC devices do not have mechanical contacts that can erode, weld closed or cause electromagnetic interference (EMI) due to arcing, a phenomenon that is particularly evident when switching an inductive load such as a motor.
- PPTC devices do not have mechanical contacts that can develop insulating silica deposits, which can occur when a silicone lubricant is used in the presence of an arc.
- PolySwitch PPTC devices with advanced polymer technology are more resistant to the effects of hydrocarbon oils and greases that can contaminate the contacts of circuit breakers and affect the resistivity of conventional PPTC products.
- The PPTC device, being a polymer based component, tends to trip in a manner that 'tracks' the current, temperature and time to damage of polymer components in the motor, including wire insulation, bobbin formers and bearing supports. As the ambient temperature rises and the motor becomes more vulnerable to damage, the PPTC device becomes more sensitive and continues to help protect the motor.
- PPTC devices have much lower resistance than ceramic positive temperature coefficient (CPTC) devices that have been used to protect small motors.

Protecting Intermittent Operation Motors

In order to reduce cost and size, intermittent operation motors are usually designed to operate for a limited time and/or with limited travel. Examples include motors used in power windows, seat tracks, mirrors and locks. Operation for longer than the design maximum will usually result

Figure 1. Actuator Circuit



in overheating and eventually in failure. Most of these motors may also be subject to stall conditions that can result in overheating.

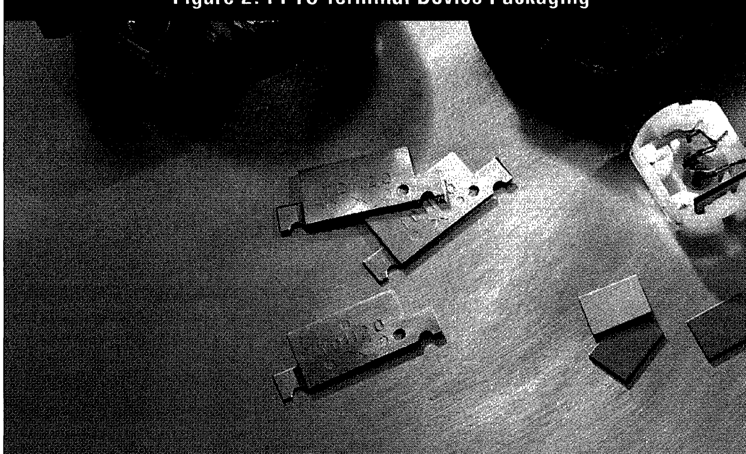
At the same time, the protection in the motor must not trip sooner than intended, which would result in a nuisance condition for the user. Consequently, it is essential to design protection devices that meet all the requirements for protecting the motor without nuisance tripping, especially when the system is operated over a wide temperature and voltage range. For this reason, most motor protection devices are custom built to work with a particular motor, and quite often for a specific application.

Figure 1 shows how a PPTC device is typically installed in a motor circuit. When the device is enclosed within the motor housing it is sensitive to the current flowing in the motor, and also to the temperature rise that will occur with a fault condition. Fault conditions may arise if the switch is held on, either because of contact failure, abuse, or error on the part of the user. Stall currents in motors of this type are about three times the normal run current. Note that on closing the switch, there will be an in-rush current of a magnitude determined by the resistance of the motor, which will flow until opposed by the back EMF of the rotating motor. A correctly sized PPTC device will have sufficient thermal mass to avoid tripping during this brief event.

Intermittent operation motors often have an electrical contact to connect to the switch and power source, and a metal fret or bus to route current within the motor. As a result, the PPTC devices used in such motors are frequently referred to as Terminal Devices (TD), one example of which is shown in Figure 2. Note that the PolySwitch device in Figure 1 is connected on one side to a motor brush and on the other to the external wiring. For the PolySwitch TD device shown in Figure 2, the external connection to the brush is usually achieved by welding the brush wire to the tab that can be seen on the far left side of the device.

The additional thermal mass of a TD type PPTC device provides it the characteristic of relatively slow operation. Many of the intermittent use motors in seat mechanisms and power windows are required to operate for a limited number of cycles without incurring damage, but operation beyond this level could result in heat damage. TD type PPTC devices can have a trip current substantially below the normal operating current of the motor but a time-to-trip several times longer than a full system operating cycle. Therefore, the device will trip after a number of system cycles but will operate much faster in the event of a stall situation where the

Figure 2. PPTC Terminal Device Packaging



motor current is several times the PPTC trip current.

The polymer technology making PolySwitch PPTC devices generally inert to motor lubricants, also enhances the resistance to nuisance tripping during motor start-up and brief stall situations. This allows conventional radial-leaded and simple chip-style devices to protect motors in applications providing both cost and size reduction. The chip style PPTC is used almost exclusively in very small motors such as those found in door locks and mirror actuators.

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Note that although a door lock motor may be operated from a body control module that provides a timed pulse of current to the motor; this does not prevent the motor from being operated beyond its design duty-cycle if a user continually cycles the lock. While such unreasonable operation would be classified as customer abuse, it is hard to prove and define, making motor protection prudent to avoid warranty and poor quality perception issues. Electronic circuits that count the motor operational cycles and then enforce a "time-out" before re-use can be both more expensive and less user-friendly. The electronic circuit would have to be "worst-case" designed for the maximum number of cycles and minimum time-out that can be tolerated in a black vehicle operated in a hot desert region. This low probability situation imposes unreasonable limitations for operation in more common temperate or cold regions.

Protecting Continuous Operation Motors

The motors most commonly considered as continuously or almost continuously operated in a motor vehicle, such as those used in the radiator fan and in the HVAC systems, are also those that would seem to be beyond the protection capability of PPTC devices, which are generally able to be used with continuous currents of around 15A maximum at 25°C. However, these motors are even more difficult to protect with conventional fuses.

Once again, continuous operation motors are designed for minimum size and cost for the application. Since they drive fans, some airflow can be diverted through the motor to allow operating under more stress than would otherwise be possible. As a result, the stall current of fan motors is usually only two times the run current, compared to a ratio of three or four times common in other applications. This makes it difficult to find a fuse that will (1) open reliably over the lifetime of the vehicle if the fan becomes blocked and (2) not nuisance blow when the motor is first switched on.

As discussed in intermittent operation motors, unlike fuses, and to a more accurate degree than circuit breakers, PPTC devices lend themselves to motor protection by altering their characteristics as the motor's vulnerability changes over temperature, offering slower response when necessary. More importantly, in applications where a fan is driven, both the PPTC device and the motor can benefit from being placed in the air stream. In these designs, the trip current of the PPTC device will be greatly increased because the airflow tends to prevent it from reaching its trip temperature. However, if the fan stalls for any reason, the cooling effect of the airflow ceases causing the motor to heat up quickly as well as the PPTC device, which then trips and helps protect the motor.

Device Selection

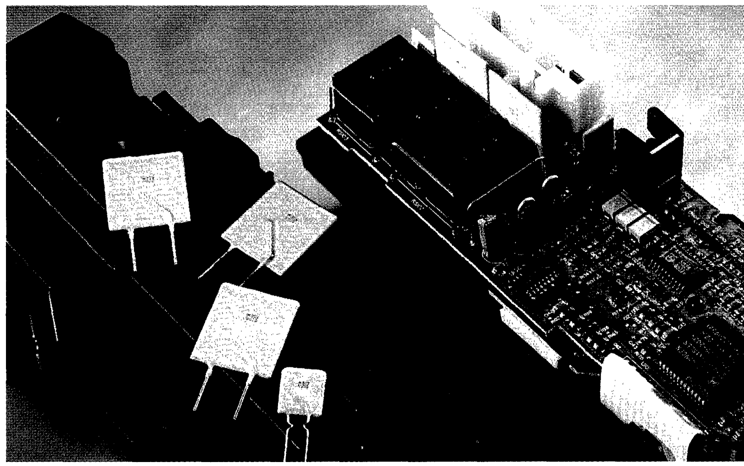
A variety of custom and standard terminal devices (TD) are available for motor applications. Additionally, PolySwitch PPTC chips may be suitable for some small motor applications in which the chip must be held between spring clips. Devices from the Automotive (AHR, AGR, AHS, ASMD series) family may also be used. Raychem's ROV line of varistors is also applicable to motor and actuator applications.

Please contact your local Raychem Circuit Protection representative for information on TD and chip devices.

Printed Circuit Board Trace Protection
Application Overview

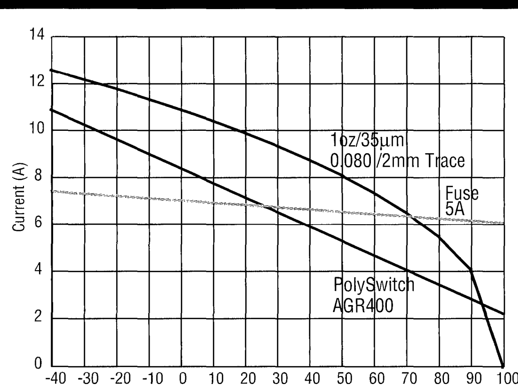
Problem/Solution

As the use of electronics in automobiles increases, automakers are faced with market demands for more interior room and must squeeze more circuitry into smaller packages. To provide an increasing number of functions and interconnections on the surface area of tighter-packed and smaller printed circuit boards, the width of the copper traces must be reduced. However, these "black box" control modules are now controlling a greater number of high-powered accessories, such as power windows, power seat adjusters, remotely controlled door locks, and radio & GPS antennas. Because these accessories are powered from high amperage circuits, there is increased potential for the narrow printed circuit board traces to sustain damage as a result of carrying excessive currents. This may happen, for example, if a power ground becomes detached from a load and the current reroutes through a narrow circuit board trace.



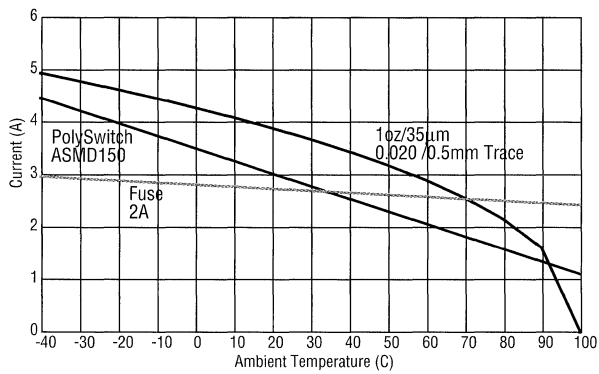
To help protect these delicate printed circuit board traces against damage from overcurrent conditions, PolySwitch resettable devices may be used. Printed circuit board traces function as wires carrying current from one point to another. Depending on its cross-sectional area, each trace can carry only so much current before the heat generated by I^2R losses causes it to fuse open. Even before it melts, a trace may get hot enough to damage the printed circuit board or some of the components mounted on it. For this reason, a protection device is necessary to limit overcurrent and help prevent damage to PCB traces.

Figure 1.



In Figures 1 & 2, it has been assumed that the circuit board designer has chosen to limit the maximum trace temperature to 100°C. Therefore, as the trace approaches this temperature it can carry less and less current. For the example in Figure 1 of a 1oz (35µm), 100mils (2.5mm) trace, a through-hole PolySwitch AGR500 device has been selected. In Figure 2 the trace width has been reduced to 20mils (0.5mm) and is protected by a

Figure 2.



surface-mount ASMD150. Note how the trip current of the PolySwitch device tracks the trace current-to-damage over the temperature range. Even if a fuse could be used here, the nearest size fails to protect above a useful and standard automotive temperature in either case.

Typical Protection Requirements

Electronic modules typically require protection from overcurrent situations that may result from a short-circuit or high stall/ inrush current on a module output or from the failure of some other portion of the system, such as a diode short or loss of a power ground. Typical requirements are 1A to 14A of hold current at system voltages of 14V.

Technology Comparison

Fuses are one-use devices that must be replaced when they blow and are not available in a closely incremented range of values needed to protect many trace permutations. Plug-in fuses can be replaced by the incorrect value, while soldered-in fuses are usually not replaceable for practical purposes, resulting in the necessity to replace a whole module. Electronic modules containing fuses would have to be removed from inaccessible areas for servicing in the event of a transient fault. Other solutions for protecting electronic modules include multi-component circuits to sense and switch (which require careful design, consume valuable board space, and may be expensive) or SmartFETs (which may be expensive and may have unacceptable failure modes).

Device Selection

Particular device selection must be based on the maximum current that the trace to be protected can safely carry. PolySwitch AGR and ASMD devices can help provide protection for the copper traces shown in Table 1. However, the table provides only general recommendations. Each specific application should be evaluated independently. Table 1 and Figures 1 & 2 illustrate steady-state conditions for uncoated surface traces. Whatever trace protection system is used, consideration should also be given to the time-to-activate. Empirical selection is then preferred because so many variables are in play, many of which may be unknown. Also typically used in these applications are the AHR and AHS series of PolySwitch resettable devices.

Table 1. Copper Trace Thickness

Width Inches (mm)	1/2 oz. (18µm)	1 oz. (35µm)	2 oz. (70µm)	3 oz. (100µm)
0.020 (0.5)	ASMD100	ASMD150	ASMD250	AGR400
0.040 (1.0)	ASMD150	ASMD200	AGR400	AGR600
0.060 (1.5)	ASMD200	ASMD250	AGR500	AGR800
0.080 (2.0)	ASMD250	AGR400	AGR600	AGR900
0.100 (2.5)	ASMD250	AGR500	AGR800	AGR1100

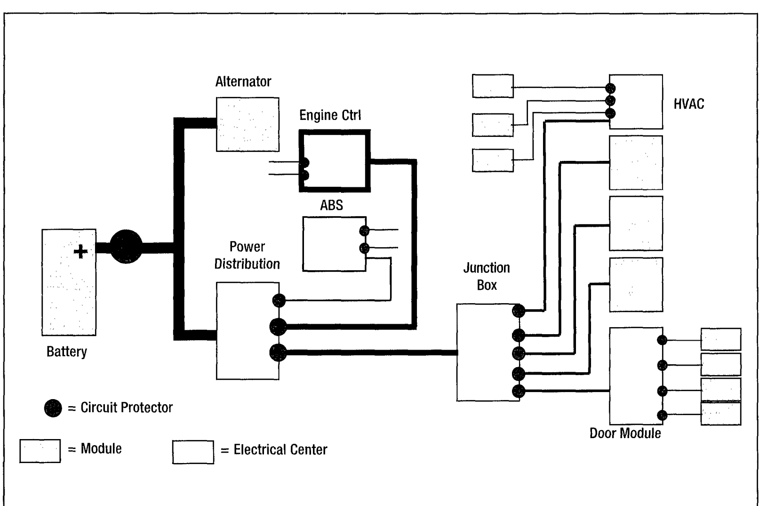
Automobile Harness Protection
Application Overview

Problem/Solution

The wiring harness architecture of automobiles has been required to undergo considerable change as vehicle electrical and electronic content has increased over recent years, and continues to do so.

Ideally a vehicle harness has a hierarchal structure resembling that of a tree; main power trunks dividing into smaller and smaller branches with overcurrent protection at each node. This system results in the use of smaller wires—which save volume, weight and cost—and maximum system protection together with fault isolation—reducing warranty costs and increasing customer satisfaction.

Figure 1 shows a greatly simplified version of such a scheme with each electrical center either feeding a module or yet another electrical center. Unfortunately the sheer number of circuits now employed has made the ideal system hard to realize in practice. With many tens of circuits emanating from an electrical center, it has become almost impossible to route all the wires in and out of a single box and at the same time locate it in a driver accessible position. System designers have resorted to: (i) combining loads, so sacrificing wire size optimization and fault isolation; (ii) literally burying electrical centers where they are only accessible at increased cost by trained service personnel; and (iii) routing back and forth between various functional systems, increasing wiring length, size and cost. For example, in practice, the HVAC system will pass power output protection and switching functions such as vent motors, blower fan and A/C clutch, to the junction box and power distribution center where its relays and fuses will be located.



Using resettable circuit protection that does not need to be driver accessible, such as PolySwitch PPTC devices, offers a number of solutions that may be used separately or in combination. For example, a single junction box located in the instrument panel may still be employed, but instead of being positioned close to the conventional fuses, the PPTCs

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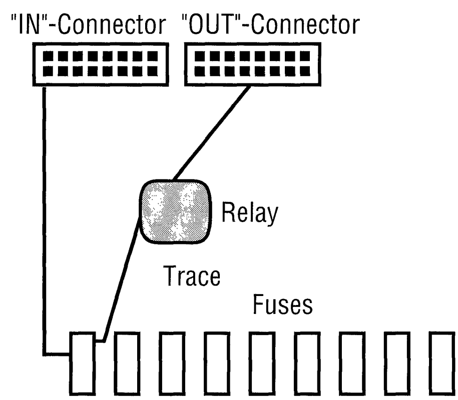
Figure 1. Conventional Current Routing



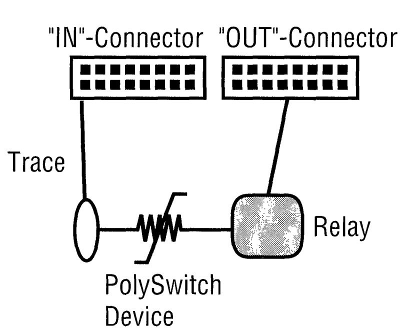
can be located inside the box—saving frontal area, and close to the connectors—reducing the volume consumed by whatever system is used to bus current around the box. See Figure 2.

Alternatively, the electrical centers can be divided into smaller units and relocated around the vehicle with no need to consider accessibility. Furthermore, with the availability of self resetting circuit protection and the very high reliability that can now be expected from relays, modules can switch and protect their own output loads and still be positioned without consideration for any user access.

In these ways, the use of PPTCs allows the electrical architecture to be designed to more closely reflect the ideal tree structure with its previously described benefits.

Through-hole devices lend themselves to use in boxes using circuit boards or IDC wired busses, while strap devices can be used in those that use metal fret routing. PPTCs are also available in much lower current ratings than conventional fuses and are therefore more appropriate for use in protecting command functions. If the electrical center or module has a printed circuit board then surface mounted PPTCs can offer further packaging benefits.

Figure 2. Current Routing using PPTCs



Typical Protection Requirements

Automotive wiring harnesses must be protected from damage and fire hazards in the event of a short-circuit in the vehicle wiring. Circuits typically require 0.10 to 30A of current at system voltages of 14V.

Technology Comparison

Fuses are one-use devices that must be replaced when they blow. This characteristic requires that fuses be mounted in accessible fuse boxes—a requirement that dictates system architecture and forces packaging and system layout compromises. PolySwitch resettable devices latch into a high-resistance state when a fault occurs. Once the fault and power are removed, the device automatically resets and is ready for normal operation.

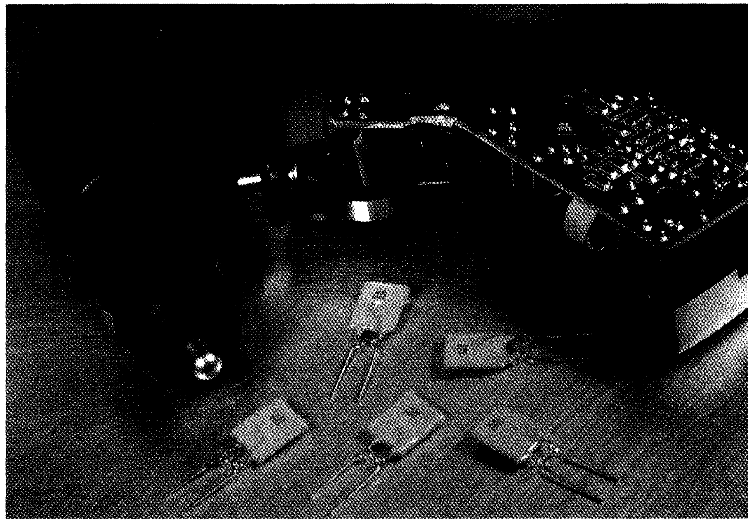
Using PPTCs has the added advantage of making the over-current protection tamper-proof. Unlike fuses that have nominal current ratings from 2A to 30A in the same form-factor and which are often substituted for one larger than the design value or are jumped out of circuit, PPTCs cannot be readily accessed, changed or abused by the user.

Device Selection

Devices typically used for wiring protection applications include the AHR, AGR, AHS, and ASMD series of PolySwitch resettable devices.

DC Cigarette Lighter Adapter—Charger Protection
Application Overview

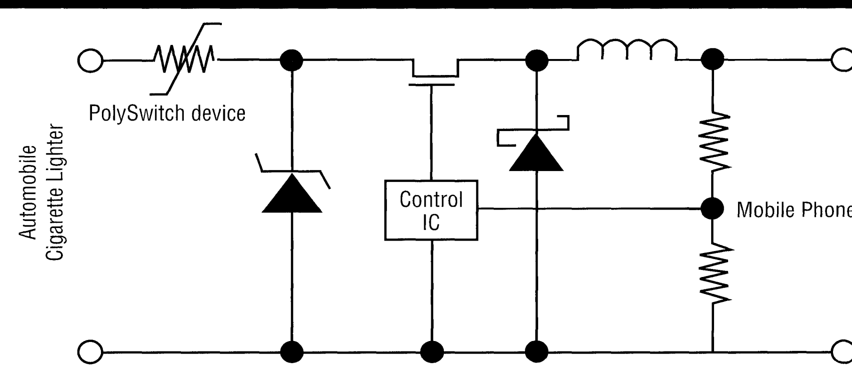
Problem/Solution
The connectors used to plug into automobile Cigarette Lighter Power Outlets often include a charger circuit for a mobile phone, an after market hands-free device, or other battery operated equipment. The whole assembly must operate over a wide range of temperatures and charging conditions that combine the harsh automotive environment with stringent electrical requirements. As a result, the chargers are often subjected to fault conditions that lead to short-circuits and blown fuses. There are three broad categories of these faults:



- Overcurrent faults - A fault in the mobile phone or other portable equipment, or its connection to the charger, draws too much current from the charger, potentially damaging the charger and circuitry.
- Charger circuit faults - A circuit fault in the charger may blow the fuse in the vehicle or damage the electrical harness.
- Reverse polarity faults - The automobile battery may be accidentally installed in reverse, resulting in circuit damage in the mobile phone or hands-free charger, or other portable equipment. The solution is to provide an overcurrent protection device at the charger input, potentially in combination with an overvoltage device, such as a Zener diode.

Protection Requirements
The protection requirement is determined by the load current of the end equipment and the fault susceptibility of power conversion circuits in the charger itself. Typically overcurrent protection such as a PolySwitch PPTC device is combined with overvoltage protection at the input to the charger (see Figure 1).

Figure 1. Typical CLA Charger Circuit



Protecting Automotive Battery Chargers from Fault Failures
Application Overview

Service station and "do-it-yourself" battery chargers provide a low cost means of charging a flat or heavily discharged battery. However, when battery cables are attached incorrectly, or the clamps or clips touch each other accidentally, the resulting fault condition may cause a blown fuse or equipment damage. Because fuses are typically mounted inside the unit and are not user accessible, and since these kinds of faults can occur easily, a simple and low cost solution would eliminate the time lost to replace the fuse, avoiding equipment downtime for the user. This type of solution could also help avoid customer complaints and costly warranty returns for the manufacturer.

3

Problem/Solution

A typical battery charger schematic is shown in Figure 1. The fuse protecting the secondary side is typically mounted inside the charger housing and in some cases may be soldered into the wiring or printed circuit board making it more difficult to replace. High current faults that can blow the fuse may also result in damaging high voltage spikes due to the leakage inductance of the transformer. The protection element on the primary can be a current fuse, thermal fuse, circuit breaker, or a positive temperature coefficient (PPTC) resettable component.

A PolySwitch PPTC device is an obvious choice to address an overcurrent situation on the secondary side. The resettable PPTC device is a series element in a circuit. The PPTC device goes from a low-resistance to a high-resistance state in response to internal heating generated by an overcurrent condition, or in response to external heating. When a PPTC device transitions to the high resistance state, it is said to have "tripped." It stays in the tripped state until the circuit is de-energized and the fault is removed, at which point the device "resets" and returns to its low resistance state. This can be an ideal approach for high current protection that avoids replacing a blown fuse.

A device such as the PolySwitch RGE1200 from Raychem Circuit Protection, a unit of Tyco Electronics, can limit current that would otherwise be as high as 100A in the fault condition. However, in some cases, the voltage rise from the secondary side of the transformer can generate very high voltages (e.g., >150V) for several microseconds across a tripped overcurrent device such as a PPTC device, which can far exceed the device's voltage rating, as well as that of the other components. These high voltage conditions most commonly occur during short circuit or reverse

Figure 1. Typical Schematic for Battery Charger

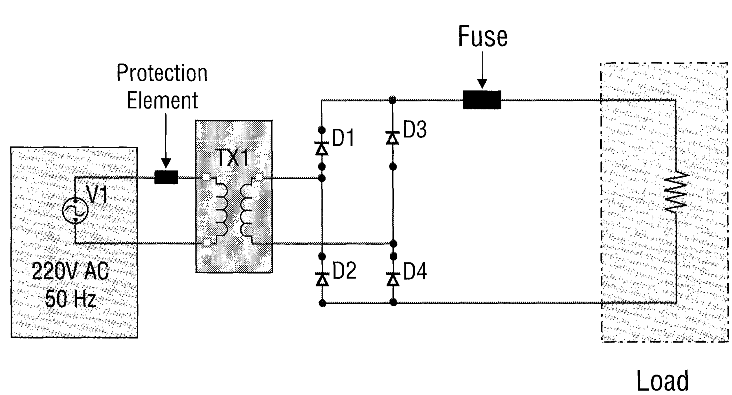
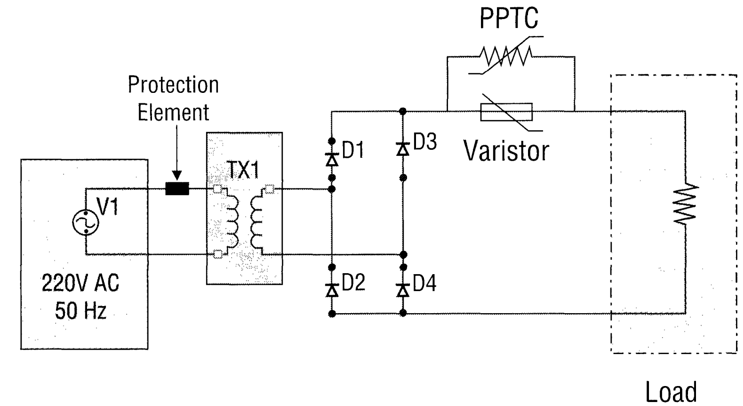


Figure 1. Battery Charger Schematic with PPTC and Varistor to Help Provide Overcurrent and Overvoltage Protection and Eliminate the Need for Secondary Side Fuse Replacement



connection of the output, and if the transformer is a lower cost unit operating in partial saturation. A metal oxide varistor (MOV) in parallel with the PPTC device will clamp the voltage, thereby helping to protect the PPTC device from the overvoltage condition and allowing time for the PPTC device to trip due to the excessive current. The MOV used in combination with the PolySwitch device provides a resettable solution. Figure 2 shows the PPTC and varistor added to the secondary side of the battery charger circuit.

Raychem Circuit Protection's ROV series of MOVs are used in parallel with an electronic device or circuit that has to be protected, in this case the PPTC device. In the normal operating mode, the resistance of the ROV varistor is very high, so the bulk of the current goes through the PPTC, and there is very little leakage current through the varistor. However, when there is a fault that produces a high voltage across the PPTC the varistor "clamps" it to a value that is safe for the PPTC in parallel with it, and protects it from being damaged by the voltage spike.

Selecting the ROV Varistor

The maximum voltage in the secondary of the 12V battery charger can be as high as 17V under normal operating conditions, so a varistor with a VDC rating greater than 17V is required. The ROV20-220M has a maximum DC operating voltage rating of 18V and a clamping voltage of 43V at 100A. The diameter of this device is 20mm to provide sufficient energy absorbing capability.

With the proper selection of a PolySwitch device and ROV varistor, protection against damage from both the overcurrent and overvoltage condition in short circuit or reverse battery connection in the battery charger can be accomplished. This resettable solution is typically much less than \$1.00—versus a warranty return costing \$10.00 to \$50.00 per occurrence—reducing the potential for costly repairs. If the transformer in the battery charger has a small leakage inductance, the overshoot will be significantly lower and the PPTC device alone may be sufficient to solve the problem making the solution even lower cost.

Other Applications for the Combined Overcurrent and Overvoltage Solution

The combination of a PPTC device and a varistor to address both overcurrent and overvoltage conditions has other potential applications. For example, this solution will also work in other heavy inductive load situations, such as motor controls, where a simple means of providing protection can avoid warranty problems.

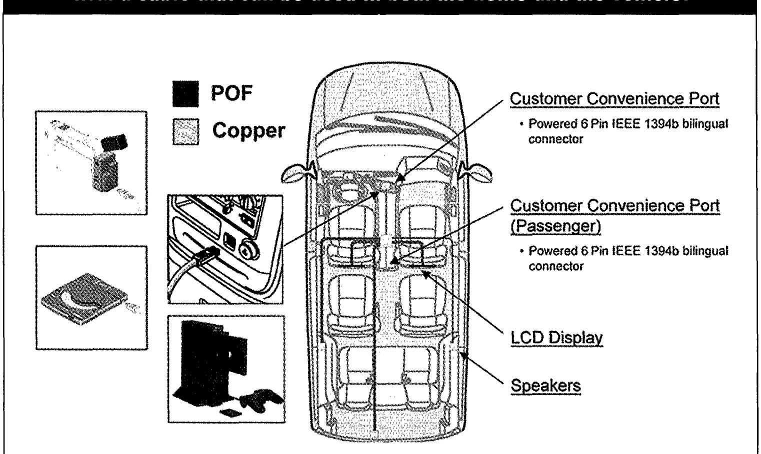
Device Applications for Automotive IEEE 1394 Networks
Application Overview

Connecting lifestyles from the home to the vehicle is an emerging trend in the automotive industry. The ability to interface consumer electronic devices and allow for quick installation in vehicles is now being facilitated through a standard global interface developed by the Automotive Multimedia Interface Collaboration (AMI-C). Designed for delivery of multimedia content, the network is known in the consumer electronics industry as the IEEE 1394 bus. The automotive supplement is titled IDB-1394 and is being developed by the 1394 Joint Automotive Working Group.

IDB-1394 is designed for high-speed multimedia applications that require large amounts of information to be moved quickly in a vehicle. This open standard bridges the gap between automotive electronics and consumer electronics by enabling the connection and interoperability of portable consumer electronic devices over the embedded network in the car.

Powered ports require overcurrent protection, and established standards for power sources that are used with existing bus systems have been in effect for many years. Because the customer convenience port, or CCP, transfers signal and power it must be protected from damage when a shorted or damaged downstream device, such as a bad cable or connector, is plugged into the port. This can be a fairly common occurrence, so CCP port short-circuit protection must be effective and reliable.

Figure 1. The automotive multimedia network includes a Customer Convenience Port (CCP) that lets passengers connect their CD players, games, and other 1394-equipped devices and peripherals to the network with a cable that can be used in both the home and the vehicle.



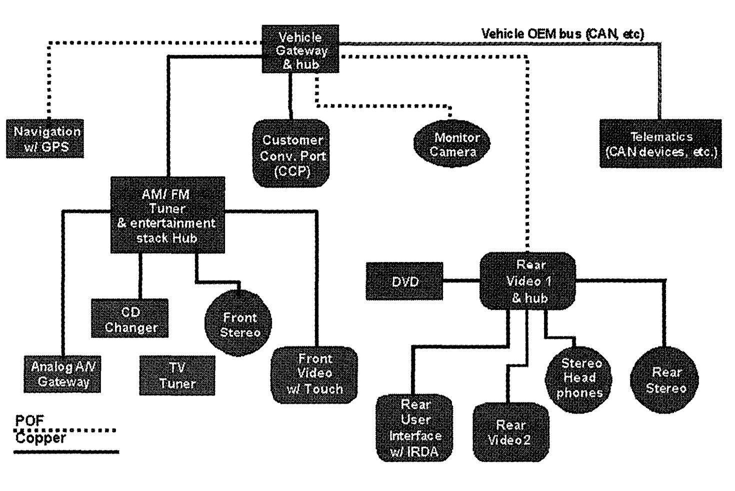
The automotive architecture is divided into an embedded network and a CCP, as shown in Figure 1. The current specification defines an embedded plastic optical fiber (POF) vehicle network similar to the existing MOST specification. It is, however, more robust, offers higher data rates, and is easier to implement. Connected by the network are various electronic components such as DVD players, video displays, navigation systems, radio head units, communications equipment such as cell phones or automatic telematics for emergency functions, and other multimedia applications.

Circuit Protection Requirements

In the hot-pluggable automotive environment, where the consumer is connecting and disconnecting peripherals on a powered port, the potential for short circuit damage is clearly present. Powered ports require overcurrent protection. Because the CCP transfers signal and power it must be protected from damage when a shorted or damaged downstream device, such as a bad cable or connector, is plugged into the port. This can be a fairly common occurrence, so CCP short-circuit protection must be effective, reliable, and preferably resettable.

Current limiting can be accomplished by using a resistor, fuse, switch, or polymeric positive temperature coefficient (PPTC) device. Resistors are rarely an acceptable solution because of

Figure 2. PolySwitch devices help circuit designers meet safety requirements and protect powered ports, telematics, and portable components that may be connected to the automotive network.



the excessive voltage drop these generate with nominal currents. One-shot fuses may be used, but they may fatigue, and must be replaced after a fault event. The limitations of bimetallic switches include cycling and the potential for contacts to weld shut. In many automotive applications the preferred solution is the PPTC device, which has low resistance in normal operation and high resistance when exposed to a fault.

PolySwitch PPTC devices are widely used for IEEE 1394 applications, providing resettable circuit protection on computers, peripherals, and portable electronics. In automotive multimedia applications the device is frequently used to help protect the I/O ports of GPS components, CD changers, stereos, and other electronic peripherals. (Figure 2)

Like traditional fuses, PolySwitch devices limit the flow of dangerously high current during fault conditions. Unlike traditional fuses, PolySwitch devices reset after the fault is cleared and power to the circuit is removed. Another advantage is their small form factor, which allows them to be mounted directly on the circuit board and located inside electronic modules, junction boxes, and power distribution centers.

Designing products built to a common electronics standard helps consumers upgrade their vehicles with new aftermarket products. A common bus also can help vehicle manufacturers facing technology obsolescence issues as technology continues to outpace automotive design cycles. In the hot-pluggable automotive environment, the potential for short circuit damage is clearly present. PPTC devices provide an effective overcurrent protection solution to this problem. These resettable circuit protection devices also help manufacturers provide a safe and reliable product, comply with regulatory agency requirements, and reduce their warranty and repair costs.

The IDB-1394 standard interface allows consumers to hot-plug portable devices. Overcurrent protection of powered ports and portable components on the multimedia network must be reliable and cost-effective. The low resistance, fast time-to-trip, low profile, and resettable functionality of the PolySwitch device helps circuit designers provide a safe and dependable product, comply with regulatory agency requirements, and reduce warranty repair costs. Other PolySwitch benefits include manufacturing compatibility with high-volume electronics assembly techniques, and greater design flexibility through a wide range of product options.

3

Device Selection
SMD150/24
miniSMDC150/24

One-Touch-Down Circuit for Power Windows and Power Sunroofs

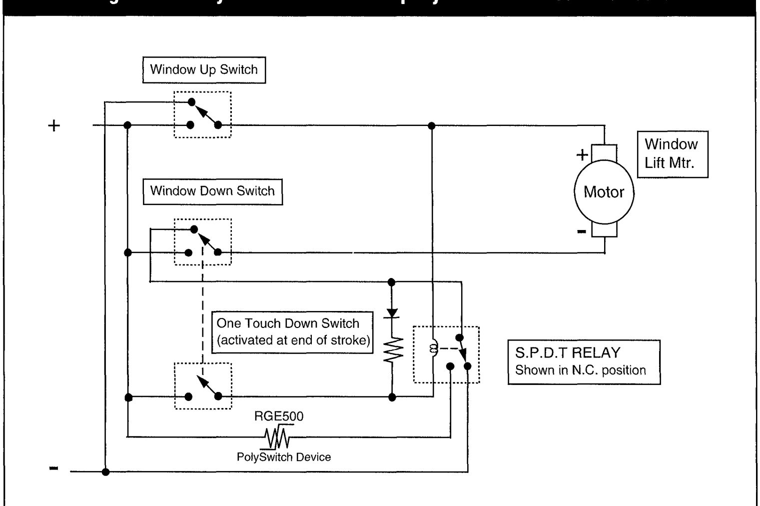
Application Overview

3

Problem/Solution

The express open feature of power windows and power sunroofs is becoming common on nearly all passenger cars and trucks. The most common technique switch manufacturers employ is to latch a relay in the energized state with a secondary activation switch. Once the relay is latched, the express, or "one touch" operation begins. Current flowing through the motor is monitored, by measuring the voltage drop across a precision value sense resistor. When the motor reaches the end of the travel, "stall condition", the current flowing will typically increase by several times the run current value. Therefore, the voltage measured across the sense resistor will also increase proportionally. An operational amplifier or a comparator circuit changes states when a predetermined threshold voltage is reached. This de-activates the latched relay. Additional electronic functions are required to reject inrush current and transient voltages, and a fail-safe time-out feature is often added as a back-up for the event the primary system fails. The electronic components employed to make up these circuits can range from standard off-the-shelf semiconductor products to custom-manufactured ASICs.

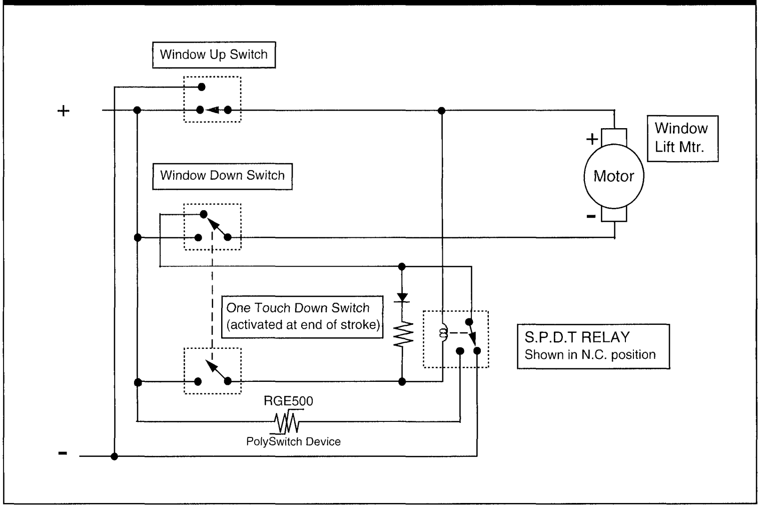
Figure 1. PolySwitch Device Employed in One-Touch Circuit



A low cost alternative solution is to use the circuit shown in Figure 1 which employs a PolySwitch device. The PolySwitch device functions both as a sense component and a switch component, replacing the sense resistor, comparator, driver, and control circuitry. Since there are no ASICs or Microprocessors used in this revised circuit, reverse bather protection and transient overvoltage suppression devices may also be eliminated The simplicity of the PolySwitch device solution offers enhanced reliability through reduced component count.

This circuit consists of a manual up (closing the window) switch, a

Figure 2. Motor Rotating in Upward Direction



manual down (opening the window) switch, an auto-down initiate switch, a low current blocking diode, a resistor, and a single-pole-double-throw (SPDT) relay. The manual up and down switch is mechanically interconnected to provide a mutually exclusive operation. The auto down switch is mechanically interconnected to the manual down switch, and is activated at the end of travel in a mutually inclusive operation with the manual down switch.

Both motor terminals are connected to the negative terminal of the power supply (vehicle battery) when none of the switches is activated. When the manual up switch is activated, the positive terminal of the power supply is connected to the positive terminal of the motor, and the negative terminal of the motor is connected to the negative terminal of the power supply. The motor will rotate in the upward direction (Figure 2).

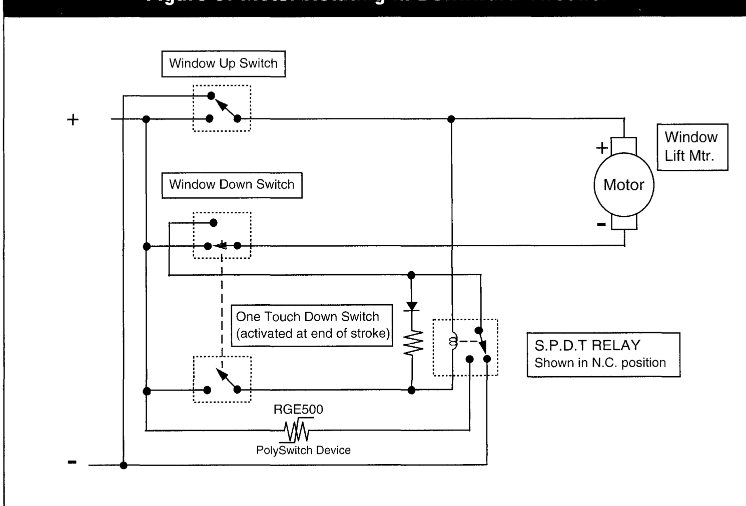
When the manual down switch is activated, the positive terminal of the power supply is connected to the negative terminal of the motor, and the negative terminal of the motor is connected to the positive terminal of the power supply. The motor will rotate in the downward direction (Figure 3).

When the auto down switch is activated, the relay coil will be energized connecting the positive terminal of the power supply through the PolySwitch device to the normally open contacts of the relay. The diode and resistor provide a current path to "latch" the relay in it's energized state (Figure 4). The negative terminal of the power supply is connected to the negative terminal of the relay coil through the normally closed contacts of the manual up switch.

When the manual down and auto-down switches are released, the positive terminal of the power supply maintains its connection to the negative terminal of the motor but is now connected through the PolySwitch device and the latched relay contacts (Figure 5).

When the motor reaches the end of travel and stalls, the current will be increased by up to four times the normal running current of the motor. This causes the PolySwitch device to heat-up and increase in resistance (due to its PTC characteristic). As the PolySwitch device heats, the voltage drop across it increases and the voltage across the relay coil drops. Once the voltage across

Figure 3. Motor Rotating in Downward Direction



the relay coil drops below its "drop-out" level, the relay will be de-energized, and the relay contacts will open interrupting the current flow to the motor.

This method of one-touch-down replaces the opening function of various methods used in existing systems. i.e., the system that is initiated by second detent, "momentary-on" activated, or timer activated one-touch open switches can be replaced by this method. The use of PolySwitch devices reduces the component count drastically. A lower component count usually means cost-savings.

Device Selection

AHR, AGR, AHS, ASMD

Figure 4. Diode and Resistor "Latch" Relay in Energized State

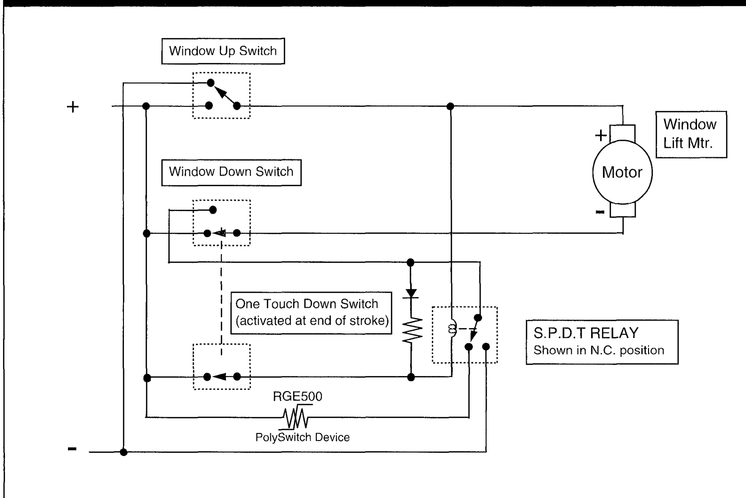
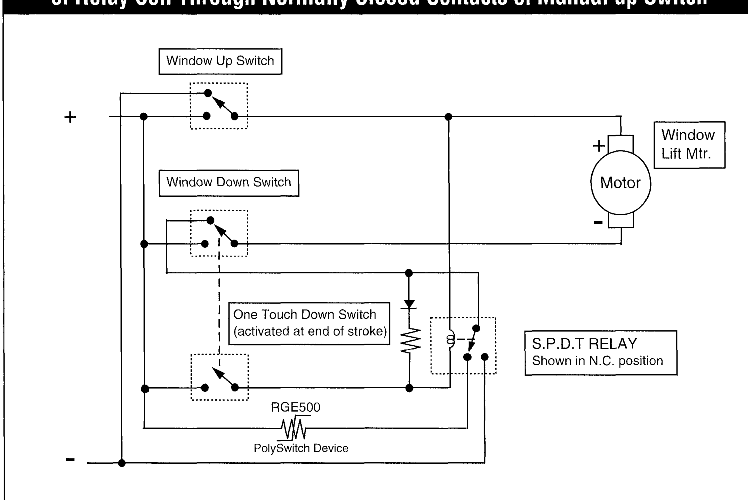


Figure 5. Negative Terminal of Power Supply Connected to Negative Terminal of Relay Coil Through Normally Closed Contacts of Manual up Switch



H-Bridge Protection from Reverse Battery Damage

Application Overview

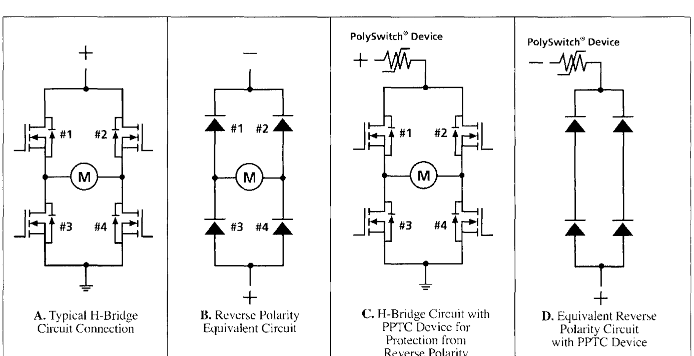
Automotive electronics must be protected from reverse polarity power sources, that may occur when jumper cables are connected to the wrong polarity of a dead or excessively discharged battery, or when a new battery is installed backwards. Without protection, excessive heating can lead to failures in electronic modules or inadvertent activation of vehicle loads such as solenoids and motors, which can lead to unsafe conditions. Traditional protection techniques can be expensive or cause an excessive voltage drop, affecting the performance of some systems. New techniques that use polymeric positive temperature coefficient (PPTC) devices, such as PolySwitch PPTC devices, address both of these shortcomings and provide additional advantages.

H-Bridge/Motor Protection

Most of the fractional horsepower motors used in vehicles for comfort and convenience are brush DC motors. The solid-state method for driving bi-directional motors such as power windows, power seats, and power locks is to use an "H-bridge" configuration consisting of four Power MOSFETs connected as shown in Figure 1A.

To rotate the motor in the positive direction, MOSFETs 1 and 4 are turned on simultaneously. To rotate the motor in the negative direction, MOSFETs 2 and 3 are turned on simultaneously. The reverse-polarity connection to an H-bridge circuit produces the equivalent circuit of two series intrinsic diodes connected in parallel between the positive and negative terminals of the power source (Figure 1B), which essentially creates a short circuit.

Figure 1.



For the same reasons as stated earlier, the use of a series blocking diode, may not be economically feasible. However, the use of a series PPTC device helps provide reverse-polarity protection economically while minimizing the voltage loss in the system (Figure 1C). The equivalent circuit in a reverse-polarity condition is shown in Figure 1D. Generally, the FETs intrinsic diode will easily provide the momentary surge current necessary to cause the PPTC device to trip within milliseconds.

For certain circuits, the diodes that created the current path under the reverse-polarity conditions must have surge capacity ratings that will cause the PPTC device to trip while staying within the Safe Operating Area (SOA) of the diode. In other words, the "time-to-trip" of the PPTC device must not exceed the diode's surge current-time capability. PPTC devices are available with a range of current and maximum time-to-trip ratings to satisfy most applications.

Device Selection

Radial-leaded or Surface-mount devices

3

3

Products

4

Standard PolySwitch and SiBar product series include LVR, RGE, RUE, RUSB, RXE, SMD, miniSMD, TS, TR/TC, TVB, LTP, VTP, LR4, TAC, RTE, VLR, RHE, AHR, AGR, BBR, TGC, AHS, ASMD, microSMD, nanoSMD, and SRP. In addition, terminal devices (TD) and custom chip devices for automotive actuators and medium motors, and disc devices for battery cells, are offered as custom parts. Please contact your local Raychem Circuit Protection representative for more information on these custom devices.

Special devices are manufactured to handle performance requirements that may be outside of the performance band of the standard products listed in this Databook. Please contact Raychem Circuit Protection to discuss your special product needs.

Users should independently evaluate the suitability of and test each product selected for their own application.

PolySwitch Product Series Summary

The chart below provides a quick comparison of PolySwitch overcurrent product series features.

Product Series	LVR	RXE	RTE	RUE	RUSB	AHR	RHE	AGR	RGE	BBR
Primary Section	Radial-leaded	Radial-leaded	Radial-leaded	Radial-leaded	Radial-leaded	Automotive	Radial-leaded	Automotive	Radial-leaded	Telecom & Network
Maximum Rated Voltage	240V	60 to 72V	33V	30V	6 to $16V_{DC}$	$16V_{DC}$	$16V_{DC}$	$16V_{DC}$	$16V_{DC}$	90V
Maximum Interrupt Voltage	265V	—	—	—	—	—	—	—	—	—
Maximum Rated Current	20A	40A	40A	40A	40A	100A	100A	100A	100A	20A
Maximum Interrupt Current	—	—	—	—	—	200A	—	200A	—	—
Operating Current Range	0.05 to 0.55mA	50mA to 3.75A	1.2 to 1.9A	0.9 to 9.0A	0.75 to 2.5A	4.5 to 13A	0.7 to 13A	4.0 to 14.0A	3.0 to 14.0A	550 to 750mA
Typical Activation Temperature	125˚C	125˚C	125˚C	125˚C	125˚C	170˚C	170˚C	125˚C	125˚C	125˚C
Temperature Range	-40 to 85˚C	-40 to 85˚C	-40 to 85˚C	-40 to 85˚C	-40 to 85˚C	-40 to 125˚C	-40 to 125˚C	-40 to 85˚C	-40 to 85˚C	-40 to 85˚C
Thermal Derating	Medium	Medium	Medium	Medium	Medium	Low	Low	Medium	Medium	Medium
Resistance	Med. to High	High to Med.	Medium	Medium	Low to Med.	Low to Med.	Low to Med.	Low	Low	Med. to High
Form factor	Radial-leaded	Radial-leaded	Radial-leaded	Radial-leaded	Radial-leaded	Radial-leaded	Radial-leaded	Radial-leaded	Radial-leaded	Radial-leaded
Height Above Board	12.0 to 21.7mm	11.6 to 30.1mm	12.2 to 13.5mm	12.2 to 29.7mm	11.0 to 18.3mm	15.6 to 28.7mm	10.8 to 28.7mm	14.1 to 28.7mm	11.0 to 27.9mm	14.0 to 15.5mm
Agency Specifications	UL, CSA, TÜV	UL, CSA, TÜV	UL, CSA, TÜV	UL, CSA, TÜV	UL, CSA, TÜV	—	UL, TÜV, CSA pending	—	UL, CSA, TÜV	UL
Telecom* Specifications	—	—	—	—	—	—	—	—	—	—
Time-to-trip	Medium	Medium Medium	Fast to	Medium Medium	Fast to	Medium	Medium	Medium	Medium	Medium
Tape and Reel*	EIA468B	EIA468B	EIA468B	EIA468B	EIA468B	EIA468B	EIA468B	EIA468B	EIA468B	EIA468B
Typical Mechanical Attachment	PCB thru-hole	PCB thru-hole	PCB thru-hole	PCB thru-hole	PCB thru-hole	PCB thru-hole	PCB thru-hole	PCB thru-hole	PCB thru-hole	PCB thru-hole

*See details in related product section.

PolySwitch Product Series Summary

The chart below provides a quick comparison of PolySwitch overcurrent product series features.

Product Series	TR250	TR600	TC	TGC	TS250	TSV250	TSL250	TS600	AHS
Primary Section	Telecom & Network	Telecom & Network	Telecom & Network	Telecom & Network	Telecom & Network	Telecom & Network	Telecom & Network	Telecom & Network	Automotive
Maximum Rated Voltage	60V	60V	60V	60V	60V	60V	80V	60V	16V
Maximum Interrupt Voltage	250V	600V	250V	250V	250V	250V	250V	600V	200V
Maximum Rated Current	3A	3A	3A	3A	3A	3A	3A	3A	70A
Maximum Interrupt Current	3 to 10A	3A	3A	3A	3A	3A	3A	3A	—
Operating Current Range	80 to 180mA	150 to 160mA	120 to 180ma	120 to 145mA	130mA	130mA	80mA	170 to 200mA	0.80 to 1.6A
Typical Activation Temperature	125°C	125°C	125°C	125°C	125°C	125°C	125°C	125°C	170°C
Temperature Range	-40 to 85°C	-40 to 85°C	-40 to 85°C	-40 to 85°C	-40 to 85°C	-40 to 85°C	-40 to 85°C	-40 to 85°C	-40 to 125°C
Thermal Derating	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Low
Resistance	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Low
Form factor	Radial-leaded	Radial-leaded	Chip	Chip	Surface-mount	Surface-mount	Surface-mount	Surface-mount	Surface-mount
Height Above Board	9.3 to 12.6mm	12.6mm	2.5mm	2.3mm	3.4mm	6.9mm	3.7mm	12.3mm	5.44 to 6.71mm
Agency Specifications	UL, TÜV CSA	UL, CSA	—	—	UL, TÜV CSA	UL, TÜV CSA	UL, TÜV CSA	UL, CSA	—
Telecom* Specifications	ITU K.20, K.21	Telcordia UL1950	ITU K.20, K.21	ITU K.20, K.21	ITU K.20, K.21	ITU K.20, K.21	Telcordia Intrabuilding	Telcordia UL1950	—
Time-to-trip	Medium	Fast to Medium	Application Specific	Application Specific	Fast to Medium	Fast to Medium	Fast	Medium	Medium
Tape and Reel*	EIA468-B	EIA468-B	—	—	EIA481	EIA481	EIA481	EIA481	EIA481-2
Typical Mechanical Attachment	PCB thru-hole	PCB thru-hole	Clip	Clip	PCB surface	PCB surface	PCB surface	PCB surface	PCB surface

*See details in related product section.

4

PolySwitch Product Series Summary

The chart below provides a quick comparison of PolySwitch overcurrent product series features.

Product Series	ASMD	SMD2	SMD	midSMD	mini-SMDE	mini-SMDM	mini-SMDC	micro-SMD	nano-SMDM	nano-SMDC
Primary Section	Automotive	Surface-mount	Surface-mount	Surface-mount	Battery Protectors	Surface-mount	Surface-mount	Surface-mount	Surface-mount	Surface-mount
Maximum Rated Voltage	16V	15 to 33V	6 to 60V	6 to 60V	16V	6 to 24V	6 to 60V	6 to 30V	6V	6V
Maximum Interrupt Voltage	200A	—	—	—	—	—	—	—	—	—
Maximum Rated Current	10 to 40A	40 to 70A	10 to 40A	20 to 40A	100A	40A	10 to 40A	10-40A	40A	40A
Maximum Interrupt Current	200A	—	—	—	100A	—	—	—	—	—
Operating Current Range	0.23 to 1.97A	1.5 to 2.5A	0.3 to 3.0A	0.3 to 2.0A	1.9A	0.75 to 2.6A	0.14 to 2.6A	0.05 to 1.5A	0.5 to 1A	1.5A
Typical Activation Temperature	125°C	125 to 170°C	125°C	125°C	110°C	125°C	125°C	125°C	125°C	125°C
Temperature Range	-40 to 85°C	-40 to 85°C**	-40 to 85°C	-40 to 85°C	-40 to 85°C	-40 to 85°C	-40 to 85°C	-40 to 85°C	-40 to 85°C	-40 to 85°C
Thermal Derating	Low to Med.	Low to Med.	Low to Med.	Low to Med.	Low to Med.	Medium	Medium	Medium	Medium	Medium
Resistance	Medium	Medium	Medium	Low to Med	Medium	Low to Med	Low to Med	Low	Very Low	Low
Form factor	Surface-mount	Surface-mount	Surface-mount	Surface-mount	Surface-mount	Surface-mount	Surface-mount	Surface-mount	Surface-mount	Surface-mount
Height Above Board	4.93 to 6.71mm	3.0mm	3.0 to 3.18mm	1.52 to 1.78mm	0.53mm	2.0mm	0.48mm to 1.25mm	0.62 to 0.85mm	1.2mm	1.4mm
Agency Specifications	–	UL, CSA, TÜV	UL, CSA, TÜV	UL, CSA, TÜV	UL, CSA, TÜV	UL, CSA, TÜV	UL, CSA, TÜV	UL, CSA, TÜV	UL, CSA, TÜV	UL, CSA, TÜV
Telecom* Specifications	—	—	—	—	—	—	—	—	—	—
Time-to-trip	Medium	Medium	Medium	Medium	Medium	Medium	Med. to Fast	Fast	Fast	Fast
Tape and Reel*	EIA481-2	EIA481-2	EIA481-2	EIA481-2	EIA481-2	EIA481-1	EIA481-1	EIA481-1	EIA481-1	EIA481-1
Typical Mechanical Attachment	PCB surface	PCB surface	PCB surface	PCB surface	Flexprint surface	PCB surface	PCB surface	PCB surface	PCB surface	PCB surface

*See details in related product section.

**125°C for SMDH160.

4

PolySwitch Product Series Summary

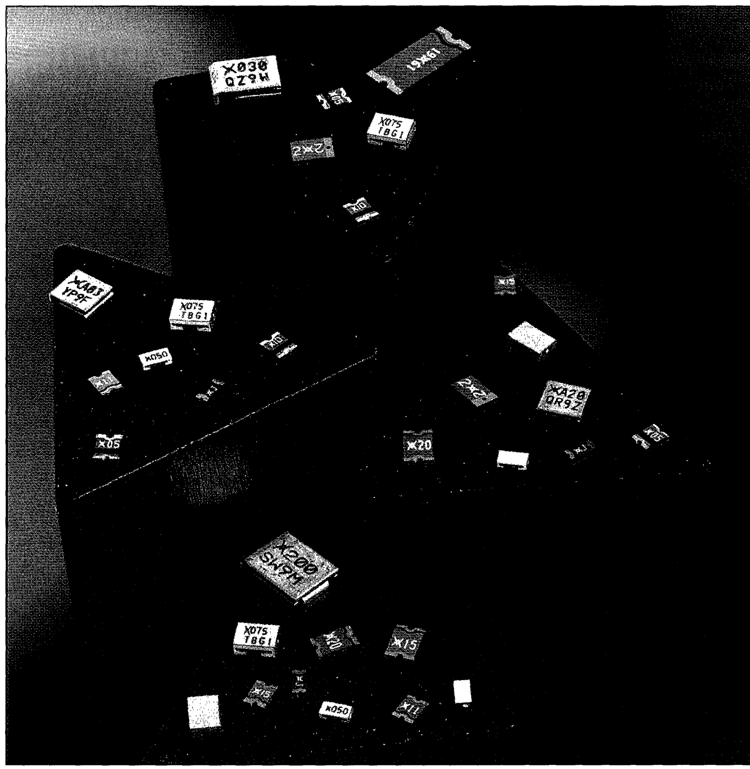
The chart below provides a quick comparison of PolySwitch overcurrent product series features.

Product Series	SRP	LR4	TAC	LTP	VTP	VLR	Disc	Chip	TD
Primary Section	Battery Protectors	Battery Protectors	Battery Protectors	Battery Protectors	Battery Protectors	Battery Protectors	**Custom device, contact Raychem Circuit Protection**		
Maximum Rated Voltage	15 to 30V	15 to 20V	15V	15 to 24V	16V	12V	≤15V	15 to 90V	16 to 30V
Maximum Interrupt Voltage	—	—	—	—	—	—	—	—	—
Maximum Rated Current	100A	100A	50A	100A	100A	100A	—	—	—
Maximum Interrupt Current	100A	100A	50A	100A	100A	100A	≤50A	≤50A	≤50A
Operating Current Range	1.2 to 4.2A	1.7 to 7.3A	1.0 to 2.1A	0.7 to 3.4A	1.1 to 2.4A	1.7 to 2.3A	Custom	Custom	Custom
Typical Activation Temperature	125°C	125°C	110 to 125°C	110°C	90°C	85°C	110 to 125°C	125 to 175°C	125 to 175°C
Temperature Range	-40 to 85°C	-40 to 85°C	-40 to 85°C	-40 to 85°C	-40 to 85°C	-40 to 85°C	-40 to 85°C	-40 to 125°C	-40 to 125°C
Thermal Derating	Medium	Low to Medium	Medium	Medium to High	High	High	Medium to High	Medium to Low	Medium to Low
Resistance	Medium	Low	Low to Medium	Low to Medium	Low	Very Low	Low	Medium	Low
Form factor	Axial-leaded	Axial-leaded	Axial-leaded (special)	Axial-leaded	Axial-leaded	Axial-leaded	Annulus disc	Circular or rectangular chip	Custom
Height Above Board (mm)	1.1mm	1.0mm	0.9mm	1.1mm	0.8mm	0.8mm	0.4mm		
Agency* Specifications	UL, CSA, TÜV	UL, CSA, TÜV	UL, CSA, TÜV	UL, CSA, TÜV	UL, CSA, TÜV	UL, CSA, TÜV	UL*	—	—
Telecom Specifications	—	—	—	—	—	—	—	—	—
Time-to-trip	Medium	Medium to Fast	Medium	Medium	Fast to Medium	Fast to Medium	Application Specific	Application Specific	Application Specific
Tape and Reel*	*	*	*	*	*	*	—	—	—
Typical Mechanical Attachment	To battery cells	To battery cells	To battery cells	To battery cells	To battery cells	To battery cells	To lid assembly of cells	Mechanical or clips	Mechanical or welded

*See details in related product section.

PolySwitch Surface-mount
Resettable Devices

More than ten years ago, Raychem Circuit Protection introduced the SMD product family, and polymeric PTC devices quickly became the computer industry standard for keyboard, mouse, and disk drive protection. In 1995, Raychem Circuit Protection advanced the technology, reducing the size and cost of surface-mount resettable devices with the introduction of its miniSMD product series. The recent additions to the surface-mount family include the nanoSMD series, which reduces the size to a 3216mm (1206mils) foot print, one-third the size of the popular miniSMD series.



Benefits:
- Smaller size saves board space and cost
- Many product choices give engineers more design flexibility
- Compatible with high-volume electronics assembly
- Assists in meeting regulatory requirements
- Higher voltage ratings allow use in new applications

Features:
- Broadest range of resettable devices available in the industry
- Current ratings from 0.05 to 3A
- Voltage ratings from 6V computer and electronic applications to 60V (600V Telecom)
- Agency recognition: UL, CSA, TÜV
- Small footprint
- Fast time-to-trip
- Low resistance

Applications:
- Computer motherboards
- Modems
- USB hub, ports and peripherals
- IEEE1394 ports
- Digital cameras
- Disk drives
- CD-ROMs
- Game machines
- Battery packs
- Phones
- Fax machines
- Analog and digital line cards
- Printers
- PDAs
- Chargers

Products in this section are grouped by:

Product Dimensions, Product Series, Hold Current

Step 1. Determine the circuit's operating parameters.

Fill in the following information about the circuit:

Maximum ambient operating temperature	________________
Normal operating current	________________
Maximum operating voltage (i.e. miniSMDC014 is $60V_{DC}$ max.)	________________
Maximum interrupt current	________________

Step 2. Select the PolySwitch device that will accommodate the circuit's maximum ambient temperature and normal operating current.

Look across the top of Table S2 to find the temperature that most closely matches the circuit's maximum operating temperature. Look down that column to find the value equal to or greater than the circuit's normal operating current. Now look to the far left of that row to find the part number for the PolySwitch surface-mount device that will best accommodate the circuit. Devices in this section are grouped by device dimensions, so your operating-current requirement may be found in more then one grouping.

The thermal derating curves located in Figure S1 are the normalized representations of the data in Table S2.

Step 3. Compare the selected device's maximum electrical ratings with the circuit's maximum operating voltage and interrupt current.

Look down the first column of Table S3 to find the part number you selected in Step 2. Look to the right in that row to find the device's maximum operating voltage (V_{MAX}) and maximum interrupt current (I_{MAX}). Ensure that V_{MAX} and I_{MAX} are greater than or equal to the circuit's maximum operating voltage and maximum interrupt current.

Step 4. Determine time-to-trip.

Time-to-trip is the amount of time it takes for a device to switch to a high-resistance state once a fault current has been applied across the device. Identifying the PolySwitch device's time-to-trip is important in order to provide the desired protection capabilities. If the device you choose trips too fast, undesired or nuisance tripping will occur. If the device trips too slowly, the components being protected may be damaged before the device switches to a high-resistance state.

Figures S11-S19 show the typical time-to-trip at 20°C for each of the PolySwitch devices.

If the PolySwitch device's time-to-trip is too fast or too slow for the circuit, go back to Step 2 and choose an alternate device.

Step 5. Verify ambient operating conditions.

Ensure that your application's minimum and maximum ambient temperatures are within the operating temperature of -40°C to 85°C (-40°C to 125°C for SMDH160).

Step 6. Verify the PolySwitch device dimensions.

Using dimensions in Table S4, compare the dimensions of the PolySwitch device you selected with the application's space considerations.

Protection Application Selection Table for Surface-mount Devices

The table below lists Polyswitch devices typically used in these applications.

Specifications for the suggested device part numbers can be found in this section.

Once a part has been selected, the user should evaluate and test each product for the intended application.

Protection Application	Additional Comments	Overcurrent Overvoltage	PolySwitch Resettable Devices—Key Selection Criteria: Small Size	Low Resistance	Fast Time-to-trip (Temperature Protection)
AC adapter input power	use w/ Zener & triac		SMD250	SMD250	SMD200
Battery pack protection			nanoSMDC150	miniSMDC260	miniSMDE190
Charger protection			nanoSMDM050	miniSMDM110/16	nanoSMDM075
CPU/IC protection			nanoSMDM100	nanoSMDC150	nanoSMDM075
Data acquisition/sensor			microSMD005	—	microSMD005
DC input/output power	≤6V		nanoSMDM075	nanoSMDC150	nanoSMDM050
	≤12V		miniSMDC075	miniSMDM110/16	miniSMDC075
DDC			nanoSMDM075	nanoSMDM100	nanoSMDM050
Device Bay system	DB12, DB20		miniSMDC200	miniSMDC260	miniSMDC200
	DB32		miniSMDC260	SMD300	miniSMDM200
Ethernet/Lan			nanoSMDM050	miniSMDM110/16	nanoSMDM075
Fan			microSMD035	microSMD050	microSMD035
IEEE 802.3af	VOIP		SMD050-2018	SMD050-2018	SMD050-2018
IEEE-1394	power provider		SMD100/33	SMD185	SMD100/33
	alt. power provider		SMD185	SMD185	SMD150/33
	self-powered		SMD185	SMD185	SMD150/33
LCD inverter			nanoSMDM050	miniSMDM110/16	nanoSMDM075
LCD screen power			nanoSMDM050	nanoSMDM050	microSMD035
LNB (Low Noise Block)			SMD075	SMD075	SMD050
Motor	≤6V		nanoSMDM100	nanoSMDC150	microSMDM075
	≤13.2V		miniSMDC075	miniSMDM110/16	miniSMDC075
PS/2 mouse/keyboard			nanoSMDM075	nanoSMDM100	nanoSMDM050
Signal - data communication	≤6V		nanoSMDM075	nanoSMDM075	nanoSMDM075
	≤13.2V		miniSMDC050	miniSMDM075	miniSMDC020
	≤30V		SMD030-2018	SMD075	SMD050
SCSI			nanoSMDM100	nanoSMDC150	nanoSMDM075
Smart card reader			microSMD010	microSMD035	microSMD005
Telecom - modem	UL1950	OC OV	TS600-170 TVB270SA or SC*	TS250-130 TVB270SA or SC*	TS600-170 TVB270SA or SC*
	ITU-T K.21	OC OV	TS250, TSV250 TVB270SA*	TS250, TSV250-130 TVB270SA*	TS250-130-RB TVB270SA*
	Digital line	OC OV	miniSMDC014 TVB270SC*	miniSMDC014 TVB270SC*	miniSMDC014 TVB270SC*
Telecom - PBX	UL1950	OC OV	TS600-170 TVB270SA or SC*	TS600-200-RA TVB270SA or SC*	TS600-170 TVB270SA or SC*
	ITU-T K.21	OC OV	TS250, TSV250 TVB270SA*	TS250-130 TVB270SA*	TS250-130-RB TVB270SA*
	Subscriber	OC	miniSMDC014	miniSMDC014	miniSMDC014
Telecom - line card	Telcordia GR-1089	OC OV	TS600-200-RA-B-0.5 TVB270SC*	TS600-200-RA-B-0.5 TVB270SC*	TS600-200-RA-B-0.5 TVB270SC*
	ITU-T K.20	OC OV	TS250, TSV250 TVB270SA*	TS250-130-RA TVB270SA*	TS250 TVB270SA*
Intrabuilding protection	Telcordia GR1089		TSL250-080	SMD030-2018	TSL250-080
Temperature sensor	CPU		nanoSMDM050	nanoSMDM075	nanoSMDM050
USB	Individual Port		nanoSMDM075	nanoSMDM100	nanoSMDM050
	2 port ganged		nanoSMDC150	miniSMDC150	miniSMDC125
	3 port ganged		miniSMDC200	miniSMDM200	miniSMDM200

*Refer to the SiBar thyristor product section for more information.

This list is not exhaustive. Raychem Circuit Protection welcomes our customers' input for additional application ideas for Polyswitch Resettable devices.

Table S1. Product Series: Size, Current Rating, Voltage Rating/Typical Resistance for Surface-mount Devices

	nanoSMDC nanoSMDM	microSMD	miniSMDC miniSMDM	midSMD	SMD	SMD2	miniSMDE	TS250 TSL250 TSV250	TS600
Size mm (mils)	3216 (1206)	3225 (1210)	4532 (1812)	5050 (2018)	7555 (2920)	8763 (3425)	11550 (4420)	*	*
Hold Current (A)	—	—	—	—	—	—	—	—	—
0.05	—	30V$_{DC}$/25Ω	—	—	—	—	—	—	—
0.08	—	—	—	—	—	—	—	80V/12.5Ω	—
0.100	30V$_{DC}$/12Ω	—	—	—	—	—	—	—	—
0.125	30V$_{DC}$/—	—	—	—	—	—	—	—	—
0.13	—	—	—	—	—	—	—	60V/6.0-8.0Ω	—
0.14	—	—	60V$_{DC}$/4.0Ω	—	—	—	—	—	—
0.160	30V$_{DC}$/—	—	—	—	—	—	—	—	—
0.17	—	—	—	—	—	—	—	—	60V/11.0Ω
0.18	—	—	—	—	—	—	—	—	—
0.20	24V$_{DC}$/—	—	30V$_{DC}$/1.4Ω	—	—	—	—	—	60V/8.5Ω
0.30	—	—	—	60V$_{DC}$/1.4Ω	60V$_{DC}$/3.0Ω	—	—	—	—
0.35	—	6V$_{DC}$/0.81Ω	—	—	—	—	—	—	—
0.50	6V$_{DC}$/0.40Ω	13.2V$_{DC}$/0.55Ω	24V$_{DC}$/0.60Ω	57V$_{DC}$/0.5Ω	60V$_{DC}$/0.87Ω	—	—	—	—
0.75	6V$_{DC}$/0.20Ω	6V$_{DC}$/0.29Ω	13.2V$_{DC}$/0.23Ω 24V$_{DC}$/0.20Ω	—	30V$_{DC}$/0.67Ω	—	—	—	—
1.00	6V$_{DC}$/0.15Ω	—	—	15V$_{DC}$/0.25Ω	30V$_{DC}$/0.30Ω 33V$_{DC}$/0.27Ω	—	—	—	—
1.10	6V$_{DC}$/—	6V$_{DC}$/0.14Ω	6V$_{DC}$/0.12Ω 8V$_{DC}$/0.14Ω 16V$_{DC}$/0.12Ω	—	—	—	—	—	—
1.25	—	—	6V$_{DC}$/0.09Ω	—	15V$_{DC}$/0.16Ω	—	—	—	—
1.50	6V$_{DC}$/0.08Ω	6V$_{DC}$/0.07Ω	6V$_{DC}$/0.07Ω	15V$_{DC}$/0.13Ω	—	15V$_{DC}$/0.16Ω 33V$_{DC}$/0.15Ω	—	—	—
1.60	—	—	8V$_{DC}$/0.066Ω	—	—	16V$_{DC}$/0.10Ω	—	—	—
1.85	—	—	—	—	—	33V$_{DC}$/0.12Ω	—	—	—
1.90	—	—	—	—	—	—	16V$_{DC}$/0.065Ω	—	—
2.00	—	—	6V$_{DC}$/0.050Ω 8V$_{DC}$/0.040Ω	6V$_{DC}$/0.07Ω	—	15V$_{DC}$/0.09Ω	—	—	—
2.50	—	—	—	—	—	15V$_{DC}$/0.06Ω	—	—	—
2.60	—	—	6V$_{DC}$/0.035Ω 6V$_{DC}$/0.030Ω	—	6V$_{DC}$/0.05Ω	—	—	—	—
3.00	—	—	—	—	6V$_{DC}$/0.033Ω	—	—	—	—

*Refer to Telecommunications and Networking section for dimensions; voltage for these parts is RMS max.

Table S2-A. Thermal Derating for Surface-mount Devices [Hold Current (A) at Ambient Temperature (°C)]

Part Number	Maximum Ambient Temperature -40°C	-20°C	0°C	20°C	25°C	40°C	50°C	60°C	70°C	80°C	85°C	125°C
nanoSMDC Series Size 3216 mm/1206 mils												
nanoSMDC150	2.20	1.99	1.77	1.55	1.50	1.34	1.23	1.10	1.01	0.90	0.84	—
Lead-free devices are listed in Table S2-B												
nanoSMDM Series Size 3216 mm/1206 mils												
nanoSMDM012	0.19	0.17	0.15	0.13	0.125	0.11	0.10	0.09	0.08	0.07	0.07	—
nanoSMDM016	0.24	0.22	0.19	0.17	0.16	0.14	0.13	0.10	0.09	0.09	0.08	—
nanoSMDM050	0.76	0.68	0.59	0.52	0.50	0.44	0.40	0.35	0.32	0.28	0.26	—
nanoSMDM075	1.11	1.00	0.85	0.78	0.75	0.67	0.61	0.52	0.50	0.44	0.42	—
nanoSMDM100	1.49	1.34	1.15	1.04	1.00	0.89	0.81	0.70	0.66	0.58	0.55	—
Lead-free devices are listed in Table S2-B												
microSMD Series Size 3225 mm/1210 mils												
microSMD005	0.08	0.07	0.06	0.05	0.05	0.04	0.04	0.03	0.03	0.02	0.02	—
microSMD010	0.15	0.13	0.12	0.10	0.10	0.09	0.08	0.07	0.06	0.05	0.05	—
microSMD035	0.51	0.46	0.40	0.35	0.34	0.30	0.27	0.24	0.22	0.19	0.18	—
microSMD050	0.76	0.66	0.58	0.50	0.48	0.42	0.38	0.35	0.29	0.25	0.23	—
microSMD075	1.10	0.97	0.86	0.75	0.72	0.64	0.58	0.55	0.47	0.42	0.39	—
microSMD110	1.60	1.42	1.26	1.10	1.06	0.94	0.86	0.80	0.70	0.62	0.58	—
microSMD150	2.30	2.02	1.76	1.50	1.43	1.24	1.11	1.00	0.85	0.72	0.65	—
Lead-free devices are listed in Table S2-B												
miniSMDC Series Size 4532 mm/1812 mils												
miniSMDC014	0.23	0.20	0.17	0.14	0.13	0.11	0.10	0.09	0.07	0.06	0.05	—
miniSMDC020	0.30	0.27	0.23	0.20	0.19	0.17	0.15	0.13	0.12	0.10	0.09	—
miniSMDC050	0.59	0.57	0.55	0.50	0.48	0.45	0.43	0.35	0.30	0.25	0.23	—
miniSMDC075	1.10	0.99	0.87	0.75	0.72	0.63	0.57	0.49	0.45	0.39	0.35	—
miniSMDC110	1.60	1.45	1.28	1.10	1.07	0.92	0.83	0.71	0.66	0.57	0.52	—
miniSMDC125	2.00	1.69	1.47	1.25	1.17	1.03	0.92	0.90	0.69	0.58	0.53	—
miniSMDC150	2.30	2.05	1.77	1.50	1.44	1.23	1.09	0.95	0.82	0.68	0.61	—
miniSMDC200	2.60	2.44	2.22	2.00	1.96	1.78	1.67	1.50	1.45	1.34	1.29	—
miniSMDC260	3.40	3.16	2.88	2.60	2.54	2.32	2.18	2.00	1.90	1.76	1.69	—
Lead-free devices are listed in Table S2-B												
miniSMDM Series Size 4532 mm/1812 mils												
miniSMDM075	1.11	1.00	0.81	0.78	0.75	0.67	0.61	0.49	0.47	0.45	0.42	—
miniSMDM075/24	1.11	1.00	0.85	0.78	0.75	0.67	0.61	0.52	0.50	0.44	0.42	—
miniSMDM110	1.58	1.43	1.20	1.14	1.10	0.98	0.92	0.77	0.73	0.70	0.66	—
miniSMDM110/16	1.61	1.46	1.25	1.14	1.10	0.98	0.90	0.78	0.74	0.66	0.62	—
miniSMDM150/24	2.11	1.92	1.70	1.50	1.45	1.29	1.18	1.00	0.97	0.87	0.81	—
miniSMDM160	2.32	2.10	1.80	1.66	1.60	1.43	1.32	1.14	1.10	0.99	0.93	—
miniSMDM200	2.88	2.61	2.25	2.07	2.00	1.80	1.66	1.45	1.39	1.26	1.19	—
miniSMDM260	3.70	3.36	2.90	2.68	2.60	2.35	2.18	1.90	1.84	1.67	1.59	—
Lead-free devices are listed in Table S2-B												
miniSMDE Series Size 11550 mm/4420 mils												
miniSMDE190	3.16	2.74	2.20	1.90	1.74	1.48	1.27	1.10	0.80	0.50	0.35	—
Lead-free devices are listed in Table S2-B												

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Table S2-A. Thermal Derating for Surface-mount Devices [Hold Current (A) at Ambient Temperature (°C)] *continued*

	Maximum Ambient Temperature											
Part Number	**-40°C**	**-20°C**	**0°C**	**20°C**	**25°C**	**40°C**	**50°C**	**60°C**	**70°C**	**80°C**	**85°C**	**125°C**
midSMD Size 5050 mm/2018 mils												
SMD030-2018	0.48	0.42	0.35	0.30	0.28	0.24	0.21	0.17	0.15	0.12	0.10	—
SMD050-2018	0.86	0.77	0.70	0.55	0.53	0.48	0.43	0.38	0.36	0.29	0.26	—
SMD100-2018	1.59	1.43	1.20	1.10	1.03	0.94	0.85	0.72	0.69	0.61	0.57	—
SMD150-2018	2.21	1.97	1.70	1.50	1.43	1.26	1.15	1.00	0.91	0.79	0.73	—
SMD200-2018	2.81	2.54	2.27	2.00	1.93	1.73	1.59	1.46	1.32	1.19	1.12	—
Lead-free devices are listed in Table S2-B												
SMD Size 7555 mm/2920 mils												
SMD030	0.44	0.39	0.32	0.30	0.28	0.26	0.23	0.19	0.18	0.17	0.15	—
SMD050	0.73	0.65	0.55	0.50	0.47	0.43	0.39	0.33	0.31	0.28	0.26	—
SMD075	1.11	0.99	0.84	0.75	0.71	0.63	0.57	0.49	0.45	0.39	0.36	—
SMD100	1.59	1.43	1.20	1.10	1.03	0.94	0.85	0.72	0.69	0.61	0.57	—
SMD100/33	1.48	1.35	1.20	1.10	1.06	0.98	0.91	0.83	0.79	0.73	0.69	—
SMD125	1.89	1.68	1.50	1.25	1.21	1.04	0.93	0.85	0.71	0.61	0.55	—
SMD260	3.82	3.41	2.90	2.60	2.45	2.19	1.99	1.70	1.58	1.38	1.28	—
SMD260-RB	3.82	3.41	2.90	2.60	2.45	2.19	1.99	1.70	1.58	1.38	1.28	—
SMD300	4.13	3.75	3.30	3.00	2.87	2.62	2.43	2.25	2.00	1.87	1.78	—
Lead-free devices are listed in Table S2-B												
SMD2 Size 8763 mm/3425 mils												
SMD150	2.30	2.04	1.80	1.50	1.45	1.23	1.10	0.99	0.83	0.70	0.63	—
SMD150/33	2.30	2.04	1.80	1.50	1.45	1.23	1.10	0.99	0.83	0.70	0.63	—
SMDH160	2.15	1.96	1.78	1.60	1.55	1.42	1.33	1.24	1.15	1.05	1.01	0.64
SMD185	2.54	2.29	2.20	1.85	1.80	1.55	1.43	1.31	1.19	1.06	1.00	—
SMD200	3.01	2.67	2.30	2.00	1.90	1.66	1.50	1.30	1.16	0.99	0.91	—
SMD250	3.72	3.31	2.80	2.50	2.35	2.09	1.89	1.60	1.48	1.28	1.18	—
Lead-free devices are listed in Table S2-B												
Telecom Surface-mount												
TSL250-080	0.124	0.110	0.095	0.080	0.077	0.066	0.059	0.051	0.044	0.037	0.033	—
TS250-130	0.208	0.182	0.156	0.130	0.124	0.104	0.091	0.078	0.065	0.052	0.045	—
TSV250-130	0.208	0.182	0.156	0.130	0.124	0.104	0.091	0.078	0.065	0.052	0.045	—
TS600-170	0.264	0.230	0.200	0.170	0.163	0.140	0.125	0.109	0.094	0.077	0.070	—
TS600-200-RA	0.310	0.275	0.238	0.200	0.193	0.165	0.147	0.128	0.110	0.091	0.083	—
TSM600-250	0.400	0.350	0.300	0.250	0.241	0.198	0.170	0.141	0.117	0.097	0.083	—

Table S2-B. Thermal Derating for Lead-free Surface-mount Devices [Hold Current (A) at Ambient Temperature (°C)]

	Maximum Ambient Temperature											
Part Number	**-40°C**	**-20°C**	**0°C**	**20°C**	**25°C**	**40°C**	**50°C**	**60°C**	**70°C**	**80°C**	**85°C**	**125°C**
Lead-free nanoSMDC Series Size 3216 mm/1206 mils												
nanoSMDC020F	0.34	0.30	0.26	0.22	0.20	0.17	0.15	0.13	0.11	0.09	0.08	—
nanoSMDC035F	0.58	0.51	0.44	0.38	0.35	0.31	0.28	0.24	0.21	0.18	0.16	—
nanoSMDC050F/13.2	0.78	0.69	0.61	0.52	0.50	0.44	0.39	0.35	0.30	0.25	0.24	—
nanoSMDC075F	1.15	1.04	0.92	0.78	0.75	0.69	0.63	0.58	0.51	0.46	0.43	—

Table S2-B. Thermal Derating for Lead-free Surface-mount Devices [Hold Current (A) at Ambient Temperature (°C)] *continued*

	Maximum Ambient Temperature											
Part Number	**-40°C**	**-20°C**	**0°C**	**20°C**	**25°C**	**40°C**	**50°C**	**60°C**	**70°C**	**80°C**	**85°C**	**125°C**
nanoSMDC110F	1.64	1.46	1.30	1.10	1.06	0.92	0.83	0.80	0.65	0.56	0.52	—
nanoSMDC150F	2.20	1.99	1.77	1.55	1.50	1.34	1.23	1.10	1.01	0.90	0.84	—
Lead-free nanoSMDM Series Size 3216 mm/1206 mils												
nanoSMDM012F	0.19	0.17	0.15	0.13	0.125	0.11	0.10	0.09	0.08	0.07	0.07	—
nanoSMDM020F	0.30	0.27	0.24	0.21	0.20	0.18	0.16	0.14	0.12	0.11	0.10	—
nanoSMDM050F	0.76	0.68	0.59	0.52	0.50	0.44	0.40	0.35	0.32	0.28	0.26	—
nanoSMDM050F/13.2	0.76	0.68	0.59	0.52	0.50	0.44	0.40	0.35	0.32	0.28	0.26	—
nanoSMDM075F	1.11	1.00	0.85	0.78	0.75	0.67	0.61	0.52	0.50	0.44	0.42	—
nanoSMDM100F	1.49	1.34	1.15	1.04	1.00	0.89	0.81	0.70	0.66	0.58	0.55	—
Lead-free microSMD Series Size 3225 mm/1210 mils												
microSMD005F	0.08	0.07	0.06	0.05	0.05	0.04	0.04	0.03	0.03	0.02	0.02	—
microSMD010F	0.15	0.13	0.12	0.10	0.10	0.09	0.08	0.07	0.06	0.05	0.05	—
microSMD035F	0.51	0.46	0.40	0.35	0.34	0.30	0.27	0.24	0.22	0.19	0.18	—
microSMD050F	0.76	0.66	0.58	0.50	0.48	0.42	0.38	0.35	0.29	0.25	0.23	—
microSMD075F	1.10	0.97	0.86	0.75	0.72	0.64	0.58	0.55	0.47	0.42	0.39	—
microSMD110F	1.60	1.42	1.26	1.11	1.06	0.94	0.86	0.80	0.70	0.62	0.58	—
microSMD150F	2.30	2.02	1.76	1.50	1.43	1.24	1.11	1.00	0.85	0.72	0.65	—
Lead-free miniSMDC Series Size 4532 mm/1812 mils												
miniSMDC014F	0.23	0.20	0.17	0.14	0.13	0.11	0.10	0.09	0.07	0.06	0.05	—
miniSMDC020F	0.30	0.27	0.23	0.20	0.19	0.17	0.15	0.13	0.12	0.10	0.09	—
miniSMDC050F	0.59	0.57	0.55	0.50	0.48	0.45	0.43	0.35	0.30	0.25	0.23	—
miniSMDC075F	1.10	0.99	0.87	0.75	0.72	0.63	0.57	0.49	0.45	0.39	0.35	—
miniSMDC110F	1.60	1.45	1.28	1.10	1.07	0.92	0.83	0.71	0.66	0.57	0.52	—
miniSMDC110F/16	1.68	1.49	1.30	1.10	1.05	0.92	0.83	0.75	0.64	0.55	0.50	—
miniSMDC125F	2.00	1.69	1.47	1.25	1.17	1.03	0.92	0.90	0.69	0.58	0.53	—
miniSMDC125F/16	2.00	1.69	1.47	1.25	1.17	1.03	0.92	0.90	0.69	0.58	0.53	—
miniSMDC150F	2.30	2.05	1.77	1.50	1.44	1.23	1.09	0.95	0.82	0.68	0.61	—
miniSMDC160F	2.50	2.19	1.89	1.60	1.53	1.31	1.16	1.10	0.95	0.79	0.71	—
miniSMDC200F	2.60	2.44	2.22	2.00	1.96	1.78	1.67	1.50	1.45	1.34	1.29	—
miniSMDC260F	3.40	3.16	2.90	2.60	2.54	2.32	2.18	2.00	1.90	1.76	1.69	—
miniSMDC260F/12	3.40	3.16	2.90	2.60	2.54	2.32	2.18	2.00	1.90	1.76	1.69	—
Lead-free miniSMDM Series Size 4532 mm/1812 mils												
miniSMDM075F/24	1.11	1.00	0.85	0.78	0.75	0.67	0.61	0.52	0.50	0.44	0.42	—
miniSMDM110F	1.58	1.43	1.20	1.14	1.10	0.98	0.92	0.77	0.73	0.70	0.66	—
miniSMDM110F/16	1.61	1.46	1.25	1.14	1.10	0.98	0.90	0.78	0.74	0.66	0.62	—
miniSMDM200F	2.88	2.61	2.25	2.07	2.00	1.80	1.66	1.45	1.39	1.26	1.19	—
miniSMDM260F	3.70	3.36	2.90	2.68	2.60	2.35	2.18	1.90	1.84	1.67	1.59	—
Lead-free SMD Series Size 7555 mm/2920 mils												
SMD030F	0.44	0.39	0.32	0.30	0.28	0.26	0.23	0.19	0.18	0.17	0.15	—
SMD075F	1.11	0.99	0.84	0.75	0.71	0.63	0.57	0.49	0.45	0.39	0.36	—
SMD100F/33	1.48	1.35	1.20	1.10	1.06	0.98	0.91	0.83	0.79	0.73	0.69	—
Lead-free SMD2 Series Size 8763 mm/3425 mils												
SMD150F/33	2.30	2.04	1.80	1.50	1.45	1.23	1.10	0.99	0.83	0.70	0.63	—
SMD250F	3.72	3.31	2.80	2.50	2.35	2.09	1.89	1.60	1.48	1.28	1.18	—

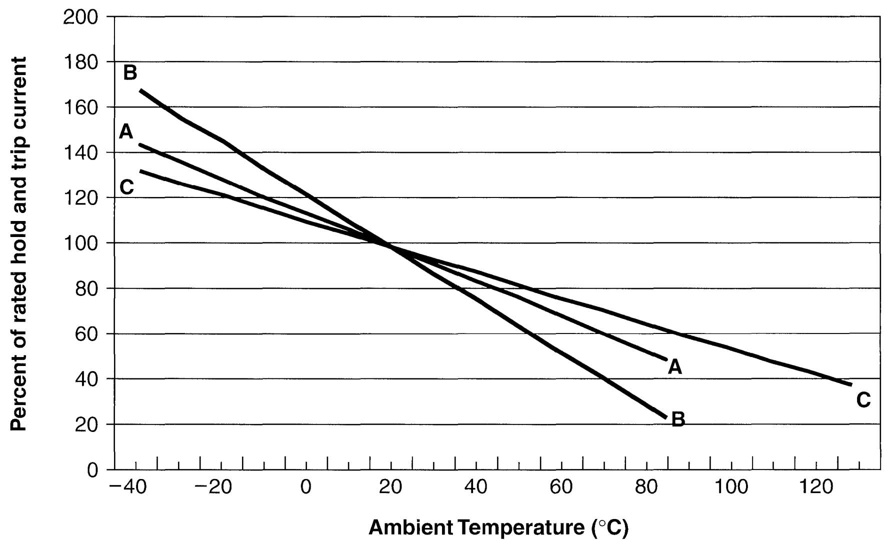
Thermal Derating Curves for Surface-mount Devices*

A = nanoSMD/microSMD/miniSMD & SMD

B = miniSMDE190

C = SMDH160

Figure S1. Thermal Derating Curve



*Refer to Telecom and Networking section for thermal derating of Telecom parts.

Table S3-A. Electrical Characteristics for Surface-mount Devices at 20°C

Part Number	I_H (A)	I_T (A)	V_{MAX} (V_{DC})	I_{MAX} (A)	$P_{D\,TYP}$ (W)	Max. Time-to-Trip (A)	Max. Time-to-Trip (s)	R_{MIN} Ω	R_{TYP} Ω	$R_{1\,MAX}$ Ω	Figure for Dimensions
nanoSMDC Series Size 3216 mm / 1206 mils											
nanoSMDC150†	1.50	3.00	6	40	0.6	8.0	0.30	0.04	0.080	0.110	S3
Lead-free devices are listed in Table S3-B											
nanoSMDM Series Size 3216 mm / 1206 mils											
nanoSMDM012†	0.125	0.29	30	10	0.4	1.0	0.20	1.50	4.5	6.000	S2
nanoSMDM016†	0.16	0.37	30	10	0.4	1.0	0.30	1.20	3.5	4.500	S2
nanoSMDM050†	0.50	1.00	6	40	0.4	8.0	0.10	0.15	0.400	0.700	S2
nanoSMDM075†	0.75	1.50	6	40	0.4	8.0	0.20	0.10	0.200	0.290	S2
nanoSMDM100†	1.00	1.80	6	40	0.4	8.0	0.30	0.06	0.150	0.210	S2
Lead-free devices are listed in Table S3-B											
microSMD Series Size 3225 mm / 1210 mils											
microSMD005	0.05	0.15	30	10	0.6	0.25	1.5	3.60	25.00	50.000	S4
microSMD010	0.10	0.25	30	10	0.6	0.5	1.0	2.10	9.00	15.000	S3
microSMD035	0.35	0.75	6	40	0.6	8.0	0.2	0.32	0.81	1.300	S3
microSMD050	0.50	1.00	13.2	40	0.6	5.0	0.1	0.25	0.55	0.900	S3
microSMD075	0.75	1.50	6	40	0.6	8.0	0.1	0.11	0.29	0.400	S3
microSMD110	1.10	2.20	6	40	0.6	5.0	1.0	0.07	0.14	0.210	S3
microSMD150	1.50	3.00	6	40	0.6	5.0	5.0	0.04	0.07	0.110	S3
Lead-free devices are listed in Table S3-B											
miniSMDC Series Size 4532 mm / 1812 mils											
miniSMDC014	0.14	0.34	60	10	0.6	1.5	0.15	1.500	4.000	6.000	S3
miniSMDC020	0.20	0.40	30	10	0.6	8.0	0.02	0.600	2.900	3.300	S3
miniSMDC050	0.50	1.00	24	40	0.6	8.0	0.15	0.150	0.600	1.000	S3
miniSMDC075	0.75	1.50	13.2	40	0.6	8.0	0.20	0.110	0.260	0.450	S3
miniSMDC110	1.10	2.20	8	40	0.6	8.0	0.30	0.040	0.120	0.210	S3
miniSMDC125	1.25	2.50	6	40	0.6	8.0	0.40	0.050	0.090	0.140	S3
miniSMDC150	1.50	3.00	6	40	0.6	8.0	0.50	0.040	0.070	0.110	S3
miniSMDC200	2.00	4.00	6	40	0.6	8.0	5.00	0.020	0.050	0.070	S3
miniSMDC260	2.60	5.00	6	40	0.6	8.0	7.00	0.015	0.035	0.047	S3
Lead-free devices are listed in Table S3-B											
miniSMDM Series Size 4532 mm / 1812 mils											
miniSMDM075†	0.75	1.50	13.2	40	0.5	8.0	0.20	0.100	0.230	0.290	S2
miniSMDM075/24†	0.75	1.50	24	40	0.6	8.0	0.30	0.090	0.200	0.290	S5
miniSMDM110†	1.10	2.00	8	40	0.5	8.0	0.30	0.060	0.140	0.180	S2
miniSMDM110/16†	1.10	1.95	16	40	0.6	8.0	0.50	0.060	0.120	0.180	S5
miniSMDM150/24	1.50	3.00	24	20	0.6	8.0	1.50	0.040	—	0.120	S5
miniSMDM160†	1.60	2.80	8	40	0.6	8.0	2.00	0.033	0.066	0.099	S5
miniSMDM200†	2.00	3.50	8	40	0.6	8.0	3.00	0.020	0.040	0.060	S5
miniSMDM260†	2.60	4.55	6	40	0.6	8.0	6.00	0.010	0.030	0.043	S5
Lead-free devices are listed in Table S3-B											
miniSMDE Series Size 11550 mm / 4420 mils											
miniSMDE190	1.90	3.80	16	100	1.4	10	2.0	0.024	0.065	0.08	S3
Lead-free devices are listed in Table S3-B											

†Electrical characteristics determined at 25°C.

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Table S3-A. Electrical Characteristics for Surface-mount Devices at 20°C *continued*

Part Number	I_H (A)	I_T (A)	V_{MAX} (V_{DC})	I_{MAX} (A)	$P_{D\,TYP}$ (W)	Max. Time-to-Trip (A)	Max. Time-to-Trip (s)	R_{MIN} Ω	R_{TYP} Ω	$R_{1\,MAX}$ Ω	Figure for Dimensions
midSMD Size 5050 mm/2018 mils											
SMD030-2018	0.30	0.80	60	20	0.7	1.5	1.5	0.500	1.40	2.300	S6
SMD050-2018	0.55	1.20	57	10	1.0	2.5	5.0	0.200	—	1.000	S6
SMD100-2018	1.10	2.20	15	40	1.2	8.0	0.5	0.100	0.25	0.400	S6
SMD150-2018	1.50	3.00	15	40	1.4	8.0	1.0	0.070	0.13	0.180	S6
SMD200-2018	2.00	4.20	6	40	1.4	8.0	3.0	0.048	0.07	0.100	S6
SMD Size 7555 mm/2920 mils											
SMD030	0.30	0.60	60	10	1.5	1.5	3.0	1.200	3.00	4.800	S7
SMD050	0.50	1.00	60	10	1.5	2.5	4.0	0.350	0.87	1.400	S7
SMD075	0.75	1.50	30	40	1.5	8.0	0.3	0.350	0.67	1.000	S7
SMD100	1.10	2.20	30	40	1.5	8.0	0.5	0.120	0.30	0.480	S7
SMD100/33	1.10	2.20	33	40	1.5	8.0	0.5	0.120	0.27	0.410	S7
SMD125	1.25	2.50	15	40	1.5	8.0	2.0	0.070	0.16	0.250	S7
SMD260	2.60	5.20	6	40	1.5	8.0	20.0	0.025	0.05	0.075	S7
SMD260-RB	2.60	5.00	6	40	1.5	5.0	60.0	0.030	0.055	0.075	S7
SMD300	3.00	6.00	6	40	1.3	8.0	35.0	0.015	0.033	0.048	S7
Lead-free devices are listed in Table S3-B											
SMD2 Size 8763 mm/3425 mils											
SMD150	1.50	3.00	15	40	1.7	8.0	5.0	0.060	0.16	0.250	S7
SMD150/33	1.50	3.00	33	40	1.7	8.0	5.0	0.080	0.15	0.230	S7
SMDH160	1.60	3.20	16	70	2.1	8.0	15.0	0.050	0.10	0.150	S7
SMD185	1.80	3.60	33	40	1.2	8.0	5.0	0.065	0.12	0.165	S7
SMD200	2.00	4.00	15	40	1.7	8.0	12.0	0.050	0.09	0.125	S7
SMD250	2.50	5.00	15	40	1.7	8.0	25.0	0.035	0.06	0.085	S7
Lead-free devices are listed in Table S3-B											

Part Number	I_H (A)	I_T (A)	V_{MAX} (V_{RMS})	I_{MAX} (A)	$P_{D\,TYP}$ (W)	Max. Time-to-Trip (A)	Max. Time-to-Trip (s)	R_{MIN} Ω	R_{TYP} Ω	$R_{1\,MAX}$ Ω	Figure for Dimensions
Telecom Surface-mount											
TSL250-080	0.080	0.16	250	3.0	1.2	1.0	0.8	5.0	11.0	20.0	S7
TS250-130	0.130	0.26	250	3.0	1.1	1.0	0.9	6.5	12.0	20.0	S8
	—	—	650	1.1	—	—	—	—	—	—	—
TSV250-130	0.130	0.26	250	3.0	1.5	1.0	2.0	4.0	7.0	12.0	S10
TS600-170	0.170	0.40	600	3.0	2.5	1.0	10.0	4.0	9.0	18.0	S9
TS600-200-RA	0.200	0.40	600	3.0	2.5	1.0	12.0	4.0	7.5	13.5	S9
TSM600-250	0.250	0.86	600	3.0	2.0	3.0	8.0	1.0	3.5	7.0	—

Table S3-B. Electrical Characteristics for Lead-free Surface-mount Devices at 20°C

Part Number	I_H (A)	I_T (A)	V_{MAX} (V_{DC})	I_{MAX} (A)	$P_{D\ TYP}$ (W)	Max. Time-to-Trip (A)	Max. Time-to-Trip (s)	R_{MIN} Ω	R_{TYP} Ω	$R_{1\ MAX}$ Ω	Figure for Dimensions
Lead-free nanoSMDC Series Size 3216 mm/1206 mils											
nanoSMDC020F†	0.20	0.42	24	100	0.6	8.0	0.10	0.65	—	2.600	S3
nanoSMDC035F†	0.35	0.75	16	20	0.6	3.5	0.10	0.45	—	1.400	S3
nanoSMDC050F/13.2†	0.50	1.10	13.2	40	0.6	8.0	0.10	0.20	—	0.800	S3
nanoSMDC075F†	0.75	1.50	6	40	0.6	8.0	0.10	0.12	—	0.400	S3
nanoSMDC110F	1.10	2.20	6	40	0.6	8.0	0.10	0.07	—	0.200	S3
nanoSMDC150F†	1.50	3.00	6	40	0.6	8.0	0.30	0.04	0.080	0.110	S3
Lead-free nanoSMDM Series Size 3216 mm/1206 mils											
nanoSMDM012F†	0.125	0.29	30	10	0.4	1.0	0.20	1.50	4.5	6.000	S2
nanoSMDM020F†	0.20	0.46	24	10	0.4	1.0	0.60	0.65	—	2.600	S2
nanoSMDM050F†	0.50	1.00	6	40	0.4	8.0	0.10	0.15	0.400	0.700	S2
nanoSMDM050F/13.2†	0.50	1.00	13.2	40	0.4	8.0	0.10	0.15	0.400	0.700	S2
nanoSMDM075F†	0.75	1.50	6	40	0.4	8.0	0.20	0.10	0.200	0.290	S2
nanoSMDM100F†	1.00	1.80	6	40	0.4	8.0	0.30	0.06	0.150	0.210	S2
Lead-free microSMD Series Size 3225 mm/1210 mils											
microSMD005F	0.05	0.15	30	10	0.6	0.25	1.5	3.60	25.00	50.000	S4
microSMD010F	0.10	0.25	30	10	0.6	0.5	1.0	2.10	9.00	15.000	S3
microSMD035F	0.35	0.75	6	40	0.6	8.0	0.2	0.33	0.81	1.300	S3
microSMD050F	0.50	1.00	13.2	40	0.6	5.0	0.1	0.25	0.55	0.900	S3
microSMD075F	0.75	1.50	6	40	0.6	8.0	0.1	0.11	0.29	0.400	S3
microSMD110F	1.10	2.20	6	40	0.6	5.0	1.0	0.07	0.14	0.210	S3
microSMD150F	1.50	3.00	6	40	0.6	5.0	5.0	0.04	0.07	0.110	S3
Lead-free miniSMDC Series Size 4532 mm/1812 mils											
miniSMDC014F	0.14	0.34	60	10	0.6	1.5	0.15	1.500	4.000	6.000	S3
miniSMDC020F	0.20	0.40	30	10	0.6	8.0	0.02	0.600	2.900	3.300	S3
miniSMDC050F	0.50	1.00	24	100	0.6	8.0	0.15	0.150	0.600	1.000	S3
miniSMDC075F	0.75	1.50	13.2	100	0.6	8.0	0.20	0.110	0.260	0.450	S3
miniSMDC110F	1.10	2.20	8	100	0.6	8.0	0.30	0.040	0.120	0.210	S3
miniSMDC110F/16	1.10	2.20	16	100	0.3	8.0	0.30	0.060	—	0.180	S3
miniSMDC125F	1.25	2.50	6	100	0.6	8.0	0.40	0.050	0.090	0.140	S3
miniSMDC125F/16	1.25	2.50	16	100	0.6	8.0	0.40	0.050	0.090	0.140	S3
miniSMDC150F	1.50	3.00	6	100	0.6	8.0	0.50	0.040	0.070	0.110	S3
miniSMDC160F	1.60	3.20	6	100	0.6	8.0	1.00	0.030	0.078	0.100	S3
miniSMDC200F	2.00	4.00	6	100	0.6	8.0	5.00	0.020	0.050	0.070	S3
miniSMDC260F	2.60	5.00	6	100	0.6	8.0	7.00	0.015	0.035	0.047	S3
miniSMDC260F/12	2.60	5.00	12	100	0.6	8.0	5.00	0.015	0.035	0.047	S3
Lead-free miniSMDM Series Size 4532 mm/1812 mils											
miniSMDM075F/24†	0.75	1.50	24	40	0.6	8.0	0.30	0.090	0.200	0.290	S5
miniSMDM110F†	1.10	2.00	8	40	0.5	8.0	0.30	0.060	0.140	0.180	S2
miniSMDM110F/16†	1.10	1.95	16	40	0.6	8.0	0.50	0.060	0.120	0.180	S2
miniSMDM200F†	2.00	3.50	8	40	0.6	8.0	3.00	0.020	0.040	0.060	S5
miniSMDM260F†	2.60	4.55	6	40	0.6	8.0	6.00	0.010	0.030	0.043	S5
Lead-free midSMD Series Size 5050 mm/2018 mils											
SMD030F-2018	0.30	0.80	60	20	0.9	1.5	1.50	0.500	1.400	2.300	S6
SMD100F-2018	1.10	2.20	15	40	1.2	8.0	0.50	0.100	0.250	0.400	S6

†Electrical characteristics determined at 25°C.

Table S3-B. Electrical Characteristics for Lead-free Surface-mount Devices at 20°C *continued*

Part Number	I_H (A)	I_T (A)	V_{MAX} (V_{DC})	I_{MAX} (A)	$P_{D\,TYP}$ (W)	Max. Time-to-Trip (A)	Max. Time-to-Trip (s)	R_{MIN} Ω	R_{TYP} Ω	$R_{1\,MAX}$ Ω	Figure for Dimensions
SMD150F-2018	1.50	3.00	15	40	1.4	8.0	1.00	0.070	0.130	0.180	S6
SMD200F-2018	2.00	4.20	6	40	1.4	8.0	3.00	0.048	0.700	0.100	S6
Lead-free SMD Series Size 7555 mm/2920 mils											
SMD030F	0.30	0.60	60	10	1.5	1.5	3.0	1.200	3.00	4.800	S7
SMD050F	0.50	1.00	60	10	1.5	2.5	4.0	0.350	0.87	1.400	S7
SMD075F	0.75	1.50	30	40	1.5	8.0	0.3	0.350	0.67	1.000	S7
SMD075F/60	0.75	1.50	60	10	1.5	8.0	0.3	0.350	0.67	1.000	S7
SMD100F	1.10	2.20	30	40	1.5	8.0	0.5	0.120	0.30	0.480	S7
SMD100F/33	1.10	2.20	33	40	1.5	8.0	0.5	0.120	0.27	0.410	S7
SMD125F	1.25	2.50	15	40	1.5	8.0	2.0	0.070	0.16	0.250	S7
SMD260F	2.60	5.20	6	40	1.5	8.0	20.0	0.025	0.05	0.075	S7
SMD300F	3.00	5.00	6	40	1.3	8.0	35.0	0.015	0.033	0.048	S7
Lead-free SMD2 Devices Size 8763 mm/3425 mils											
SMD150F	1.50	3.00	15	40	1.7	8.0	5.0	0.060	0.16	0.250	S7
SMD150F/33	1.50	3.00	33	40	1.7	8.0	5.0	0.080	0.15	0.230	S7
SMD185F	1.80	3.60	33	40	1.2	8.0	5.0	0.065	0.12	0.165	S7
SMD200F	2.00	4.00	15	40	1.7	8.0	12.0	0.050	0.09	0.125	S7
SMD250F	2.50	5.00	15	40	1.7	8.0	25.0	0.035	0.06	0.085	S7

Figures S2–S10. Physical Description for Dimensions for Surface-mount Devices

Figure S2

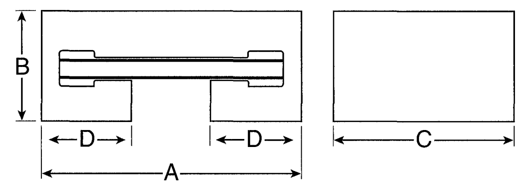


Figure S3

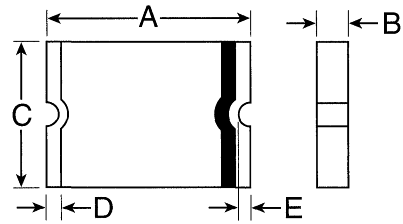


Figure S4

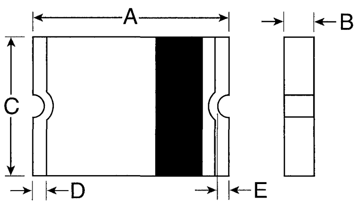


Figure S5

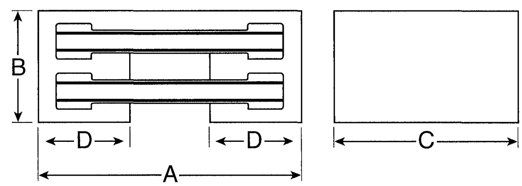


Figure S6

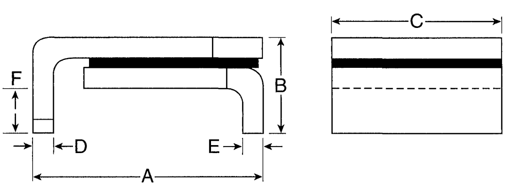


Figure S7

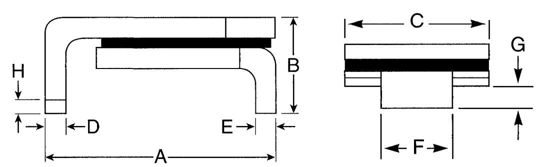


Figure S8

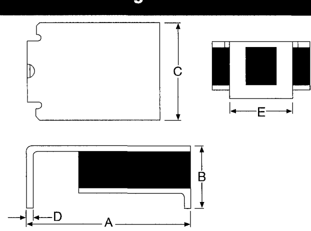


Figure S9

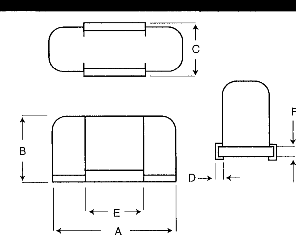


Figure S10

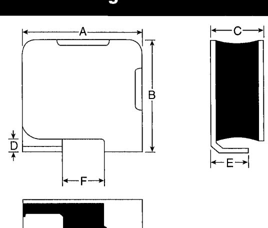


Table S4-A. Dimensions for Surface-mount Devices in Millimeters (Inches)

Part Number	Dimension A Min.	A Max.	B Min.	B Max.	C Min.	C Max.	D Min.	D Max.	E Min.	E Max.	F Min.	F Max.	G Min	G Max.	H Min.	Figure
nanoSMDC Series Size 3216 mm/1206 mils																
nanoSMDC150	3.0 (0.118)	3.4 (0.134)	0.85 (0.033)	1.4 (0.055)	1.37 (0.054)	1.8 (0.071)	0.25 (0.010)	—	0.076 (0.003)	—	—	—	—	—	—	S3
Lead-free devices are listed in Table S4-B																
nanoSMDM Series Size 3216 mm/1206 mils																
nanoSMDM012	3.0 (0.118)	3.4 (0.134)	0.8 (0.032)	1.2 (0.047)	1.4 (0.055)	1.8 (0.071)	0.75 (0.030)	1.05 (0.041)	—	—	—	—	—	—	—	S2
nanoSMDM016	3.0 (0.118)	3.4 (0.134)	0.8 (0.032)	1.2 (0.047)	1.4 (0.055)	1.8 (0.071)	0.75 (0.030)	1.05 (0.041)	—	—	—	—	—	—	—	S2
nanoSMDM050	3.0 (0.118)	3.4 (0.134)	0.8 (0.032)	1.2 (0.047)	1.4 (0.055)	1.8 (0.071)	0.75 (0.030)	1.05 (0.041)	—	—	—	—	—	—	—	S2
nanoSMDM075	3.0 (0.118)	3.4 (0.134)	0.8 (0.032)	1.2 (0.047)	1.4 (0.055)	1.8 (0.071)	0.75 (0.030)	1.05 (0.041)	—	—	—	—	—	—	—	S2
nanoSMDM100	3.0 (0.118)	3.4 (0.134)	0.8 (0.032)	1.2 (0.047)	1.4 (0.055)	1.8 (0.071)	0.75 (0.030)	1.05 (0.041)	—	—	—	—	—	—	—	S2
Lead-free devices are listed in Table S4-B																
microSMD Series Size 3225 mm/1210 mils																
microSMD005	3.00 (0.118)	3.43 (0.135)	0.50 (0.019)	0.85 (0.034)	2.35 (0.092)	2.80 (0.110)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S4
microSMD010	3.00 (0.118)	3.43 (0.135)	0.50 (0.019)	0.85 (0.034)	2.35 (0.092)	2.80 (0.110)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
microSMD035	3.00 (0.118)	3.43 (0.135)	0.38 (0.015)	0.62 (0.025)	2.35 (0.092)	2.80 (0.110)	0.30 (0.012)	—	0.25 (0.010)	—	—	—	—	—	—	S3
microSMD050	3.00 (0.118)	3.43 (0.135)	0.38 (0.015)	0.62 (0.025)	2.35 (0.092)	2.80 (0.110)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
microSMD075	3.00 (0.118)	3.43 (0.135)	0.38 (0.015)	0.62 (0.025)	2.35 (0.092)	2.80 (0.110)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
microSMD110	3.00 (0.118)	3.43 (0.135)	0.28 (0.011)	0.48 (0.019)	2.35 (0.092)	2.80 (0.110)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
microSMD150	3.00 (0.118)	3.43 (0.135)	0.51 (0.020)	1.22 (0.048)	2.35 (0.092)	2.80 (0.110)	0.30 (0.012)	—	0.25 (0.010)	—	—	—	—	—	—	S3
Lead-free devices are listed in Table S4-B																
miniSMDC Series Size 4532 mm/1812 mils																
miniSMDC014	4.37 (0.172)	4.73 (0.186)	0.635 (0.025)	0.89 (0.035)	3.07 (0.121)	3.41 (0.134)	0.30 (0.012)	—	0.20 (0.008)	—	—	—	—	—	—	S3
mniSMDC020	4.37 (0.172)	4.73 (0.186)	0.635 (0.025)	0.89 (0.035)	3.07 (0.121)	3.41 (0.134)	0.30 (0.012)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC050	4.37 (0.172)	4.73 (0.186)	0.38 (0.015)	0.62 (0.025)	3.07 (0.121)	3.41 (0.134)	0.30 (0.012)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC075	4.37 (0.172)	4.73 (0.186)	0.38 (0.015)	0.62 (0.025)	3.07 (0.121)	3.41 (0.134)	0.30 (0.012)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC110	4.37 (0.172)	4.73 (0.186)	0.38 (0.015)	0.62 (0.025)	3.07 (0.121)	3.41 (0.134)	0.30 (0.012)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC125	4.37 (0.172)	4.73 (0.186)	0.28 (0.011)	0.48 (0.019)	3.07 (0.121)	3.41 (0.134)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC150	4.37 (0.172)	4.73 (0.186)	0.28 (0.011)	0.48 (0.019)	3.07 (0.121)	3.41 (0.134)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC200	4.37 (0.172)	4.73 (0.186)	0.51 (0.020)	1.22 (0.048)	3.07 (0.121)	3.41 (0.134)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC260	4.37 (0.172)	4.73 (0.186)	0.76 (0.030)	1.25 (0.050)	3.07 (0.121)	3.41 (0.134)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
Lead-free devices are listed in Table S4-B																
miniSMDM Series Size 4532 mm/1812 mils																
miniSMDM075	4.35 (0.172)	4.75 (0.187)	1.75 (0.069)	2.00 (0.079)	3.05 (0.120)	3.60 (0.142)	1.4 (0.055)	1.7 (0.067)	—	—	—	—	—	—	—	S2
miniSMDM075/24	4.35 (0.172)	4.75 (0.187)	1.75 (0.069)	2.00 (0.079)	3.05 (0.120)	3.60 (0.142)	1.4 (0.055)	1.7 (0.067)	—	—	—	—	—	—	—	S5
Lead-free devices are listed in Table S4-B																

Table S4. Dimensions for Surface-mount Devices in Millimeters (Inches) *continued*

Part Number	Dimension A Min.	A Max.	B Min.	B Max.	C Min.	C Max.	D Min.	D Max.	E Min.	E Max.	F Min.	F Max.	G Min	G Max.	H Min.	Figure
miniSMDM Series Size 4532 mm/1812 mils *continued*																
miniSMDM110	4.35	4.75	1.75	2.00	3.05	3.60	1.4	1.7	—	—	—	—	—	—	—	S2
	(0.172)	(0.187)	(0.069)	(0.079)	(0.120)	(0.142)	(0.055)	(0.067)	—	—	—	—	—	—	—	
miniSMDM110/16	4.35	4.75	1.75	2.00	3.05	3.60	1.4	1.7	—	—	—	—	—	—	—	S5
	(0.172)	(0.187)	(0.069)	(0.079)	(0.120)	(0.142)	(0.055)	(0.067)	—	—	—	—	—	—	—	
miniSMDM150/24	4.35	4.75	1.75	2.00	3.05	3.60	1.4	1.7	—	—	—	—	—	—	—	S5
	(0.172)	(0.187)	(0.069)	(0.079)	(0.120)	(0.142)	(0.055)	(0.067)	—	—	—	—	—	—	—	
miniSMDM160	4.35	4.75	1.75	2.00	3.05	3.60	1.4	1.7	—	—	—	—	—	—	—	S5
	(0.172)	(0.187)	(0.069)	(0.079)	(0.120)	(0.142)	(0.055)	(0.067)	—	—	—	—	—	—	—	
miniSMDM200	4.35	4.75	1.75	2.00	3.05	3.60	1.4	1.7	—	—	—	—	—	—	—	S5
	(0.172)	(0.187)	(0.069)	(0.079)	(0.120)	(0.142)	(0.055)	(0.067)	—	—	—	—	—	—	—	
miniSMDM260	4.35	4.75	1.75	2.00	3.05	3.60	1.4	1.7	—	—	—	—	—	—	—	S5
	(0.172)	(0.187)	(0.069)	(0.079)	(0.120)	(0.142)	(0.055)	(0.067)	—	—	—	—	—	—	—	
Lead-free devices are listed in Table S4-B																
miniSMDE Series Size 11550 mm/4420 mils																
miniSMDE190	11.15	11.51	0.33	0.53	4.83	5.33	0.51	1.02	3.81	—	—	—	—	—	—	S3
	(0.439)	(0.453)	(0.013)	(0.021)	(0.190)	(0.210)	(0.020)	(0.040)	(0.015)	—	—	—	—	—	—	
midSMD Size 5050 mm/2018 mils																
SMD030-2018	4.72	5.44	—	1.78	4.22	4.93	0.25	0.36	0.25	0.36	0.30	0.46	—	—	—	S6
	(0.186)	(0.214)	—	(0.070)	(0.166)	(0.194)	(0.010)	(0.014)	(0.010)	(0.014)	(0.012)	(0.018)	—	—	—	
SMD050-2018	4.72	5.44	—	1.78	4.22	4.93	0.25	0.36	0.25	0.36	0.30	0.46	—	—	—	S6
	(0.186)	(0.214)	—	(0.070)	(0.166)	(0.194)	(0.010)	(0.014)	(0.010)	(0.014)	(0.012)	(0.018)	—	—	—	
SMD100-2018	4.72	5.44	—	1.52	4.22	4.93	0.25	0.36	0.25	0.36	0.30	0.46	—	—	—	S6
	(0.186)	(0.214)	—	(0.060)	(0.166)	(0.194)	(0.010)	(0.014)	(0.010)	(0.014)	(0.012)	(0.018)	—	—	—	
SMD150-2018	4.72	5.44	—	1.52	4.22	4.93	0.25	0.36	0.25	0.36	0.30	0.46	—	—	—	S6
	(0.186)	(0.214)	—	(0.060)	(0.166)	(0.194)	(0.010)	(0.014)	(0.010)	(0.014)	(0.012)	(0.018)	—	—	—	
SMD200-2018	4.72	5.44	—	1.52	4.22	4.93	0.25	0.36	0.25	0.36	0.30	0.46	—	—	—	S6
	(0.186)	(0.214)	—	(0.060)	(0.166)	(0.194)	(0.010)	(0.014)	(0.010)	(0.014)	(0.012)	(0.018)	—	—	—	
SMD Size 7555 mm/2920 mils																
SMD030	6.73	7.98	—	3.18	4.8	5.44	0.56	0.71	0.56	0.71	2.16	2.41	0.66	1.37	0.43	S7
	(0.265)	(0.314)	—	(0.125)	(0.19)	(0.214)	(0.022)	(0.028)	(0.022)	(0.028)	(0.085)	(0.095)	(0.026)	(0.054)	(0.017)	
SMD050	6.73	7.98	—	3.18	4.8	5.44	0.56	0.71	0.20	0.30	2.16	2.41	0.66	1.37	0.43	S7
	(0.265)	(0.314)	—	(0.125)	(0.19)	(0.214)	(0.022)	(0.028)	(0.008)	(0.012)	(0.085)	(0.095)	(0.026)	(0.054)	(0.017)	
SMD075	6.73	7.98	—	3.18	4.8	5.44	0.56	0.71	0.56	0.71	2.16	2.41	0.66	1.37	0.43	S7
	(0.265)	(0.314)	—	(0.125)	(0.19)	(0.214)	(0.022)	(0.028)	(0.022)	(0.028)	(0.085)	(0.095)	(0.026)	(0.054)	(0.017)	
SMD100	6.73	7.98	—	3.00	4.8	5.44	0.56	0.71	0.56	0.71	2.16	2.41	0.66	1.37	0.43	S7
	(0.265)	(0.314)	—	(0.118)	(0.19)	(0.214)	(0.022)	(0.028)	(0.022)	(0.028)	(0.085)	(0.095)	(0.026)	(0.054)	(0.017)	
SMD100/33	6.73	7.98	—	3.00	4.8	5.44	0.56	0.71	0.56	0.71	2.16	2.41	0.66	1.37	0.43	S7
	(0.265)	(0.314)	—	(0.118)	(0.19)	(0.214)	(0.022)	(0.028)	(0.022)	(0.028)	(0.085)	(0.095)	(0.026)	(0.054)	(0.017)	
SMD125	6.73	7.98	—	3.00	4.8	5.44	0.56	0.71	0.56	0.71	2.16	2.41	0.66	1.37	0.43	S7
	(0.265)	(0.314)	—	(0.118)	(0.19)	(0.214)	(0.022)	(0.028)	(0.022)	(0.028)	(0.085)	(0.095)	(0.026)	(0.054)	(0.017)	
SMD260	6.73	7.98	—	3.00	4.8	5.44	0.56	0.71	0.56	0.71	2.16	2.41	0.66	1.37	0.43	S7
	(0.265)	(0.314)	—	(0.118)	(0.19)	(0.214)	(0.022)	(0.028)	(0.022)	(0.028)	(0.085)	(0.095)	(0.026)	(0.054)	(0.017)	
SMD260-RB	6.73	7.98	—	3.00	4.8	5.44	0.56	0.71	0.56	0.71	2.16	2.41	0.66	1.37	0.43	S7
	(0.265)	(0.314)	—	(0.118)	(0.19)	(0.214)	(0.022)	(0.028)	(0.022)	(0.028)	(0.085)	(0.095)	(0.026)	(0.054)	(0.017)	
SMD300	6.73	7.98	—	3.00	4.8	5.44	0.56	0.71	0.56	0.71	2.16	2.41	0.66	1.37	0.43	S7
	(0.265)	(0.314)	—	(0.118)	(0.19)	(0.214)	(0.022)	(0.028)	(0.022)	(0.028)	(0.085)	(0.095)	(0.026)	(0.054)	(0.017)	
Lead-free devices are listed in Table S4-B																
SMD2 Size 8763 mm/3425 mils																
SMD150	8.00	9.40	—	3.00	6.0	6.71	0.56	0.71	0.56	0.71	3.68	3.94	0.66	1.37	0.43	S7
	(0.315)	(0.370)	—	(0.118)	(0.236)	(0.264)	(0.022)	(0.028)	(0.022)	(0.028)	(0.145)	(0.155)	(0.026)	(0.054)	(0.017)	
SMD150/33	8.00	9.40	—	3.00	6.0	6.71	0.56	0.71	0.56	0.71	3.68	3.94	0.66	1.37	0.43	S7
	(0.315)	(0.370)	—	(0.118)	(0.236)	(0.264)	(0.022)	(0.028)	(0.022)	(0.028)	(0.145)	(0.155)	(0.026)	(0.054)	(0.017)	
SMDH160	8.00	9.40	—	3.00	6.0	6.71	0.56	0.71	0.56	0.71	3.68	3.94	0.66	1.37	0.43	S7
	(0.315)	(0.370)	—	(0.118)	(0.236)	(0.264)	(0.022)	(0.028)	(0.022)	(0.028)	(0.145)	(0.155)	(0.026)	(0.054)	(0.017)	
SMD185	8.00	9.40	—	3.00	6.0	6.71	0.56	0.71	0.56	0.71	3.68	3.94	0.66	1.37	0.43	S7
	(0.315)	(0.370)	—	(0.118)	(0.236)	(0.264)	(0.022)	(0.028)	(0.022)	(0.028)	(0.145)	(0.155)	(0.026)	(0.054)	(0.017)	

Lead-free devices are listed in Table S4-B

Table S4-A. Dimensions for Surface-mount Devices in Millimeters (Inches) *continued*

Part Number	A Min.	A Max.	B Min.	B Max.	C Min.	C Max.	D Min.	D Max.	E Min.	E Max.	F Min.	F Max.	G Min	G Max.	H Min.	Figure
SMD2																
Size 8763 mm/3425 mils *continued*																
SMD200	8.00 (0.315)	9.40 (0.370)	—	3.00 (0.118)	6.0 (0.236)	6.71 (0.264)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	3.68 (0.145)	3.94 (0.155)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	S7
SMD250	8.00 (0.315)	9.40 (0.370)	—	3.00 (0.118)	6.0 (0.236)	6.71 (0.264)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	3.68 (0.145)	3.94 (0.155)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	S7
Lead-free devices are listed in Table S4-B																
Telecom Surface-mount																
TSL250-080	6.7 (0.265)	7.9 (0.310)	2.7 (0.110)	3.7 (0.145)	4.8 (0.190)	5.3 (0.210)	0.2 (0.008)	0.4 (0.015)	2.5 (0.100)	3.1 (0.120)	—	—	—	—	—	S7
TS250-130	8.5 (0.335)	9.4 (0.370)	—	3.4 (0.135)	—	7.4 (0.290)	0.3 (0.011)	—	3.8 (0.150)	—	—	—	—	—	—	S8
TSV250-130	—	6.1 (0.240)	—	6.9 (0.270)	—	3.2 (0.126)	0.56 (0.022)	—	—	1.9 (0.075)	1.6 (0.065)	2.31 (0.091)	—	—	—	S10
TS600-170	18.2 (0.720)	19.4 (0.765)	11.5 (0.455)	12.3 (0.485)	7.2 (0.285)	8.3 (0.325)	1.6 (0.065)	2.4 (0.095)	9.9 (0.390)	10.4 (0.410)	1.5 (0.060)	2.3 (0.090)	—	—	—	S9
TS600-200-RA	18.2 (0.720)	19.4 (0.765)	11.5 (0.455)	12.3 (0.485)	7.2 (0.285)	8.3 (0.325)	1.6 (0.065)	2.4 (0.095)	9.9 (0.390)	10.4 (0.410)	1.5 (0.060)	2.3 (0.090)	—	—	—	S9
TSM600-250 —	— (0.69)	17.6 —	— (0.46)	11.7 —	— (0.44)	11.2 —	— (0.20)	5.2 —	— (0.11)	2.8 (0.02)	0.6 —	—	—	—	—	—
TSM600-250-RA	—	17.6 (0.69)	—	11.7 (0.46)	—	11.2 (0.44)	—	5.2 (0.20)	—	2.8 (0.11)	0.6 (0.02)	—	—	—	—	—

Table S4-B. Dimensions for Lead-free Surface-mount Devices in Millimeters (Inches)

Part Number	A Min.	A Max.	B Min.	B Max.	C Min.	C Max.	D Min.	D Max.	E Min.	E Max.	F Min.	F Max.	G Min	G Max.	H Min.	Figure
Lead-free nanoSMDC Series Size 3216 mm/1206 mils																
nanoSMDC020F	3.0 (0.118)	3.4 (0.134)	0.38 (0.015)	0.64 (0.025)	1.37 (0.054)	1.80 (0.071)	0.15 (0.006)	—	0.076 (0.003)	—	—	—	—	—	—	S3
nanoSMDC035F	3.0 (0.118)	3.4 (0.134)	0.38 (0.015)	0.64 (0.025)	1.37 (0.054)	1.80 (0.071)	0.15 (0.006)	—	0.076 (0.003)	—	—	—	—	—	—	S3
nanoSMDC050F/13.2	3.0 (0.118)	3.4 (0.134)	0.38 (0.015)	0.64 (0.025)	1.37 (0.054)	1.80 (0.071)	0.15 (0.006)	—	0.076 (0.003)	—	—	—	—	—	—	S3
nanoSMDC075F	3.0 (0.118)	3.4 (0.134)	0.25 (0.010)	0.38 (0.015)	1.37 (0.054)	1.80 (0.071)	0.15 (0.006)	—	0.076 (0.003)	—	—	—	—	—	—	S3
nanoSMDC110F	3.0 (0.118)	3.4 (0.134)	0.67 (0.026)	1.00 (0.039)	1.37 (0.054)	1.80 (0.071)	0.25 (0.010)	—	0.076 (0.003)	—	—	—	—	—	—	S3
nanoSMDC150F	3.0 (0.118)	3.4 (0.134)	0.85 (0.033)	1.40 (0.055)	1.37 (0.054)	1.80 (0.071)	0.25 (0.010)	—	0.076 (0.003)	—	—	—	—	—	—	S3
Lead-free nanoSMDM Series Size 3216 mm/1206 mils																
nanoSMDM012F	3.0 (0.118)	3.4 (0.134)	0.8 (0.032)	1.2 (0.047)	1.4 (0.055)	1.8 (0.071)	0.75 (0.030)	1.05 (0.041)	—	—	—	—	—	—	—	S2
nanoSMDM020F	3.0 (0.118)	3.4 (0.134)	0.8 (0.032)	1.2 (0.047)	1.4 (0.055)	1.8 (0.071)	0.75 (0.030)	1.05 (0.041)	—	—	—	—	—	—	—	S2
nanoSMDM050F	3.0 (0.118)	3.4 (0.134)	0.8 (0.032)	1.2 (0.047)	1.4 (0.055)	1.8 (0.071)	0.75 (0.030)	1.05 (0.041)	—	—	—	—	—	—	—	S2
nanoSMDM050F/13.2	3.0 (0.118)	3.4 (0.134)	0.8 (0.032)	1.2 (0.047)	1.4 (0.055)	1.8 (0.071)	0.75 (0.030)	1.05 (0.041)	—	—	—	—	—	—	—	S2
nanoSMDM075F	3.0 (0.118)	3.4 (0.134)	0.8 (0.032)	1.2 (0.047)	1.4 (0.055)	1.8 (0.071)	0.75 (0.030)	1.05 (0.041)	—	—	—	—	—	—	—	S2
nanoSMDM100F	3.0 (0.118)	3.4 (0.134)	0.8 (0.032)	1.2 (0.047)	1.4 (0.055)	1.8 (0.071)	0.75 (0.030)	1.05 (0.041)	—	—	—	—	—	—	—	S2
Lead-free microSMD Series Size 3225 mm/1210 mils																
microSMD005F	3.00 (0.118)	3.43 (0.135)	0.50 (0.019)	0.85 (0.034)	2.35 (0.092)	2.80 (0.110)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
microSMD010F	3.00 (0.118)	3.43 (0.135)	0.50 (0.019)	0.85 (0.034)	2.35 (0.092)	2.80 (0.110)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3

Table S4-B. Dimensions for Lead-free Surface-mount Devices in Millimeters (Inches) *continued*

Part Number	A Min.	A Max.	B Min.	B Max.	C Min.	C Max.	D Min.	D Max.	E Min.	E Max.	F Min.	F Max.	G Min	G Max.	H Min.	Figure
microSMD035F	3.00 (0.118)	3.43 (0.135)	0.38 (0.015)	0.62 (0.025)	2.35 (0.092)	2.80 (0.110)	0.30 (0.012)	—	0.25 (0.010)	—	—	—	—	—	—	S3
microSMD050F	3.00 (0.118)	3.43 (0.135)	0.38 (0.015)	0.62 (0.025)	2.35 (0.092)	2.80 (0.110)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
microSMD075F	3.00 (0.118)	3.43 (0.135)	0.38 (0.015)	0.62 (0.025)	2.35 (0.092)	2.80 (0.110)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
microSMD110F	3.00 (0.118)	3.43 (0.135)	0.28 (0.011)	0.48 (0.019)	2.35 (0.092)	2.80 (0.110)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
microSMD150F	3.00 (0.118)	3.43 (0.135)	0.51 (0.020)	1.22 (0.048)	2.35 (0.092)	2.80 (0.110)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
Lead-free microSMD Series Size 3225 mm/1210 mils *continued*																
microSMD110F	3.00 (0.118)	3.43 (0.135)	0.28 (0.011)	0.48 (0.019)	2.35 (0.092)	2.80 (0.110)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
microSMD150F	3.00 (0.118)	3.43 (0.135)	0.51 (0.020)	1.22 (0.048)	2.35 (0.092)	2.80 (0.110)	0.30 (0.012)	—	0.25 (0.010)	—	—	—	—	—	—	S3
Lead-free miniSMDC Series Size 4532 mm/1812 mils																
miniSMDC014F	4.37 (0.172)	4.73 (0.186)	0.635 (0.025)	0.89 (0.035)	3.07 (0.121)	3.41 (0.134)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
mniSMDC020F	4.37 (0.172)	4.73 (0.186)	0.635 (0.025)	0.89 (0.035)	3.07 (0.121)	3.41 (0.134)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC050F	4.37 (0.172)	4.73 (0.186)	0.38 (0.015)	0.62 (0.025)	3.07 (0.121)	3.41 (0.134)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC075F	4.37 (0.172)	4.73 (0.186)	0.38 (0.015)	0.62 (0.025)	3.07 (0.121)	3.41 (0.134)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC110F	4.37 (0.172)	4.73 (0.186)	0.38 (0.015)	0.62 (0.025)	3.07 (0.121)	3.41 (0.134)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC110F/16	4.37 (0.172)	4.73 (0.186)	0.38 (0.015)	0.62 (0.025)	3.07 (0.121)	3.41 (0.134)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC125F	4.37 (0.172)	4.73 (0.186)	0.28 (0.011)	0.48 (0.019)	3.07 (0.121)	3.41 (0.134)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC125F/16	4.37 (0.172)	4.73 (0.186)	0.28 (0.011)	0.48 (0.019)	3.07 (0.121)	3.41 (0.134)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC150F	4.37 (0.172)	4.73 (0.186)	0.28 (0.011)	0.48 (0.019)	3.07 (0.121)	3.41 (0.134)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC160F	4.37 (0.172)	4.73 (0.186)	0.28 (0.011)	0.48 (0.019)	3.07 (0.121)	3.41 (0.134)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC200F	4.37 (0.172)	4.73 (0.186)	0.51 (0.020)	1.22 (0.048)	3.07 (0.121)	3.41 (0.134)	0.25 (0.010)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC260F	4.37 (0.172)	4.73 (0.186)	0.76 (0.030)	1.25 (0.050)	3.07 (0.121)	3.41 (0.134)	0.25 (0.012)	—	0.20 (0.008)	—	—	—	—	—	—	S3
miniSMDC260F/12	4.37 (0.172)	4.73 (0.186)	0.76 (0.030)	1.25 (0.050)	3.07 (0.121)	3.41 (0.134)	0.25 (0.012)	—	0.20 (0.008)	—	—	—	—	—	—	S3
Lead-free miniSMDM Series Size 4532 mm/1812 mils																
miniSMDM075F/24	4.35 (0.172)	4.75 (0.187)	1.75 (0.069)	2.00 (0.079)	3.05 (0.120)	3.60 (0.142)	1.4 (0.055)	1.7 (0.067)	—	—	—	—	—	—	—	S5
miniSMDM110F	4.35 (0.172)	4.75 (0.187)	1.75 (0.069)	2.00 (0.079)	3.05 (0.120)	3.60 (0.142)	1.4 (0.055)	1.7 (0.067)	—	—	—	—	—	—	—	S2
miniSMDM110F/16	4.35 (0.172)	4.75 (0.187)	1.75 (0.069)	2.00 (0.079)	3.05 (0.120)	3.60 (0.142)	1.4 (0.055)	1.7 (0.067)	—	—	—	—	—	—	—	S5
miniSMDM200F	4.35 (0.172)	4.75 (0.187)	1.75 (0.069)	2.00 (0.079)	3.05 (0.120)	3.60 (0.142)	1.4 (0.055)	1.7 (0.067)	—	—	—	—	—	—	—	S5
miniSMDM260F	4.35 (0.172)	4.75 (0.187)	1.75 (0.069)	2.00 (0.079)	3.05 (0.120)	3.60 (0.142)	1.4 (0.055)	1.7 (0.067)	—	—	—	—	—	—	—	S5

Table S4-B. Dimensions for Lead-free Surface-mount Devices in Millimeters (Inches) *continued*

	Dimension															
	A		B		C		D		E		F		G		H	
Part Number	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min	Max.	Min.	Figure
Lead-free midSMD Series Size 5050 mm/2018 mils																
SMD030F-2018	4.72 (0.186)	5.44 (0.214)	— —	1.78 (0.070)	4.22 (0.166)	4.93 (0.194)	0.25 (0.010)	0.36 (0.014)	0.25 (0.010)	0.36 (0.014)	0.30 (0.012)	0.46 (0.018)	— —	— —	— —	S6
SMD100F-2018	4.72 (0.186)	5.44 (0.214)	— —	1.52 (0.060)	4.22 (0.166)	4.93 (0.194)	0.25 (0.010)	0.36 (0.014)	0.25 (0.010)	0.36 (0.014)	0.30 (0.012)	0.46 (0.018)	— —	— —	— —	S6
SMD150F-2018	4.72 (0.186)	5.44 (0.214)	— —	1.52 (0.060)	4.22 (0.166)	4.93 (0.194)	0.25 (0.010)	0.36 (0.014)	0.25 (0.010)	0.36 (0.014)	0.30 (0.012)	0.46 (0.018)	— —	— —	— —	S6
SMD200F-2018	4.72 (0.186)	5.44 (0.214)	— —	1.52 (0.060)	4.22 (0.166)	4.93 (0.194)	0.25 (0.010)	0.36 (0.014)	0.25 (0.010)	0.36 (0.014)	0.30 (0.012)	0.46 (0.018)	— —	— —	— —	S6
Lead-free SMD Series Size 7555 mm/2920 mils																
SMD030F	6.73 (0.265)	7.98 (0.314)	— —	3.18 (0.125)	4.80 (0.19)	5.44 (0.214)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	2.16 (0.085)	2.41 (0.095)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	S7
SMD050F	6.73 (0.265)	7.98 (0.314)	— —	3.18 (0.125)	4.80 (0.19)	5.44 (0.214)	0.20 (0.008)	0.30 (0.012)	0.56 (0.022)	0.71 (0.028)	2.16 (0.085)	2.41 (0.095)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	S7
SMD075F	6.73 (0.265)	7.98 (0.314)	— —	3.18 (0.125)	4.80 (0.19)	5.44 (0.214)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	2.16 (0.085)	2.41 (0.095)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	S7
SMD075F/60	6.73 (0.265)	7.98 (0.314)	— —	3.18 (0.125)	4.80 (0.19)	5.44 (0.214)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	2.16 (0.085)	2.41 (0.095)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	S7
SMD100F	6.73 (0.265)	7.98 (0.314)	— —	3.00 (0.118)	4.80 (0.19)	5.44 (0.214)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	2.16 (0.085)	2.41 (0.095)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	S7
SMD100F/33	6.73 (0.265)	7.98 (0.314)	— —	3.00 (0.118)	4.80 (0.19)	5.44 (0.214)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	2.16 (0.085)	2.41 (0.095)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	S7
SMD125F	6.73 (0.265)	7.98 (0.314)	— —	3.00 (0.118)	4.80 (0.19)	5.44 (0.214)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	2.16 (0.085)	2.41 (0.095)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	S7
SMD260F	6.73 (0.265)	7.98 (0.314)	— —	3.00 (0.118)	4.80 (0.19)	5.44 (0.214)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	2.16 (0.085)	2.41 (0.095)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	S7
SMD300F	6.73 (0.265)	7.98 (0.314)	— —	3.00 (0.118)	4.80 (0.19)	5.44 (0.214)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	2.16 (0.085)	2.41 (0.095)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	S7
Lead-free SMD2 Series Size 8763 mm/3425 mils																
SMD150F	8.00 (0.315)	9.40 (0.370)	— —	3.00 (0.118)	6.00 (0.236)	6.71 (0.264)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	3.68 (0.145)	3.94 (0.155)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	S7
SMD150F/33	8.00 (0.315)	9.40 (0.370)	— —	3.00 (0.118)	6.00 (0.236)	6.71 (0.264)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	3.68 (0.145)	3.94 (0.155)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	S7
SMD185F	8.00 (0.315)	9.40 (0.370)	— —	3.00 (0.118)	6.00 (0.236)	6.71 (0.264)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	3.68 (0.145)	3.94 (0.155)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	S7
SMD200F	8.00 (0.315)	9.40 (0.370)	— —	3.00 (0.118)	6.00 (0.236)	6.71 (0.264)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	3.68 (0.145)	3.94 (0.155)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	S7
SMD250F	8.00 (0.315)	9.40 (0.370)	— —	3.00 (0.118)	6.00 (0.236)	6.71 (0.264)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	3.68 (0.145)	3.94 (0.155)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	S7

4

Figures S11–S19. Typical Time-to-trip Curves at 20°C for Surface-mount Devices

Telecom and Networking Devices

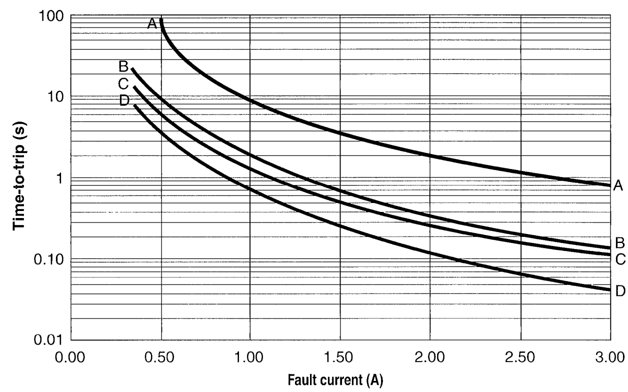
A = TS600-170/TS600-200

B = TS250-130

C = TSV250-130

D = TSL250-080

Figure S11



nanoSMDC and nanoSMDCxxxF

A = nanoSMDC020F

B = nanoSMDC035F

C = nanoSMDC050F/13.2

D = nanoSMDC075F

E = nanoSMDC110F

F = nanoSMDC150, nanoSMDC150F

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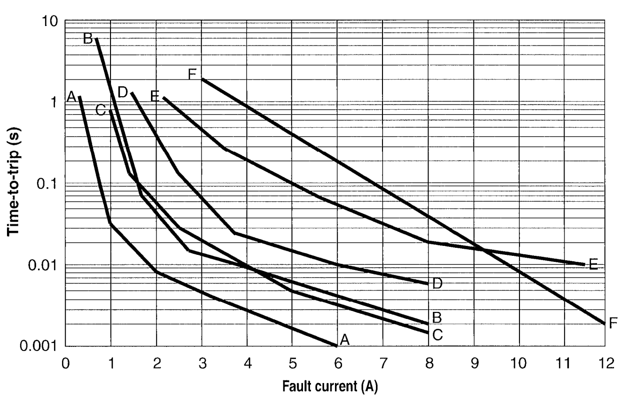
Figure S12



nanoSMDM and nanoSMDMxxxF

A = nanoSMDM012, nanoSMDM012F

B = nanoSMDM016

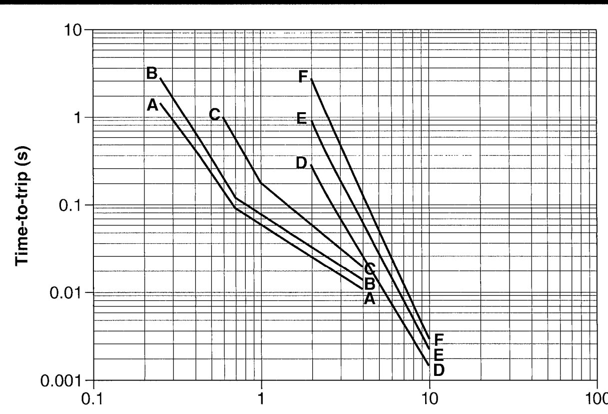
C = nanoSMDM020F

D = nanoSMDM050, nanoSMDM050F, nanoSMDM050F/13.2

E = nanoSMDM075, nanoSMDM075F

F = nanoSMDM100, nanoSMDM100F

Figure S13

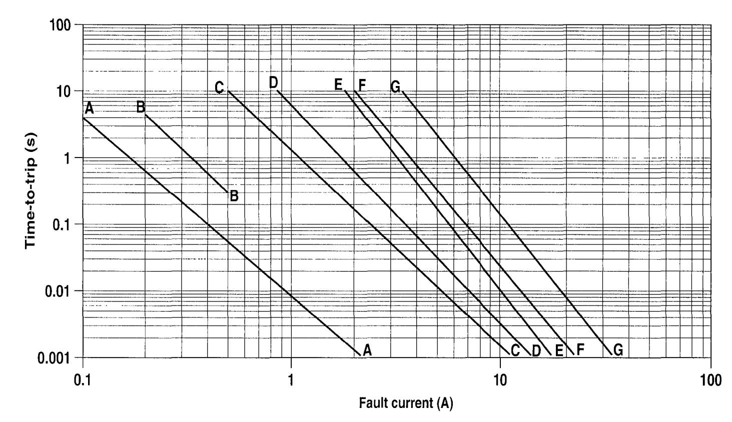


Figures S11–S19. Typical Time-to-trip Curves at 20°C for Surface-mount Devices *continued*

microSMD and microSMDF

- A = microSMD005, microSMD005F
- B = microSMD010, microSMD010F
- C = microSMD035, microSMD035F
- D = microSMD050, microSMD050F
- E = microSMD075, microSMD075F
- F = microSMD110, microSMD110F
- G = microSMD150, microSMD150F

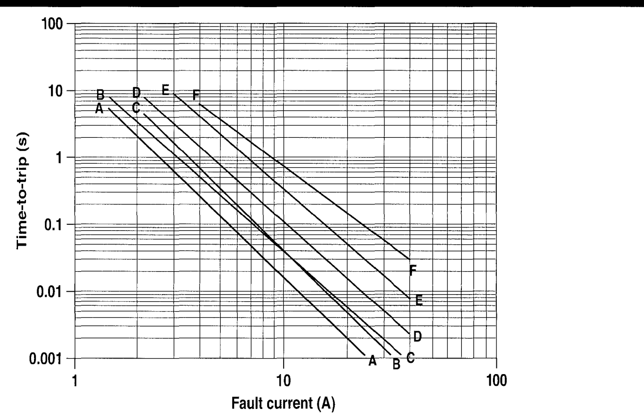
Figure S14



miniSMDM and miniSMDMxxxF (data at 25°C)

- A = miniSMDM075, miniSMDM075/24, miniSMDM075F/24
- B = miniSMDM110, miniSMDM110F, miniSMDM110/16, miniSMDM110F/116
- C = miniSMDM150/24
- D = miniSMDM160
- E = miniSMDM200, miniSMDM200F
- F = miniSMDM260, miniSMDM260F

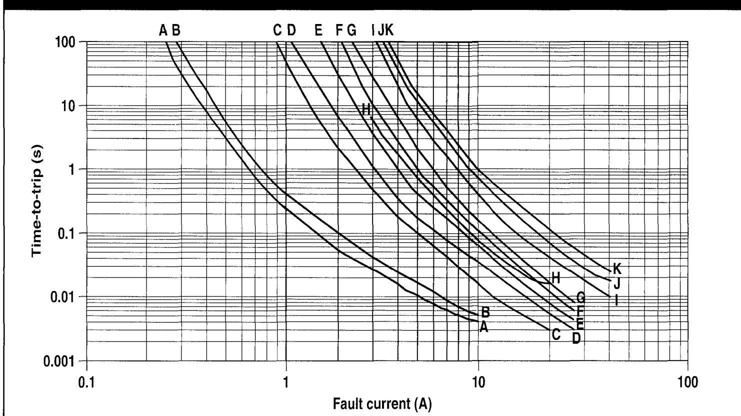
Figure S15



miniSMDC, miniSMDCxxxF and miniSMDE

- A = miniSMDC014, miniSMDC014F
- B = miniSMDC020, miniSMDC020F
- C = miniSMDC050, miniSMDC050F
- D = miniSMDC075, miniSMDC075F
- E = miniSMDC110, miniSMDC110F, miniSMDC110F/16
- F = miniSMDC125, miniSMDC125F, miniSMDC125F/16
- G = miniSMDC150, miniSMDC150F
- H = miniSMDC160F
- I = miniSMDC200, miniSMDC200F
- J = miniSMDE190
- K = miniSMDC260, miniSMDC260F, miniSMDC260F/12

Figure S16



Figures S11–S19. Typical Time-to-Trip Curves at 20°C for Surface-mount Devices

midSMD

A = SMD030-2018, SMD030F-2018

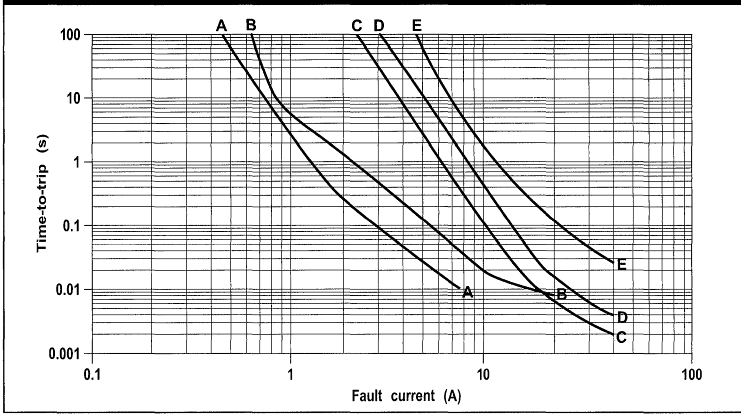
B = SMD050-2018

C = SMD100-2018, SMD100F-2018

D = SMD150-2018, SMD150F-2018

E = SMD200-2018, SMD200F-2018

Figure S17



SMD and SMDxxxF

A = SMD030, SMD030F

B = SMD050, SMD050F

C = SMD075, SMD075F, SMD075F/60

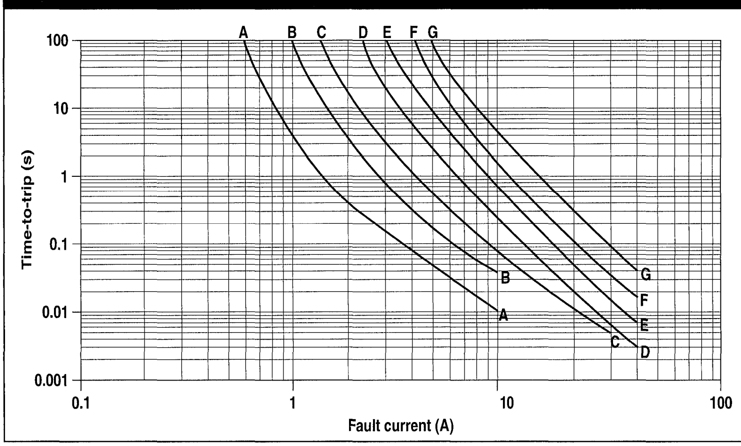
D = SMD100, SMD100F, SMD100/33, SMD100F/33

E = SMD125, SMD125F

F = SMD260, SMD260RB, SMD260F

G = SMD300, SMD300F

Figure S18



SMD2 and SMDxxxF

A = SMD150, SMD150F, SMD150/33, SMD150F/33

B = SMDH160

C = SMD185, SMD185F

D = SMD200, SMD200F

E = SMD250, SMD250F

Figure S19

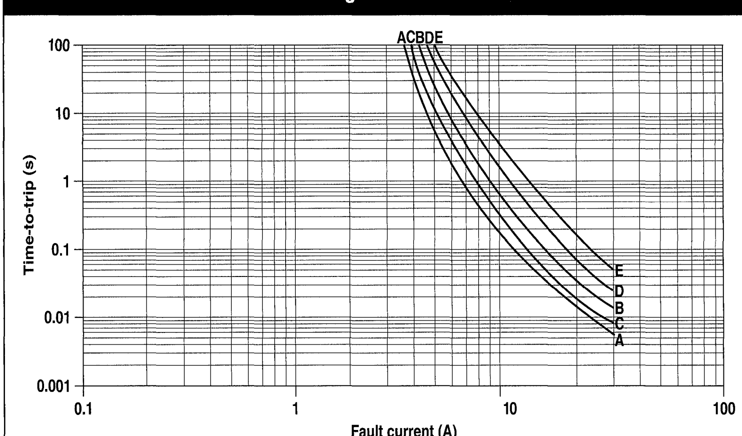


Table S5. Physical Characteristics and Environmental Specifications for Surface-mount Devices Operating temperature range -40°C to 85°C, -40°C to 125°C for SMDH160

Physical Characteristics

Terminal pad material	Solder-plated copper for nanoSMDC, microSMD, and miniSMDC series Gold plating for nanoSMDM, and miniSMDM series 98% tin for SMD series
Soldering characteristics	ANSI/J-STD-002B Category 3 for nanoSMDC, nanoSMDM, microSMD, miniSMDC, and miniSMDM series ANSI/J-STD-002B Category 1 for SMD series
Solder heat withstand	per IEC-STD 68-2-20, Test Tb, Section 5, Method 1A
Flammability resistance	per IEC 695-2-2 Needle Flame Test for 20 sec.
Recommended storage conditions	40°C max, 70% R.H. max; devices may not meet specified ratings if storage conditions are exceeded.

Environmental Specifications

Test	Test Method	Conditions	Resistance Change
Passive aging	Raychem PS300, Section 5.3.2	60°C, 1000 hours	±3% typical
		85°C, 1000 hours	±5% typical
Humidity aging	Raychem PS300, Section 5.3.1	85°C, 85% RH, 100 hours	±1.2% typical
Thermal shock	MIL-STD-202, Method 107G	85°C, -40°C (20 times)	-33% typical
		125°C, -55°C (10 times)	-33% typical
Vibration	MIL-STD-883C	per MIL-STD-883C	No change
Solvent resistance	Raychem PS300, Section 5.2.2	Freon	No change
		Trichloroethane	No change
		Hydrocarbons	No change

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Agency Recognition for Surface-mount Devices*

UL	File # E74889 for all surface-mount devices
CSA	File # CA78165 for SMD/miniSMDC/miniSMDM/microSMD/nanoSMDC/nanoSMDM series
TÜV	Certificate # R9872048 for microSMD/miniSMDC/miniSMDM series Certificate # R2172061 for nanoSMDM/nanoSMDC series Certificate # R9872049 for SMD series

*Refer to Telecom and Networking section for agency recognition on Telecom and Networking Surface Mount Devices.

Table S6-A. Packaging and Marking Information for Surface-mount Devices

Part Number	Tape & Reel Quantity	Standard Package	Part Marking	Recommended Pad Layout Figures [mm (In.)] Dimension A (Nom.)	Dimension B (Nom.)	Dimension C (Nom.)	Agency Recognition
nanoSMDC Series Size 3216 mm/1206 mils							
nanoSMDC150	3,000	15,000	**J**	1.60 (0.063)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
Lead-free devices are listed in Table S6-B							
nanoSMDM Series Size 3216 mm/1206 mils							
nanoSMDM012	3,000	15,000	**012**	1.80 (0.071)	1.00 (0.039)	1.5 (0.059)	UL, CSA, TÜV
nanoSMDM016	3,000	15,000	**016**	1.80 (0.071)	1.00 (0.039)	1.5 (0.059)	UL, CSA, TÜV
nanoSMDM050	3,000	15,000	**050**	1.80 (0.071)	1.00 (0.039)	1.5 (0.059)	UL, CSA, TÜV
nanoSMDM075	3,000	15,000	**075**	1.80 (0.071)	1.00 (0.039)	1.5 (0.059)	UL, CSA, TÜV
nanoSMDM100	3,000	15,000	**100**	1.80 (0.071)	1.00 (0.039)	1.5 (0.059)	UL, CSA, TÜV
Lead-free devices are listed in Table S6-B							
microSMD Series Size 3225 mm/1210 mils							
microSMD005	4,000	20,000	**05**	2.50 (0.098)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
microSMD010	4,000	20,000	**10**	2.50 (0.098)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
microSMD035	4,000	20,000	**3**	2.50 (0.098)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
microSMD050	4,000	20,000	**50**	2.50 (0.098)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
microSMD075	4,000	20,000	**75**	2.50 (0.098)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
microSMD110	4,000	20,000	**11**	2.50 (0.098)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
microSMD150	4,000	20,000	**15**	2.50 (0.098)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
Lead-free devices are listed in Table S6-B							
miniSMDC Series Size 4532 mm/1812 mils							
miniSMDC014	2,000	10,000	**14**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC020	2,000	10,000	**2**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC050	2,000	10,000	**5**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC075	2,000	10,000	**7**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC110	2,000	10,000	**1**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC125	2,000	10,000	**12**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC150	2,000	10,000	**15**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC200	2,000	10,000	**20**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC260	1,500	7,500	**26**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
Lead-free devices are listed in Table S6-B							
miniSMDM Series Size 4532 mm/1812 mils							
miniSMDM075	3,000	15,000	**075**	3.20 (0.126)	1.50 (0.059)	2.50 (0.098)	UL, CSA, TÜV
miniSMDM075/24	3,000	15,000	**075G**	3.20 (0.126)	1.50 (0.059)	2.50 (0.098)	UL, CSA, TÜV
miniSMDM110	3,000	15,000	**110**	3.20 (0.126)	1.50 (0.059)	2.50 (0.098)	UL, CSA, TÜV
miniSMDM110/16	3,000	15,000	**110G**	3.20 (0.126)	1.50 (0.059)	2.50 (0.098)	UL, CSA, TÜV
miniSMDM150/24	3,000	15,000	**150**	3.20 (0.126)	1.50 (0.059)	2.50 (0.098)	UL, CSA, TÜV
miniSMDM160	3,000	15,000	**160**	3.20 (0.126)	1.50 (0.059)	2.50 (0.098)	UL, CSA, TÜV
miniSMDM200	3,000	15,000	**200**	3.20 (0.126)	1.50 (0.059)	2.50 (0.098)	UL, CSA, TÜV
miniSMDM260	3,000	15,000	**260**	3.20 (0.126)	1.50 (0.059)	2.50 (0.098)	UL, CSA, TÜV
Lead-free devices are listed in Table S6-B							
miniSMDE Series Size 11550 mm/4420 mils							
miniSMDE190	5,000	20,000	**19**	4.75 (0.187)	1.45 (0.057)	9.57 (0.377)	UL, CSA, TÜV

Table S6-A. Packaging and Marking Information for Surface-mount Devices *continued*

Part Number	Tape & Reel Quantity	Standard Package	Part Marking	Recommended Pad Layout Figures [mm (In.)] Dimension A (Nom.)	Dimension B (Nom.)	Dimension C (Nom.)	Agency Recognition
midSMD Size 5050 mm/2018 mils							
SMD030-2018	4,000	20,000	**A03**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA, TÜV
SMD050-2018	4,000	20,000	**A05**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA
SMD100-2018	4,000	20,000	**A10**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA, TÜV
SMD150-2018	4,000	20,000	**A15**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA, TÜV
SMD200-2018	4,000	20,000	**A20**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA, TÜV
SMD Size 7555 mm/2920 mils							
SMD030	2,000	10,000	**030**	3.1 (0.12)	2.3 (0.09)	5.1 (0.201)	UL, CSA, TÜV
SMD050	2,000	10,000	**050**	3.1 (0.12)	2.3 (0.09)	5.1 (0.201)	UL, CSA, TÜV
SMD075	2,000	10,000	**075**	3.1 (0.12)	2.3 (0.09)	5.1 (0.201)	UL, CSA, TÜV
SMD100	2,000	10,000	**100**	3.1 (0.12)	2.3 (0.09)	5.1 (0.201)	UL, CSA, TÜV
SMD100/33	2,000	10,000	**103**	3.1 (0.12)	2.3 (0.09)	5.1 (0.201)	UL, CSA, TÜV
SMD125	2,000	10,000	**125**	3.1 (0.12)	2.3 (0.09)	5.1 (0.201)	UL, CSA, TÜV
SMD260	2,000	10,000	**260**	3.1 (0.12)	2.3 (0.09)	5.1 (0.201)	UL, CSA, TÜV
SMD260-RB	2,000	10,000	**260**	3.1 (0.12)	2.3 (0.09)	5.1 (0.201)	UL, CSA, TÜV
SMD300	2,000	10,000	**300**	3.1 (0.12)	2.3 (0.09)	5.1 (0.201)	UL, CSA, TÜV
Lead-free devices are listed in Table S6-B							
SMD2 Size 8763 mm/3425 mils							
SMD150	1,500	7,500	**150**	4.6 (0.18)	2.3 (0.09)	6.1 (0.240)	UL, CSA, TÜV
SMD150/33	1,500	7,500	**153**	4.6 (0.18)	2.3 (0.09)	6.1 (0.240)	UL, CSA, TÜV
SMDH160	1,500	7,500	**160**	4.6 (0.18)	2.3 (0.09)	6.1 (0.240)	
SMD185	1,500	7,500	**185**	4.6 (0.18)	2.3 (0.09)	6.1 (0.240)	UL, CSA, TÜV
SMD200	1,500	7,500	**200**	4.6 (0.18)	2.3 (0.09)	6.1 (0.240)	UL, CSA, TÜV
SMD250	1,500	7,500	**250**	4.6 (0.18)	2.3 (0.09)	6.1 (0.240)	UL, CSA, TÜV
Lead-free devices are listed in Table S6-B							
Telecom Surface-mount							
TSL250-080	1,500	7,500	**T08**	3.6 (0.14)	1.8 (0.07)	5.5 (0.22)	UL, CSA, TÜV
TS250-130	1,500	7,500	**T13**	4.6 (0.18)	1.8 (0.07)	6.1 (0.24)	UL, CSA, TÜV
TSV250-130	1,200	6,000	**T13V**	*	*	*	UL, CSA, TÜV
TS600-170	300	900	**T20**	9.91 (0.390)	3.30 (0.130)	3.35 (0.132)	UL, CSA
TS600-200-RA	300	900	**T20**	9.91 (0.390)	3.30 (0.130)	3.35 (0.132)	UL, CSA
TSM600-250	200	1,000	**TSM600**	*	*	*	UL, CSA

*For TSV250-130 and BM 600-250 pad layout, see Telecom and Networking Section.

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Table S6-B. Packaging and Marking Information for Lead-free Surface-mount Devices

Part Number	Tape & Reel Quantity	Standard Package	Part Marking	Recommended Pad Layout Figures [mm (In.)] Dimension A (Nom.)	Dimension B (Nom.)	Dimension C (Nom.)	Agency Recognition
Lead-free nanoSMDC Series Size 3216 mm/1206 mils							
nanoSMDC020F	3,000	15,000	**02**	1.60 (0.063)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
nanoSMDC035F	3,000	15,000	**03**	1.60 (0.063)	1.00 (0.039)	2.00 (0.079)	UL, CSA
nanoSMDC050F/13.2	3,000	15,000	**M**	1.60 (0.063)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
nanoSMDC075F	3,000	15,000	**L**	1.60 (0.063)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
nanoSMDC110F	3,000	15,000	**K**	1.60 (0.063)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
nanoSMDC150F	3,000	15,000	**J**	1.60 (0.063)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
Lead-free nanoSMDM Series Size 3216 mm/1206 mils							
nanoSMDM012F	3,000	15,000	**012F**	1.80 (0.071)	1.00 (0.039)	1.5 (0.059)	UL, CSA, TÜV
nanoSMDM020F	3,000	15,000	**02F**	1.80 (0.071)	1.00 (0.039)	1.5 (0.059)	UL, CSA, TÜV
nanoSMDM050F	3,000	15,000	**05F**	1.80 (0.071)	1.00 (0.039)	1.5 (0.059)	UL, CSA, TÜV
nanoSMDM050F/13.2	3,000	15,000	**5FG**	1.80 (0.071)	1.00 (0.039)	1.5 (0.059)	UL, CSA, TÜV
nanoSMDM075F	3,000	15,000	**07F**	1.80 (0.071)	1.00 (0.039)	1.5 (0.059)	UL, CSA, TÜV
nanoSMDM100F	3,000	15,000	**10F**	1.80 (0.071)	1.00 (0.039)	1.5 (0.059)	UL, CSA, TÜV
Lead-free microSMD Series Size 3225 mm/1210 mils							
microSMD005F	4,000	20,000	**05F**	2.50 (0.098)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
microSMD010F	4,000	20,000	**10**	2.50 (0.098)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
microSMD035F	4,000	20,000	**3**	2.50 (0.098)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
microSMD050F	4,000	20,000	**50**	2.50 (0.098)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
microSMD075F	4,000	20,000	**75**	2.50 (0.098)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
microSMD110F	4,000	20,000	**11**	2.50 (0.098)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
microSMD150F	4,000	20,000	**15**	2.50 (0.098)	1.00 (0.039)	2.00 (0.079)	UL, CSA, TÜV
Lead-free miniSMDC Series Size 4532 mm/1812 mils							
miniSMDC014F	2,000	10,000	**14**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC020F	2,000	10,000	**2**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC050F	2,000	10,000	**5**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC075F	2,000	10,000	**7**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC110F	2,000	10,000	**1**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC110F/16	2,000	10,000	**110F 16V**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC125F	2,000	10,000	**12**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC125F/16	2,000	10,000	**125F 16V**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC150F	2,000	10,000	**15**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC160F	2,000	10,000	**16**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC200F	2,000	10,000	**20**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC260F	1,500	7,500	**26**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV
miniSMDC260F/12	1,500	7,500	**260F 12V**	3.15 (0.124)	1.78 (0.070)	3.45 (0.136)	UL, CSA, TÜV

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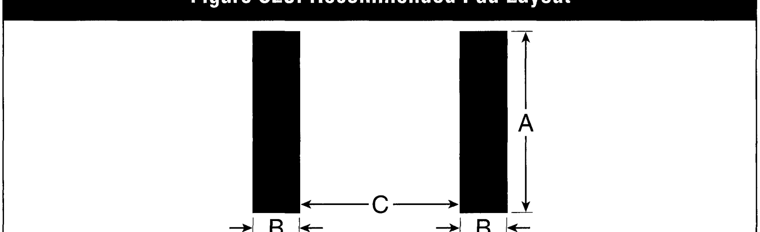
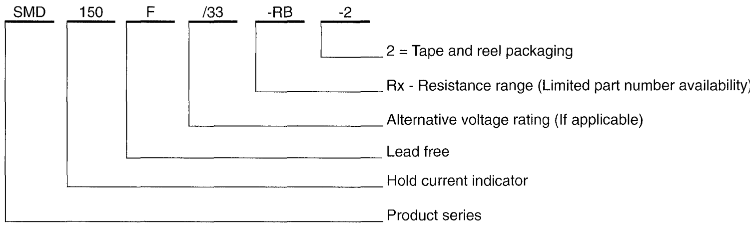
Table S6-B. Packaging and Marking Information for Lead-free Surface-mount Devices *continued*

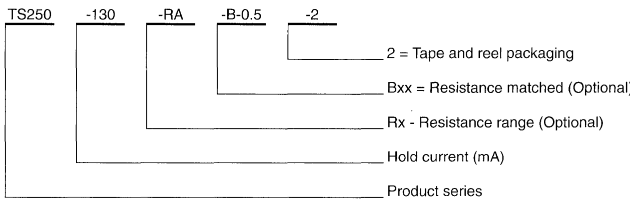
				Recommended Pad Layout Figures [mm (In.)]			
Part Number	Tape & Reel Quantity	Standard Package	Part Marking	Dimension A (Nom.)	Dimension B (Nom.)	Dimension C (Nom.)	Agency Recognition
Lead-free miniSMDM Series Size 4532 mm/1812 mils							
miniSMDM075F/24	3,000	15,000	**07FG**	3.20 (0.126)	1.50 (0.059)	2.50 (0.098)	UL, CSA, TÜV
miniSMDM110F	3,000	15,000	**110F**	3.20 (0.126)	1.50 (0.059)	2.50 (0.098)	UL, CSA, TÜV
miniSMDM110F/16	3,000	15,000	**11FG**	3.20 (0.126)	1.50 (0.059)	2.50 (0.098)	UL, CSA, TÜV
miniSMDM200F	3,000	15,000	**200F**	3.20 (0.126)	1.50 (0.059)	2.50 (0.098)	UL, CSA, TÜV
miniSMDM260F	3,000	15,000	**260F**	3.20 (0.126)	1.50 (0.059)	2.50 (0.098)	UL, CSA, TÜV
Lead-free midSMD Series Size 5050 mm/2018 mils							
SMD030F-2018	4,000	20,000	**A03F**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA, TÜV
SMD100F-2018	4,000	20,000	**A10F**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA, TÜV
SMD150F-2018	4,000	20,000	**A15F**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA, TÜV
SMD200F-2018	4,000	20,000	**A20F**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA, TÜV
Lead-free SMD Series Size 7555 mm/2920 mils							
SMD030F	2,000	10,000	**030F**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA, TÜV
SMD050F	2,000	10,000	**050F**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA, TÜV
SMD075F	2,000	10,000	**075F**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA, TÜV
SMD075F/60	2,000	10,000	**075F**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA
SMD100F	2,000	10,000	**100F**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA, TÜV
SMD100F/33	2,000	10,000	**103F**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA, TÜV
SMD125F	2,000	10,000	**125F**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA, TÜV
SMD260F	2,000	10,000	**260F**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA, TÜV
SMD300F	2,000	10,000	**300F**	4.6 (0.18)	1.50 (0.059)	3.4 (0.134)	UL, CSA, TÜV
Lead-free SMD2 Devices Size 8763 mm/3425 mils							
SMD150F	1,500	7,500	**150F**	4.6 (0.18)	2.3 (0.09)	6.1 (0.240)	UL, CSA, TÜV
SMD150F/33	1,500	7,500	**153F**	4.6 (0.18)	2.3 (0.09)	6.1 (0.240)	UL, CSA, TÜV
SMD185F	1,500	7,500	**185F**	4.6 (0.18)	2.3 (0.09)	6.1 (0.240)	UL, CSA, TÜV
SMD200F	1,500	7,500	**200F**	4.6 (0.18)	2.3 (0.09)	6.1 (0.240)	UL, CSA, TÜV
SMD250F	1,500	7,500	**250F**	4.6 (0.18)	2.3 (0.09)	6.1 (0.240)	UL, CSA, TÜV

Figure S20. Recommended Pad Layout



Part Numbering System



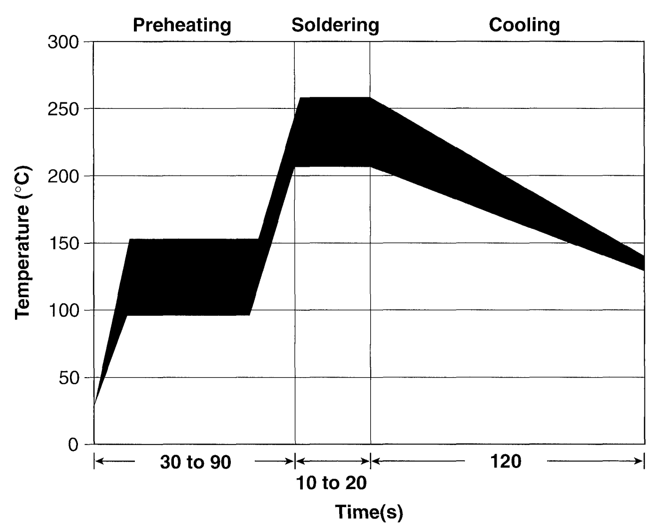


Solder Reflow and Rework Recommendations for Surface-mount Devices

Solder Reflow

- Recommended reflow methods: IR, Vapor phase, and hot air oven.
- The following product series are not designed to be wave soldered to circuit boards:
  - nanoSMDM
  - miniSMDM
  - midSMD
  - SMD
  - SMD2
  - TS
- The following product series are designed to be wave soldered to circuit boards:
  - nanoSMDC
  - microSMD
  - miniSMDC, miniSMDE
- Recommended maximum paste thickness for the microSMD, miniSMDC, and miniSMDE devices is 0.25 mm (10mils), 0.13-0.25 mm for miniSMDM and nanoSMDM, and 0.38 mm for SMD.
- Devices can be cleaned using standard methods and solvents.

Figure S21



Caution:

- If reflow temperatures exceed the recommended profile, devices may not meet the performance specifications.

Rework

- Use standard industry practices for the nanoSMDC, nanoSMDM, microSMD, miniSMDC, miniSMDM, and miniSMDE devices.
- For SMD and midSMD series and all TS devices rework should be confined to removal of the installed product and replacement with a fresh device.

Table S7. Tape and Reel Specifications for Surface-mount Devices (in Millimeters)

	nanoSMDC nanoSMDM	microSMD	miniSMDC miniSMDM	miniSMDE190	midSMD	SMD	SMD2
	EIA 481-1	**EIA 481-1**	**EIA 481-1**	**EIA 481-2**	**EIA 481-2**	**EIA 481-2**	**EIA 481-2**
W	8.0 ± 0.30	8.0 ± 0.30	12.0 ± 0.30	24.0 ± 0.30	16.0 ± 0.30	16.0 ± 0.30	16.0 ± 0.30
P_0	4.0 ± 0.10	4.0 ± 0.10	4.0 ± 0.10	4.0 ± 0.10	4.0 ± 0.10	4.0 ± 0.10	4.0 ± 0.10
P_1	4.0 ± 0.10	4.0 ± 0.10	8.0 ± 0.10	8.0 ± 0.10	8.0 ± 0.10	8.0 ± 0.10	12.0 ± 0.10
P_2	2.0 ± 0.05	2.0 ± 0.05	2.0 ± 0.05	2.0 ± 0.10	2.0 ± 0.10	2.0 ± 0.10	2.0 ± 0.10
A_0	Table S7a	2.9 ± 0.10	Table S7b	5.70 ± 0.10	5.11 ± 0.15	5.6 ± 0.23	6.9 ±0.23
B_0	Table S7a	3.5 ± 0.10	Table S7b	11.90 ± 0.10	5.6 ± 0.23	8.1 ± 0.15	9.6 ± 0.15
B_1 max.	4.35	4.35	8.2**	20.1	12.1	12.1	12.1
D_0	1.5 + 0.10/ -.00	1.5 + 0.10/ -.00	1.5 + 0.10/ -.00	1.5 + 0.10/ -.00	1.5 + 0.10/ -.00	1.5 + 0.10/ -.00	1.5 + 0.10/ -.00
F	3.5 ± 0.05	3.5 ± 0.05	5.5 ± 0.05	11.5 ± 0.10	7.5 ± 0.10	7.5 ± 0.10	7.5 ± 0.10
E_1	1.75 ± 0.10	1.75 ± 0.10	1.75 ± 0.10	1.75 ± 0.10	1.75 ± 0.10	1.75 ± 0.10	1.75 ± 0.10
E_2 min.	6.25	6.25	10.25	22.25	14.25	14.25	14.25
T max.	0.6	0.6	0.6	0.6	0.6	0.6	0.6
T_1 max.	0.1	0.1	0.1	0.1	0.1	0.1	0.1
K_0	Table S7a	0.90 ± 0.10*	Table S7b	0.95 ± 0.10	1.8 ± 0.15	3.2 ± 0.15	3.4 ± 0.15
Leader min.	390***	390	390***	400	400	400	400
Trailer min.	160***	160	160***	160	160	160	160

*1.1±0.05 for microSMD150
**5.9 for miniSMDM
***200 for nanoSMDM, miniSMDM

Table S7a

	nanoSMDC150	nanoSMDM
A_0	2.3 ± 0.10	1.88 ± 0.10
B_0	3.5 ± 0.10	3.5 ± 0.10
K_0	1.45 ± 0.10	1.4 ± 0.10

Table S7b

	miniSMDC	miniSMDC260	miniSMDM
A_0	3.5 ± 0.23	3.7 ± 0.10	3.5 ± 0.23
B_0	5.1 ± 0.15	4.9 ± 0.10	5.1 ± 0.15
K_0	0.9 ± 0.15	1.4 ± 0.10	2.3 ± 0.15

Table S7c. Reel Dimensions for Surface-mount Devices (in millimeters)

	nanoSMDC nanoSMDM	microSMD	miniSMDC	miniSMDM	miniSMDE190	midSMD	SMD	SMD2
A max.	180	180	180	340	330	330	330	330
N min.	50	50	50	50	60	50	50	50
W_1	8.5 + 1.5/-.00	8.4 + 1.5/-.00	12.4 + 2.0/-.00	12.4 + 2.0/-.00	24.4 + 2.0/-.00	16.4 + 2.0/-.00	16.4 + 2.0/-.00	16.4 + 2.0/-.00
W_2 max.	14.4	14.4	18.4	18.4	30.4	22.4	22.4	22.4

Figure S21. EIA Taped Component Dimensions

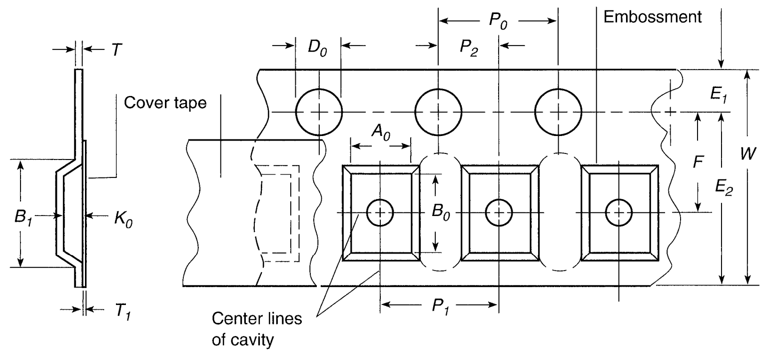
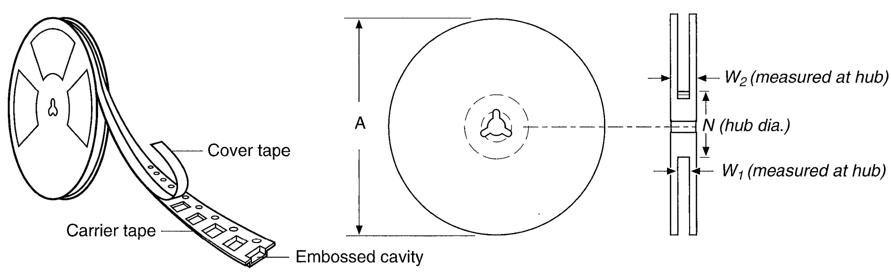


Figure S22. EIA Reel Dimensions



4

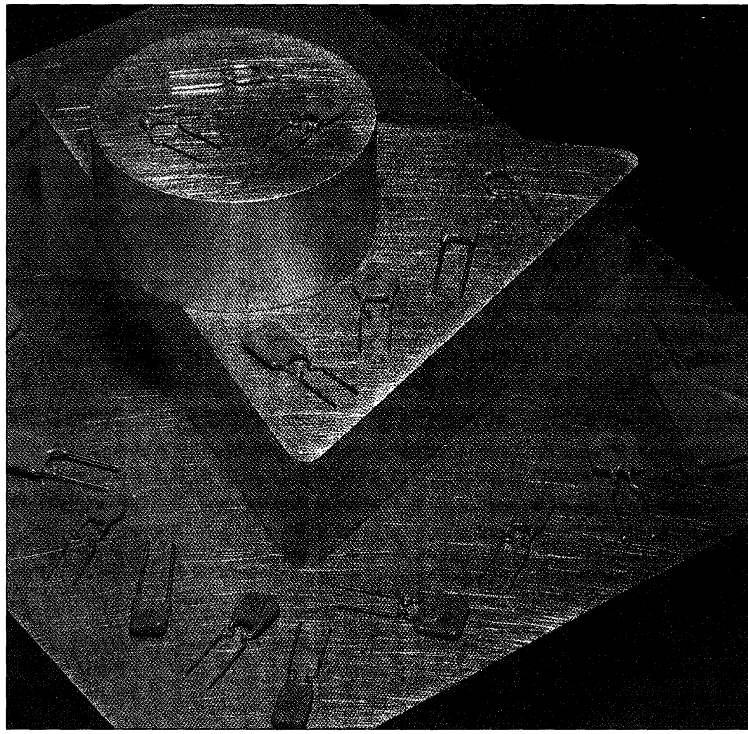
Latest Information

- Please visit us at www.circuitprotection.com or contact your local representative for the latest information.
- The information in this data package contains some preliminary information. Raychem Circuit Protection, a division of Tyco Electronics, reserves the right to change any of the specifications without notice. In addition, Tyco Electronics reserves the right to make changes—without notification to Buyer—to materials or processing that do not affect compliance with any applicable specification.

WARNING:

- Operation beyond the maximum ratings or improper use may result in device damage and possible electrical arcing and flame.
- The devices are intended for protection against occasional overcurrent or overtemperature fault conditions and should not be used when repeated fault conditions or prolonged trip events are anticipated.
- Contamination of the PPTC material with certain silicon based oils or some aggressive solvents can adversely impact the performance of the devices.
- Device performance can be impacted negatively if devices are handled in a manner inconsistent with recommended electronic, thermal, and mechanical procedures for electronic components.
- Operation in circuits with a large inductance can generate a circuit voltage ($L\,{}^{di}/_{dt}$) above the rated voltage of the PolySwitch resettable device.

PolySwitch Radial-leaded
Resettable Devices



Raychem Circuit Protection has pioneered PPTC technology for over twenty years. Our radial-leaded products represent the widest range of product capabilities.

- RGE series for hold currents up to 14A
- RHE series for flatter thermal derating and operating temperatures up to 125°C
- RUE series for balance of voltage rating (30V) and hold current (up to 9A)
- RUSB series for fast time-to-trip and low-resistance computer applications
- RTE series specifically designed for IEEE-1394 applications
- RXE series for low hold currents (down to 50mA) and high voltage rating (up to 72V)
- LVR series for line voltage applications up to a continuous operating voltage of $265V_{AC}$
- TR600 series for North America telephone applications
- TR250 series for ITU telephone applications
- BBR series for cable telephone applications
- Now offering Pb-free versions of all products. For Pb-free versions of R-line products simply add an "F" to the end of the series description.

Whether for design or volume application, our radial-leaded products represent the most comprehensive and complete set of PPTC products available in the industry today.

Benefits:
- Many product choices give engineers more design flexibility
- Compatible with high-volume electronics assembly
- Assists in meeting regulatory requirements
- Higher voltage ratings allow use in new applications

Features:
- Broadest range of radial-leaded resettable devices available in the industry
- Current ratings from 50mA to 15A
- Voltage ratings from 6V (computer and electronic applications) to $265V_{AC}$ line voltage applications
- Agency recognition: UL, CSA, TÜV
- Fast time-to-trip
- Low resistance

Applications:
- Satellite video receivers
- Industrial controls
- Transformers
- Computer motherboards
- Modems
- USB hub, ports and peripherals
- IEEE1394 ports
- CD-ROMs
- Game machines
- Battery packs
- Phones
- Fax machines
- Analog and digital line cards
- Printers

Devices in this section are grouped by:
Voltage Rating, Device Series, Hold Current

Step 1. Determine the circuit's operating parameters.

Fill in the following information about the circuit:

Maximum ambient operating temperature	________
Normal operating current	________
Maximum operating voltage (i.e., RUE135 is 30V max.)	________
Maximum interrupt current	________

Step 2. Select the PolySwitch device that will accommodate the circuit's maximum ambient temperature and normal operating current.

Look across the top of Table R2 to find the temperature that most closely matches the circuit's maximum operating temperature. Look down that column to find the value equal to or greater than the circuit's normal operating current. Now look to the far left of that row to find the part number for the PolySwitch device that will best accommodate the circuit. Devices in this section are grouped by voltage rating; therefore, your operating current requirement may be found in more than one product grouping.

The thermal derating curves located in Figures R1–R5 are the normalized representations of the data in Table R2.

Step 3. Compare the maximum electrical ratings of the selected device with the maximum operating voltage and maximum interrupt currents of the circuit.

Look down the first column of Table R3 to find the part number you selected in Step 2. Look to the right in that row to find the device's maximum operating voltage (V_{MAX}) and maximum interrupt current (I_{MAX}). Ensure that V_{MAX} and I_{MAX} are greater than or equal to operating voltage and maximum interrupt current.

Step 4. Determine time-to-trip.

Time-to-trip is the amount of time it takes for a device to switch to a high-resistance state once a fault current has been applied across the device. Identifying the PolySwitch device's time-to-trip is important in order to provide the desired protection capabilities. If the device you choose trips too fast, undesired or nuisance tripping will occur. If the device trips too slowly, the components being protected may be damaged before the device switches to a high-resistance state.

Refer to the typical time-to-trip curves for each of the PolySwitch devices found in Figures R17–R23.

If the time-to-trip of the PolySwitch device is too fast or too slow for the circuit, go back to Step 2 and choose an alternate device.

Step 5. Verify ambient operating conditions.

Ensure that your application's minimum and maximum ambient temperatures are within the operating temperature of -40°C to 85°C (-40 to 125°C for RHE device series).

Step 6. Verify the PolySwitch device dimensions.

Using the dimensions in Table R4, compare the dimensions of the PolySwitch device you selected with the application's space considerations.

Protection Application Selection Guide for Radial-leaded Devices

The guide below lists PolySwitch devices that are typically used in these applications.

Specifications for the suggested device part numbers can be found in this section.

Once a part number has been selected, the user should evaluate and test each product for its intended application.

	PolySwitch Resettable Devices—Key Selection Criteria		
Protection Application	**Small Size**	**Flatter Derating**	**Lower Current Higher Voltage**
Electromagnetic loads	RGE (<16V), RUE (<30V)	RHE (<16V)	RXE (<72V)
Halogen lighting	RGE (<16V), RUE (<30V)	RHE (<16V)	RXE (<72V)
Lighting ballast	RXE (<72V), BBR (<99V_{AC})		LVR (<265V_{AC})
Loudspeakers	RXE (<72V)		RXE (<72V)
Medical equipment	RGE (<16V), RUE (<30V)	RHE (<16V)	RXE (<72V)
MOSFET devices	RGE (<16V), RUE (<30V)	RHE (<16V)	RXE (<72V)
Motors, fans, and blowers	RXE (<72V), RGE (<16V)	RHE (<16V)	LVR (<265V_{AC})
POS equipment	RXE (<72V), RUE (<30V)		
Process and industrial controls	RXE (<72V), RUE (<30V)		
Satellite video receivers	RGE (<16V), RUE (<30V)	RHE (<16V)	RXE (<72V)
Security and fire alarm systems	RGE (<16V), RUE (<30V)	RHE (<16V)	RXE (<72V), LVR (<265V_{AC})
Test and measurement equipment	RGE (<16V), RUE (<30V)	RHE (<16V)	RXE (<72V), LVR (<265V_{AC})
Transformers	RGE (<16V), RUE (<30V)	RHE (<16V)	RXE (<72V), LVR (<265V_{AC})
UL1950/FCC Part 68 requirements	RXE (<72V)		
DDC computer video ports	RUE (<30V)		
IEEE-1394 computer and consumer electronics	RTE (<33V)		
Mouse and keyboard	RUE (<30V)		
SCSI	RUE (<30V)		
USB	RUSB (<16V)		
Traces and printed circuit board protection	RGE (<16V), RUE (<30V)	RHE (<16V)	RXE (<72V)

This list is not exhaustive. Raychem Circuit Protection welcomes customer's input for additional application ideas for PolySwitch resettable devices.

4

Table R1. Product Series – Current Rating, Voltage Rating/Typical Resistance for Radial-leaded Devices

Voltage Rating	LVR $265V_{AC}$	BBR 99V	TR600 60/600V*	TR250 60/250V*	RXE 72V	RXE 60V	RTE 33V	RUE 30V	RGE 16V	RHE 16V	RHE 30V	RUSB 16V	RUSB 6V
Hold Current (A)	—	—	—	—	—	—	—	—	—	—	—	—	—
0.050	25Ω	—	—	—	—	9.2Ω	—	—	—	—	—	—	—
0.080	9.8Ω	—	—	17.0Ω	—	—	—	—	—	—	—	—	—
0.100	—	—	—	—	—	3.50Ω	—	—	—	—	—	—	—
0.110	—	—	—	—	—	—	—	—	—	—	—	—	—
0.120	4.8Ω	—	—	6.0Ω	—	—	—	—	—	—	—	—	—
0.145	—	—	—	4.5Ω	—	—	—	—	—	—	—	—	—
0.150	—	—	9.0Ω	—	—	—	—	—	—	—	—	—	—
0.160	3.4Ω	—	7.0Ω	—	—	—	—	—	—	—	—	—	—
0.170	—	—	—	—	—	4.30Ω	—	—	—	—	—	—	—
0.180	—	—	—	1.4Ω	—	—	—	—	—	—	—	—	—
0.200	—	—	—	—	2.29Ω	—	—	—	—	—	—	—	—
0.250	1.7Ω	—	—	—	1.60Ω	—	—	—	—	—	—	—	—
0.300	—	—	—	—	1.11Ω	—	—	—	—	—	—	—	—
0.330	1.0Ω	—	—	—	—	—	—	—	—	—	—	—	—
0.400	0.80Ω	—	—	—	0.71Ω	—	—	—	—	—	—	—	—
0.500	—	—	—	—	0.64Ω	—	—	—	—	—	0.68Ω	—	—
0.550	—	1.05Ω	—	—	—	—	—	—	—	—	—	—	—
0.650	—	—	—	—	0.40Ω	—	—	—	—	—	—	—	—
0.700	—	—	—	—	—	—	—	—	—	—	0.42Ω	—	—
0.750	—	0.58Ω	—	—	0.325Ω	—	—	—	—	—	—	—	0.14Ω
0.900	—	—	—	—	0.255Ω	—	—	0.095Ω	—	—	—	0.10Ω	—
1.00	—	—	—	—	—	—	—	—	—	—	0.24Ω	—	—
1.10	—	—	—	—	0.200Ω	—	—	0.075Ω	—	—	—	0.075Ω	—
1.20	—	—	—	—	—	—	0.097Ω	—	—	—	—	—	0.080Ω
1.35	—	—	—	—	0.155Ω	—	0.080Ω	0.060Ω	—	—	—	0.060Ω	—
1.55	—	—	—	—	—	—	—	—	—	—	—	—	0.058Ω
1.60	—	—	—	—	0.115Ω	—	—	0.050Ω	—	—	—	0.050Ω	—
1.85	—	—	—	—	0.100Ω	—	—	0.045Ω	—	—	—	0.045Ω	—
1.90	—	—	—	—	—	—	0.054Ω	—	—	—	—	—	—
2.00	—	—	—	—	—	—	—	—	—	0.061Ω	—	—	—
2.50	—	—	—	—	0.065Ω	—	—	0.030Ω	0.038Ω	—	—	0.030Ω	—
3.00	—	—	—	—	0.050Ω	—	—	0.035Ω	0.0514Ω	—	—	—	—
3.75	—	—	—	—	0.040Ω	—	—	—	—	—	—	—	—
4.00	—	—	—	—	—	—	—	0.020Ω	0.030Ω	0.024Ω	—	—	—
4.50	—	—	—	—	—	—	—	—	—	0.029Ω	—	—	—
5.00	—	—	—	—	—	—	—	0.020Ω	0.0192Ω	—	—	—	—
6.00	—	—	—	—	—	—	—	0.013Ω	0.0145Ω	0.0175Ω	—	—	—
6.50	—	—	—	—	—	—	—	—	—	0.0144Ω	—	—	—
7.00	—	—	—	—	—	—	—	0.013Ω	0.0105Ω	—	—	—	—
7.50	—	—	—	—	—	—	—	—	—	0.012Ω	—	—	—
8.00	—	—	—	—	—	—	—	0.013Ω	0.0086Ω	—	—	—	—
9.00	—	—	—	—	—	—	—	0.008Ω	0.0070Ω	0.010Ω	—	—	—
10.0	—	—	—	—	—	—	—	—	0.0056Ω	0.0083Ω	—	—	—
11.0	—	—	—	—	—	—	—	—	0.0050Ω	—	—	—	—
12.0	—	—	—	—	—	—	—	—	0.0046Ω	—	—	—	—
13.0	—	—	—	—	—	—	—	—	—	0.0055Ω	—	—	—
14.0	—	—	—	—	—	—	—	—	0.0040Ω	—	—	—	—
15.0	—	—	—	—	—	—	—	—	—	0.0048Ω	—	—	—

*Refer to Telecommunications and Networking section for specific voltage rating information.

Table R2. Thermal Derating for Radial-leaded Devices [Hold Current (A) at Ambient Temperature (°C)]

	Maximum Ambient Temperature										
Part Number	**-40°C**	**-20°C**	**0°C**	**20°C**	**25°C**	**40°C**	**50°C**	**60°C**	**70°C**	**85°C**	**125°C**
LVR (Pb-free product) **240V$_{AC}$**											
New LVR005	—	0.08	0.06	0.05	0.05	0.04	0.04	0.03	0.03	0.02	—
New LVR008	—	0.12	0.10	0.08	0.08	0.07	0.06	0.05	0.04	0.03	—
New LVR012	—	0.18	0.15	0.12	0.12	0.10	0.09	0.07	0.06	0.04	—
New LVR016	—	0.24	0.20	0.16	0.16	0.13	0.11	0.10	0.08	0.05	—
New LVR025	—	0.38	0.32	0.26	0.25	0.21	0.18	0.15	0.13	0.09	—
New LVR033	—	0.50	0.42	0.34	0.33	0.27	0.23	0.20	0.17	0.11	—
New LVR040	—	0.61	0.51	0.41	0.40	0.33	0.28	0.24	0.20	0.14	—
New LVR055K	—	0.80	0.68	0.55	0.54	0.46	0.40	0.35	0.29	0.22	—
New LVR055S	—	0.80	0.68	0.55	0.54	0.46	0.40	0.35	0.29	0.22	—
BBR (BBRF for Pb-free version of product) **99V$_{AC}$**											
BBR550	0.85	0.75	0.65	0.55	—	0.45	0.40	0.35	0.3	0.22	—
BBR750	1.15	1.00	0.90	0.75	—	0.61	0.55	0.48	0.41	0.30	—
TR250, TR600 **60/600V** For a complete selection of the TR series see the Telecommunications and Network section.											
TR250-080U	0.124	0.110	0.095	0.080	0.077	0.066	0.059	0.051	0.044	0.033	—
TR250-120	0.186	0.165	0.143	0.120	0.115	0.099	0.088	0.077	0.066	0.050	—
TR250-145	0.225	0.199	0.172	0.145	0.139	0.119	0.106	0.093	0.080	0.060	—
TRF250-180	0.269	0.240	0.211	0.180	0.173	0.153	0.138	0.123	0.109	0.087	—
TR600-150	0.233	0.206	0.178	0.150	0.143	0.124	0.110	0.096	0.083	0.062	—
TR600-160	0.249	0.219	0.190	0.160	0.153	0.132	0.117	0.103	0.088	0.066	—
RXE (RXEF for Pb-free version of product) **60V**											
RXE005	0.078	0.068	0.06	0.05	0.048	0.04	0.035	0.032	0.027	0.02	—
RXE010	0.16	0.14	0.11	0.10	0.096	0.08	0.072	0.067	0.05	0.04	—
RXE017	0.26	0.23	0.21	0.17	0.16	0.14	0.12	0.11	0.09	0.07	—
RXE (RXEF for Pb-free version of product) **72V**											
RXE020	0.31	0.27	0.24	0.20	0.19	0.16	0.14	0.13	0.11	0.08	—
RXE025	0.39	0.34	0.30	0.25	0.24	0.20	0.18	0.16	0.14	0.10	—
RXE030	0.47	0.41	0.36	0.30	0.29	0.24	0.22	0.20	0.16	0.12	—
RXE040	0.62	0.54	0.48	0.40	0.38	0.32	0.29	0.25	0.22	0.16	—
RXE050	0.78	0.68	0.60	0.50	0.48	0.41	0.36	0.32	0.27	0.20	—
RXE065	1.01	0.88	0.77	0.65	0.62	0.53	0.47	0.41	0.35	0.26	—
RXE075	1.16	1.02	0.89	0.75	0.72	0.61	0.54	0.47	0.41	0.30	—
RXE090	1.40	1.22	1.07	0.90	0.86	0.73	0.65	0.57	0.49	0.36	—
RXE110	1.71	1.50	1.31	1.10	1.06	0.89	0.79	0.69	0.59	0.44	—
RXE135	2.09	1.84	1.61	1.35	1.30	1.09	0.97	0.85	0.73	0.54	—
RXE160	2.48	2.18	1.90	1.60	1.54	1.30	1.15	1.01	0.86	0.64	—
RXE185	2.87	2.52	2.20	1.85	1.78	1.50	1.33	1.17	1.00	0.74	—
RXE250	3.88	3.40	2.98	2.50	2.40	2.03	1.80	1.58	1.35	1.00	—
RXE300	4.65	4.08	3.57	3.00	2.88	2.43	2.16	1.89	1.62	1.20	—
RXE375	5.81	5.10	4.46	3.75	3.60	3.04	2.70	2.36	2.03	1.50	—

Table R2. Thermal Derating for Radial-leaded Devices [Hold Current (A) at Ambient Temperature (°C)] *continued*

	Maximum Ambient Temperature										
Part Number	**-40°C**	**-20°C**	**0°C**	**20°C**	**25°C**	**40°C**	**50°C**	**60°C**	**70°C**	**85°C**	**125°C**
RTE (RTEF for Pb-free version of product) **33V**											
RTE120	1.74	1.56	1.38	1.20	1.16	1.00	0.92	0.82	0.73	0.60	—
RTE135	1.96	1.76	1.55	1.35	1.31	1.12	1.04	0.92	0.82	0.68	—
RTE190	2.76	2.47	2.19	1.90	1.84	1.58	1.50	1.29	1.16	0.95	—
RUE (RUEF for Pb-free version of product) **30V**											
RUE090	1.31	1.17	1.04	0.90	0.87	0.75	0.69	0.61	0.55	0.47	—
RUE110	1.60	1.43	1.27	1.10	1.07	0.91	0.85	0.75	0.67	0.57	—
RUE135	1.96	1.76	1.55	1.35	1.31	1.12	1.04	0.92	0.82	0.70	—
RUE160	2.32	2.08	1.84	1.60	1.55	1.33	1.23	1.09	0.98	0.83	—
RUE185	2.68	2.41	2.13	1.85	1.79	1.54	1.42	1.26	1.13	0.96	—
RUE250	3.63	3.25	2.88	2.5	2.43	2.08	1.93	1.70	1.53	1.30	—
RUE300	4.35	3.90	3.45	3.0	2.91	2.49	2.31	2.04	1.83	1.56	—
RUE400	5.80	5.20	4.60	4.0	3.88	3.32	3.08	2.72	2.44	2.08	—
RUE500	7.25	6.50	5.75	5.0	4.85	4.15	3.85	3.40	3.05	2.60	—
RUE600	8.70	7.80	6.90	6.0	5.82	4.98	4.62	4.08	3.66	3.12	—
RUE700	10.15	9.10	8.05	7.0	6.79	5.81	5.39	4.76	4.27	3.64	—
RUE800	11.60	10.40	9.20	8.0	7.76	6.64	6.16	5.44	4.88	4.16	—
RUE900	13.05	11.70	10.35	9.0	8.73	7.47	6.93	6.12	5.49	4.68	—
RHE (RHEF for Pb-free version of product) **30V - High Temperature**											
New RHE050	0.68	0.62	0.56	0.51	0.5	0.44	0.40	0.36	0.34	0.28	0.12
New RHE070	0.95	0.87	0.79	0.72	0.7	0.62	0.56	0.51	0.47	0.39	0.17
New RHE100	1.36	1.24	1.13	1.03	1.00	0.89	0.80	0.73	0.67	0.56	0.24
RUSB (RUSBF for Pb-free version of product) **16V**											
RUSB090	1.31	1.17	1.04	0.90	0.87	0.75	0.69	0.61	0.55	0.47	—
RUSB110	1.60	1.43	1.27	1.10	1.07	1.00	0.92	0.75	0.67	0.57	—
RUSB135	1.96	1.76	1.55	1.35	1.31	1.12	1.04	0.92	0.82	0.70	—
RUSB160	2.32	2.08	1.84	1.60	1.55	1.33	1.23	1.09	0.98	0.83	—
RUSB185	2.68	2.41	2.13	1.85	1.79	1.54	1.42	1.26	1.13	0.96	—
RUSB250	3.63	3.25	2.88	2.50	2.43	2.08	1.93	1.70	1.53	1.30	—
RGE (RGEF for Pb-free version of product) **16V**											
New RGE250	3.7	3.3	3.0	2.6	2.5	2.2	2.0	1.3	1.6	1.2	—
RGE300	4.4	4.0	3.6	3.1	3.0	2.6	2.4	2.1	1.9	1.4	—
RGE400	5.9	5.3	4.8	4.1	4.0	3.5	3.2	2.8	2.5	1.9	—
RGE500	7.3	6.6	6.0	5.2	5.0	4.4	4.0	3.6	3.1	2.4	—
RGE600	8.8	8.0	7.2	6.2	6.0	5.2	4.8	4.2	3.8	2.8	—
RGE700	10.3	9.3	8.4	7.3	7.0	6.2	5.6	5.0	4.4	3.3	—
RGE800	11.7	10.7	9.6	8.3	8.0	6.9	6.4	5.6	5.1	3.7	—
RGE900	13.2	11.9	10.7	9.4	9.0	7.9	7.2	6.4	5.6	4.2	—
RGE1000	14.7	13.3	12.0	10.3	10.0	8.7	8.0	7.0	6.3	4.7	—
RGE1100	16.1	14.6	13.1	11.5	11.0	9.7	8.8	7.8	6.9	5.2	—
RGE1200	17.6	16.0	14.4	12.4	12.0	10.4	9.6	8.4	7.6	5.6	—
RGE1400	20.5	18.7	16.8	14.5	14.0	12.1	11.2	9.8	8.9	6.5	—

Table R2. Thermal Derating for Radial-leaded Devices [Hold Current (A) at Ambient Temperature (°C)] *continued*

Part Number	Maximum Ambient Temperature -40°C	-20°C	0°C	20°C	25°C	40°C	50°C	60°C	70°C	85°C	125°
RHE (RHEF for Pb-free version of product) 16V - High Temperature											
New RHE200	2.71	2.49	2.26	2.06	2.00	1.77	1.60	1.46	1.34	1.11	0.49
RHE400	5.40	5.00	4.60	4.10	4.00	3.50	3.20	3.00	2.60	2.20	0.98
RHE450	6.10	5.60	5.10	4.60	4.50	4.00	3.60	3.30	3.00	2.50	1.10
RHE600	8.20	7.50	6.80	6.20	6.00	5.30	4.90	4.40	4.00	3.30	1.50
RHE650	8.80	8.10	7.40	6.70	6.50	5.70	5.30	4.80	4.30	3.60	1.60
RHE750	10.20	9.40	8.60	7.70	7.50	6.60	6.10	5.60	5.00	4.10	1.90
New RHE900	12.21	11.19	10.16	9.26	9.00	7.97	7.20	6.56	6.04	5.01	2.19
RHE1000	13.60	12.50	11.40	10.30	10.00	8.80	8.10	7.40	6.60	5.50	2.50
RHE1300	17.70	16.30	14.80	13.40	13.00	11.40	10.50	9.60	8.60	7.20	3.30
RHE1500	20.40	18.80	17.10	15.50	15.00	13.20	12.10	11.10	9.90	8.30	3.80
RUSB (RUSBF for Pb-free version of product) 6V											
RUSB075	1.05	0.95	0.85	0.75	0.73	0.65	0.60	0.55	0.50	0.43	—
RUSB120	1.69	1.52	1.36	1.20	1.16	1.04	0.96	0.88	0.80	0.68	—
RUSB155	2.17	1.96	1.75	1.55	1.50	1.34	1.24	1.14	1.03	0.88	—

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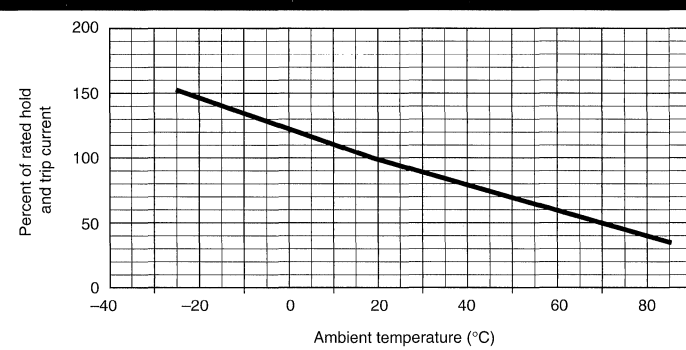
Figures R1–R5. Thermal Derating Curves for Radial-leaded Devices

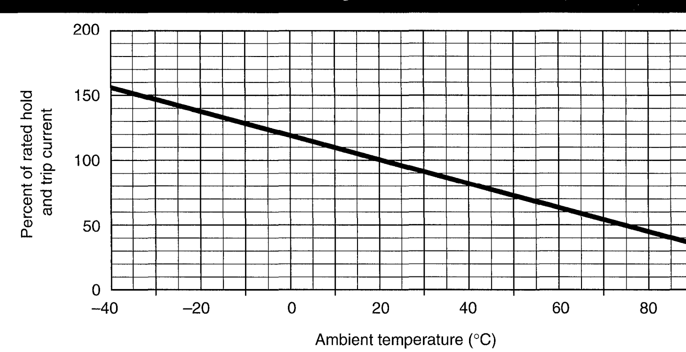
LVR

Figure R1



RXE/RXEF and BBR/BBRF

Figure R2

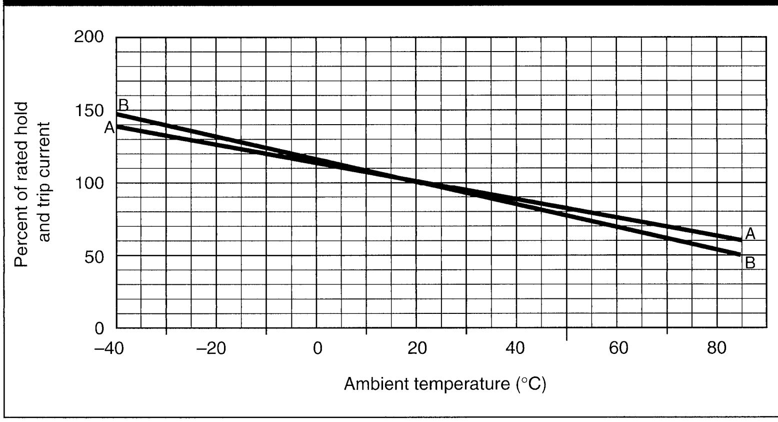


Figures R1–R5. Thermal Derating Curve for Radial-leaded Devices *continued*

A = RUSB075/RUSBF075 RUSB120/RUSBF120 and RUSB155/RUSBF155 devices

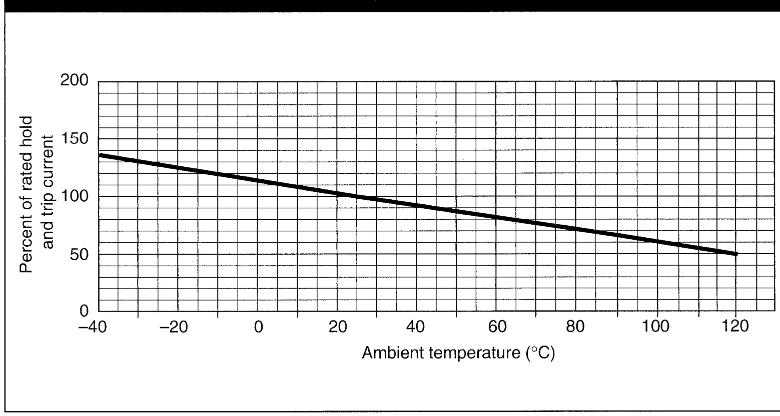
B = RUE/RUEF, RTE/RTEF, and all other RUSB/RUSBF devices

Figure R3



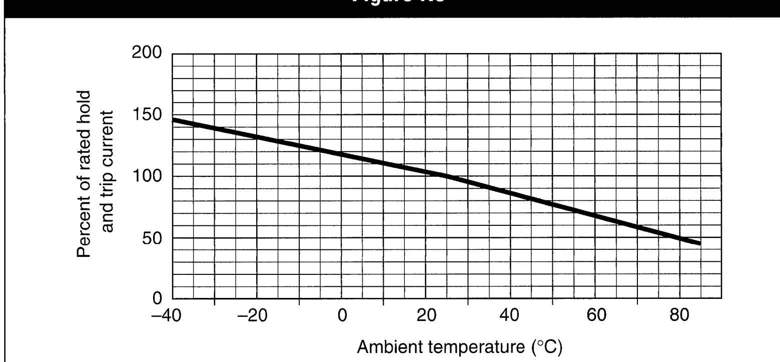
RHE/RHEF

Figure R4



RGE/RGEF

Figure R5



For thermal derating of all TR series see the Telecommunications and Networking section.

Table R3. Electrical Characteristics for Radial-leaded Devices

Part Number	I_H (A)	I_T (A)	V_{MAX} (V)	V_{MAX} Interrupt (V_{AC})	I_{MAX} (A)	$P_{D\ TYP}$ (W)	Max. Time-to-trip (A)	Max. Time-to-trip (s)	R_{MIN} (Ω)	R_{MAX} (Ω)	$R_{1\ MAX}$ (Ω)	Figures for Dimensions	Lead Size [mm² (AWG)]
LVR (Pb-free product) **240V_{AC}**													
LVR005K	0.05	0.12	240	265	1.0	0.7	0.25	15	18.5	31.0	65.0	R7	[0.205mm²(24)]
LVR005S	0.05	0.12	240	265	1.0	0.7	0.25	15	18.5	31.0	65.0	R7	[0.205mm²(24)]
LVR008K	0.08	0.19	240	265	1.2	0.8	0.4	15	7.4	12.0	26.0	R7	[0.205mm²(24)]
LVR008S	0.08	0.19	240	265	1.2	0.8	0.4	15	7.4	12.0	26.0	R7	[0.205mm²(24)]
LVR012K	0.12	0.30	240	265	1.2	1.0	0.6	15	3.0	6.5	12.0	R7	[0.205mm²(24)]
LVR012S	0.12	0.30	240	265	1.2	1.0	0.6	15	3.0	6.5	12.0	R7	[0.205mm²(24)]
LVR016K	0.16	0.37	240	265	2.0	1.4	0.8	15	2.5	4.1	7.8	R7	[0.205mm²(24)]
LVR016S	0.16	0.37	240	265	2.0	1.4	0.8	15	2.5	4.1	7.8	R7	[0.205mm²(24)]
LVR025K	0.25	0.56	240	265	3.5	1.5	1.25	18.5	1.3	2.1	3.8	R8	[0.33mm²(22)]
LVR025S	0.25	0.56	240	265	3.5	1.5	1.25	18.5	1.3	2.1	3.8	R8	[0.33mm²(22)]
LVR033S	0.33	0.74	240	265	4.5	1.7	1.25	18.5	0.83	1.24	2.6	R8	[0.33mm²(22)]
LVR033K	0.33	0.74	240	265	4.5	1.7	1.25	18.5	0.83	1.24	2.6	R8	[0.33mm²(22)]
LVR040K	0.40	0.90	240	265	5.5	2.0	2.0	24.0	0.6	0.97	1.9	R8	[0.33mm²(22)]
LVR040S	0.40	0.90	240	265	5.5	2.0	2.0	24.0	0.6	0.97	1.9	R8	[0.33mm²(22)]
LVR055K	0.55	1.25	240	265	7.0	3.4	2.75	26.0	0.45	0.73	1.45	R8	[0.52mm²(20)]
LVR055S	0.55	1.25	240	265	7.0	3.4	2.75	26.0	0.45	0.73	1.45	R8	[0.52mm²(20)]
BBR (BBRF for Pb-free version of product) **99V_{AC}**													
BBR550	0.55	1.1	99	—	20	1.5	1.6	60	0.8	1.3	1.95	R6, R15, R16	[0.52mm² (20)]
BBR750	0.75	1.5	99	—	20	1.7	2.0	60	0.40	0.75	1.2	R6, R15, R16	[0.52mm² (20)]
TR250, TR600 **60/600V Product** For a complete selection of the TR devices, see the Telecommunications and Networking section.													
TR250-080U	0.080	0.160	60	250	3.0	1.0	0.35	3.0	14.0	20.0	33.0	R7	[0.33mm² (22)]
TR250-120	0.120	0.240	60	250	3.0	1.0	1.0	1.5*	4.0	8.0	16.0	R8	[0.33mm² (22)]
TR250-145	0.145	0.290	60	250	3.0	1.0	1.0	2.5*	3.0	6.0	14.0	R8	[0.33mm² (22)]
TR250-180U	0.180	0.360	60	250	10.0	1.0	1.0	12.0*	0.8	2.0	4.0	R8	[0.33mm² (22)]
TR600-150	0.150	0.300	60	250	3.0	1.0	1.0	5.0*	6.0	12.0	22.0	R8	[0.33mm² (22)]
TR600-160	0.160	0.320	60	250	3.0	1.0	1.0	7.0*	4.0	10.0	18.0	R8	[0.33mm² (22)]

*Time-to-trip value is typical.

Part Number	I_H (A)	I_T (A)	V_{MAX} (V)	V_{MAX} Interrupt (V_{AC})	I_{MAX} (A)	$P_{D\ TYP}$ (W)	Max. Time-to-trip (A)	Max. Time-to-trip (s)	R_{MIN} (Ω)	R_{MAX} (Ω)	$R_{1\ MAX}$ (Ω)	Figures for Dimensions	Lead Size [mm² (AWG)]
RXE (RXEF for Pb-free version of product) **60V**													
RXE005	0.05	0.10	60	—	40	0.26	0.25	5.0	7.3	11.10	20.0	R9, R15, R16	[0.128mm² (26)]
RXE010	0.10	0.20	60	—	40	0.38	0.50	4.0	2.5	4.50	7.5	R10, R15, R16	[0.205mm² (24)]
RXE017	0.17	0.34	60	—	40	0.48	0.85	3.0	3.3	5.21	8.0	R10, R15, R16	[0.205mm² (24)]
RXE (RXEF for Pb-free version of product) **72V**													
RXE020	0.20	0.40	72	—	40	0.41	1.00	2.2	1.83	2.75	4.40	R10, R15, R16	[0.205mm² (24)]
RXE025	0.25	0.50	72	—	40	0.45	1.25	2.5	1.25	1.95	3.00	R10, R15, R16	[0.205mm² (24)]
RXE030	0.30	0.60	72	—	40	0.49	1.50	3.0	0.88	1.33	2.10	R10, R15, R16	[0.205mm² (24)]
RXE040	0.40	0.80	72	—	40	0.56	2.00	3.8	0.55	0.86	1.29	R10, R15, R16	[0.205mm² (24)]
RXE050	0.50	1.00	72	—	40	0.77	2.50	4.0	0.50	0.77	1.17	R10, R15, R16	[0.205mm² (24)]
RXE065	0.65	1.30	72	—	40	0.88	3.25	5.3	0.31	0.48	0.72	R10, R15, R16	[0.205mm² (24)]
RXE075	0.75	1.50	72	—	40	0.92	3.75	6.3	0.25	0.40	0.60	R10, R15, R16	[0.205mm² (24)]
RXE090	0.90	1.80	72	—	40	0.99	4.50	7.2	0.20	0.31	0.47	R10, R15, R16	[0.205mm² (24)]
RXE110	1.10	2.20	72	—	40	1.50	5.50	8.2	0.15	0.25	0.38	R11, R15, R16	[0.52mm² (20)]
RXE135	1.35	2.70	72	—	40	1.70	6.75	9.6	0.12	0.19	0.30	R11, R15, R16	[0.52mm² (20)]
RXE160	1.60	3.20	72	—	40	1.90	8.00	11.4	0.09	0.14	0.22	R11, R15, R16	[0.52mm² (20)]
RXE185	1.85	3.70	72	—	40	2.10	9.25	12.6	0.08	0.12	0.19	R11, R15, R16	[0.52mm² (20)]
RXE250	2.50	5.00	72	—	40	2.50	12.50	15.6	0.05	0.08	0.13	R11, R15, R16	[0.52mm² (20)]
RXE300	3.00	6.00	72	—	40	2.80	15.00	19.8	0.04	0.06	0.10	R11, R15, R16	[0.52mm² (20)]
RXE375	3.75	7.50	72	—	40	3.20	18.75	24.0	0.03	0.05	0.08	R11, R15, R16	[0.52mm² (20)]

Table R3. Electrical Characteristics for Radial-leaded Devices *continued*

Part Number	I_H (A)	I_T (A)	V_{MAX} (V)	V_{MAX} Interrupt (V_{RMS})	I_{MAX} (A)	$P_{D\ TYP}$ (W)	Max. Time-to-trip (A)	Max. Time-to-trip (s)	R_{MIN} (Ω)	R_{MAX} (Ω)	$R_{1\ MAX}$ (Ω)	Figures for Dimensions	Lead Size [mm² (AWG)]
RTE (RTEF for Pb-free version of product) **33V**													
RTE120	1.20	2.3	33	—	40	0.78	6.0	3.5	0.074	0.12	0.18	R12, R15, R16	[0.205mm² (24)]
RTE135	1.35	2.5	33	—	40	0.84	6.75	4.5	0.059	0.10	0.143	R12, R15, R16	[0.205mm² (24)]
RTE190	1.90	3.0	33	—	40	0.90	9.5	3.5	0.045	0.063	0.092	R12, R15, R16	[0.205mm² (24)]
RUE (RUEF for Pb-free version of product) **30V**													
RUE090	0.90	1.8	30	—	40	0.6	4.5	5.9	0.070	0.12	0.22	R12, R15, R16	[0.205mm² (24)]
RUE110	1.10	2.2	30	—	40	0.7	5.5	6.6	0.050	0.10	0.17	R12, R15, R16	[0.205mm² (24)]
RUE135	1.35	2.7	30	—	40	0.8	6.75	7.3	0.040	0.08	0.13	R12, R15, R16	[0.205mm² (24)]
RUE160	1.60	3.2	30	—	40	0.9	8.5	8.0	0.030	0.07	0.11	R12, R15, R16	[0.205mm² (24)]
RUE185	1.85	3.7	30	—	40	1.0	9.25	8.7	0.030	0.06	0.09	R12, R15, R16	[0.205mm² (24)]
RUE250	2.5	5.0	30	—	40	1.2	12.5	10.3	0.020	0.04	0.07	R12, R15, R16	[0.205mm² (24)]
RUE300	3.0	6.0	30	—	40	2.0	15.0	10.8	0.020	0.05	0.08	R13, R15, R16	[0.52mm² (20)]
RUE400	4.0	8.0	30	—	40	2.5	20.0	12.7	0.010	0.03	0.05	R13, R15, R16	[0.52mm² (20)]
RUE500	5.0	10.0	30	—	40	3.0	25.0	14.5	0.010	0.03	0.05	R13, R15, R16	[0.52mm² (20)]
RUE600	6.0	12.0	30	—	40	3.5	30.0	16.0	0.005	0.02	0.04	R13, R15, R16	[0.52mm² (20)]
RUE700	7.0	14.0	30	—	40	3.8	35.0	17.5	0.005	0.02	0.03	R13, R15, R16	[0.52mm² (20)]
RUE800	8.0	16.0	30	—	40	4.0	40.0	18.8	0.005	0.013	0.02	R13, R15, R16	[0.52mm² (20)]
RUE900	9.0	18.0	30	—	40	4.2	45.0	20.0	0.005	0.01	0.02	R13, R15, R16	[0.52mm² (20)]
RHE (RHEF for Pb-free version of product) **30V - High Temperature**													
New RHE050†	0.50	0.90	30	—	40	0.9	2.5	2.5	0.48	0.79	1.1	R10, R15, R16	[0.205mm² (24)]
New RHE070†	0.7	1.4	16	—	40	1.4	3.5	4.0	0.30	0.54	0.8	R12, R15, R16	[0.205mm² (24)]
New RHE100†	1.0	1.8	30	—	40	1.4	5.0	5.2	0.18	0.31	0.43	R10, R15, R16	[0.205mm² (24)]
RUSB (RUSBF for Pb-free version of product) **16V**													
RUSB090	0.90	1.8	16	—	40	0.6	8.0	1.2	0.070	0.120	0.180	R12, R15, R16	[0.205mm² (24)]
RUSB110	1.10	2.2	16	—	40	0.7	8.0	2.3	0.050	0.095	0.140	R12, R15, R16	[0.205mm² (24)]
RUSB135	1.35	2.7	16	—	40	0.8	8.0	4.5	0.040	0.074	0.115	R12, R15, R16	[0.205mm² (24)]
RUSB160	1.60	3.2	16	—	40	0.9	8.0	9.0	0.030	0.061	0.110	R12, R15, R16	[0.205mm² (24)]
RUSB185	1.85	3.7	16	—	40	1.0	8.0	10.0	0.030	0.051	0.090	R12, R15, R16	[0.205mm² (24)]
RUSB250	2.5	5.0	16	—	40	1.2	8.0	40.0	0.020	0.036	0.060	R12, R15, R16	[0.205mm² (24)]
RGE (RGEF for Pb-free version of product) **16V**													
New RGE250†	2.5	4.7	16	—	100	1.0	12.5	5.0	0.022	0.035	0.053	R12, R15, R16	[0.205mm² (24)]
RGE300†	3.0	5.1	16	—	100	2.3	15.0	1.0	0.038	0.0645	0.0975	R13, R15, R16	[0.52mm² (20)]
RGE400†	4.0	6.8	16	—	100	2.4	20.0	1.7	0.021	0.0385	0.0600	R13, R15, R16	[0.52mm² (20)]
RGE500†	5.0	8.5	16	—	100	2.6	25.0	2.0	0.015	0.0230	0.0340	R13, R15, R16	[0.52mm² (20)]
RGE600†	6.0	10.2	16	—	100	2.8	30.0	3.3	0.010	0.0185	0.0280	R13, R15, R16	[0.52mm² (20)]
RGE700†	7.0	11.9	16	—	100	3.0	35.0	3.5	0.0077	0.0130	0.0200	R13, R15, R16	[0.52mm² (20)]
RGE800†	8.0	13.6	16	—	100	3.0	40.0	5.0	0.0056	0.0110	0.0175	R13, R15, R16	[0.52mm² (20)]
RGE900†	9.0	15.3	16	—	100	3.3	45.0	5.5	0.0047	0.0092	0.0135	R13, R15, R16	[0.52mm² (20)]
RGE1000†	10.0	17.0	16	—	100	3.6	50.0	6.0	0.0040	0.0071	0.0102	R13, R15, R16	[0.52mm² (20)]
RGE1100†	11.0	18.7	16	—	100	3.7	55.0	7.0	0.0037	0.0062	0.0089	R13, R15, R16	[0.52mm² (20)]
RGE1200†	12.0	20.4	16	—	100	4.2	60.0	7.5	0.0033	0.00595	0.0086	R13, R15, R16	[0.823mm² (18)]
RGE1400†	14.0	23.8	16	—	100	4.6	70.0	9.0	0.0026	0.00445	0.0064	R13, R15, R16	[0.823mm² (18)]

†Electrical characteristics determined at 25ºC.

Table R3. Electrical Characteristics for Radial-leaded Devices *continued*

Part Number	I_H (A)	I_T (A)	V_{MAX} (V)	V_{MAX} Interrupt (V_{AC})	I_{MAX} (A)	$P_{D\ TYP}$ (W)	Max. Time-to-trip (A)	Max. Time-to-trip (s)	R_{MIN} (Ω)	R_{MAX} (Ω)	$R_{1\ MAX}$ (Ω)	Figures for Dimensions	Lead Size [mm² (AWG)]
RHE High Temperature (RHEF for Pb-free version of product)													
16V													
New RHE200†	2.0	3.8	16	—	100	1.4	12.5	3.0	0.045	0.074	0.11	R10, R15, R16	[0.205mm² (24)]
RHE400†	4.0	7.0	16	—	100	2.0	20.0	8.0	0.018	0.029	0.044	R14, R15, R16	[0.205mm² (24)]
RHE450†	4.5	7.8	16	—	100	3.6	22.5	3.0	0.022	0.0355	0.054	R14, R15, R16	[0.579mm² (20)]
RHE600†	6.0	10.8	16	—	100	4.1	30.0	5.0	0.013	0.0215	0.032	R14, R15, R16	[0.579mm² (20)]
RHE650†	6.5	12.0	16	—	100	4.3	32.5	5.5	0.011	0.0175	0.026	R14, R15, R16	[0.579mm² (20)]
RHE750†	7.5	13.1	16	—	100	4.5	37.5	7.0	0.0094	0.0150	0.022	R14, R15, R16	[0.579mm² (20)]
New RHE900†	9.0	16.5	16	—	100	5.0	45	10.0	0.0074	0.0120	0.017	R14, R15, R16	[0.579mm² (20)]
RHE1000†	10.0	18.5	16	—	100	5.3	50.0	9.0	0.0062	0.0103	0.015	R14, R15, R16	[0.579mm² (20)]
RHE1300†	13.0	24.0	16	—	100	6.9	65.0	13.0	0.0041	0.0068	0.010	R14, R15, R16	[0.823mm² (18)]
RHE1500†	15.0	28.0	16	—	100	7.0	75.0	20.0	0.0032	0.0063	0.0092	R14, R15, R16	[0.823mm² (18)]
RUSB (RUSBF for Pb-free version of product)													
6V													
RUSB075	0.75	1.30	6	—	40	0.3	8.0	0.4	0.110	0.175	0.23	R10, R15, R16	[0.205mm² (24)]
RUSB120	1.20	2.00	6	—	40	0.6	8.0	0.5	0.065	0.0975	0.14	R10, R15, R16	[0.205mm² (24)]
RUSB155	1.55	2.65	6	—	40	0.6	8.0	0.5	0.043	0.0705	0.10	R10, R15, R16	[0.205mm² (24)]

Notes:

I_H = Hold current: maximum current device will pass without interruption in 20°C still air.

I_T = Trip current: minimum current that will switch the device from low resistance to high resistance in 20°C still air.

R_{MIN} = Minimum resistance of device as supplied at 20°C unless otherwise specified.

R_{MAX} = Maximum resistance of device as supplied at 20°C unless otherwise specified.

V_{MAX} = Maximum continuous voltage device can withstand without damage at rated current.

V_{MAX} Interrupt = Under specified conditions this is the highest voltage that can be applied to the device at the maximum current.

I_{MAX} = Maximum fault current device can withstand without damage at rated voltage.

P_D = Power dissipated from device when in the tripped state in 20°C still air.

$R_{1\ MAX}$ = Maximum resistance of device when measured one hour post reflow (surface-mount device) or one hour post trip (radial leaded device) at 20°C unless otherwise specified.

†Electrical characteristics determined at 25°C.

Figures R6–R16. Physical Description for Dimensions for Radial-leaded Devices

Figure R6

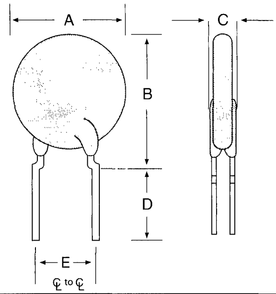


Figure R7

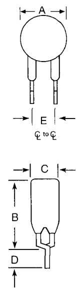


Figure R8

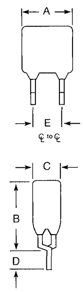


Figure R9

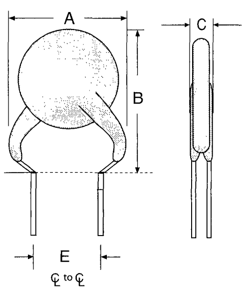


Figure R10

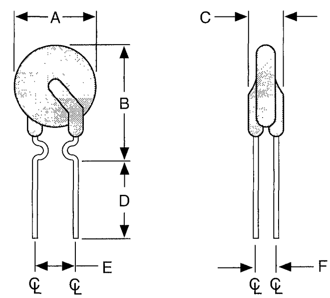


Figure R11

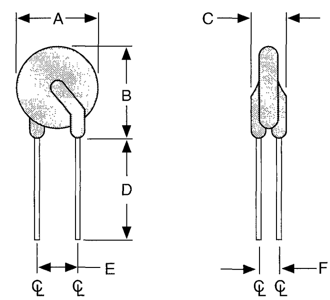


Figure R12

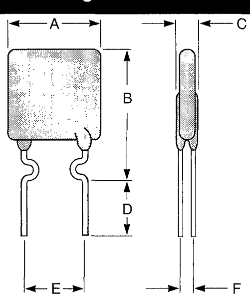


Figure R13

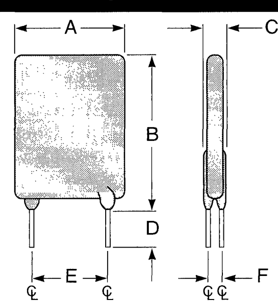


Figure R14

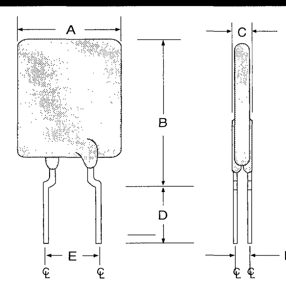


Figure R15

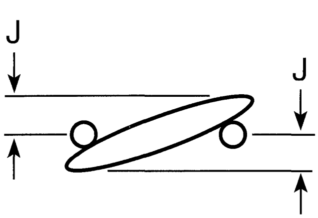


Figure R16

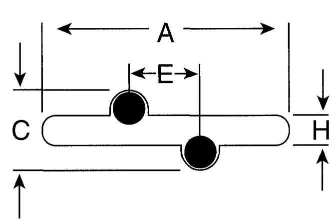


Table R4. Dimensions for Radial-leaded Devices in Millimeters (Inches)

	Dimension													
	A		B		C		D		E		F	H	J	
Part Number	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Typ.	Typ.	Typ.	Figures
LVR 240V														
LVR005K	—	8.3 (0.33)	—	12.9 (0.51)	—	3.8 (0.15)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	R7
LVR005S	—	8.3 (0.33)	—	10.7 (0.43)	—	3.8 (0.15)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	R7
LVR008K	—	8.3 (0.33)	—	12.9 (0.51)	—	3.8 (0.15)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	R7
LVR008S	—	8.3 (0.33)	—	10.7 (0.43)	—	3.8 (0.15)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	R7
LVR012K	—	8.3 (0.33)	—	12.9 (0.51)	—	3.8 (0.15)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	R7
LVR012S	—	8.3 (0.33)	—	10.7 (0.43)	—	3.8 (0.15)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	—
LVR016K	—	9.9 (0.39)	—	13.8 (0.54)	—	3.8 (0.15)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	R7
LVR016S	—	9.9 (0.39)	—	12.5 (0.50)	—	3.8 (0.15)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	R7
LVR025K	—	9.6 (0.38)	—	18.8 (0.74)	—	3.8 (0.15)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	R8
LVR025S	—	9.6 (0.38)	—	17.4 (0.69)	—	3.8 (0.15)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	R8
LVR033S	—	11.4 (0.45)	—	16.5 (0.65)	4.3 (0.17)	5.8 (0.23)	7.6 (0.30)	—	—	3.8 (0.15)	—	—	—	R8
LVR033K	—	11.4 (0.45)	—	19.0 (0.75)	4.3 (0.17)	5.8 (0.23)	7.6 (0.30)	—	—	3.8 (0.15)	—	—	—	R8
LVR040K	—	11.5 (0.46)	—	20.9 (0.82)	—	3.8 (0.15)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	R8
LVR040S	—	11.5 (0.46)	—	19.5 (0.77)	—	3.8 (0.15)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	R8
LVR055K	—	14.0 (0.55)	—	21.7 (0.85)	—	5.8 (0.23)	7.6 (0.30)	—	2.0 (0.08)	3.0 (0.12)	—	—	—	R8
LVR055S	—	14.0 (0.55)	—	21.7 (0.85)	—	5.8 (0.23)	7.6 (0.30)	—	—	3.8 (0.15)	—	—	—	R8
BBR 99V														
BBR550	—	10.9 (0.43)	—	14.0 (0.55)	—	3.6 (0.14)	7.6 (0.3)	—	4.3 (0.17)	5.8 (0.23)	—	1.37 (0.054)	1.2 (0.05)	R6, R15, R16
BBR750	—	11.9 (0.47)	—	15.5 (0.61)	—	3.6 (0.14)	7.6 (0.3)	—	4.3 (0.17)	5.8 (0.23)	—	1.37 (0.054)	1.2 (0.05)	R6, R15, R16
TR250, TR600 60/600V														
TR250-080U	—	4.8 (0.189)	—	9.3 (0.366)	—	3.8 (0.15)	4.7 (0.185)	—	5.00* (0.197)	—	—	—	—	R7
TR250-120	—	6.5 (0.256)	—	11.0 (0.433)	—	4.6 (0.180)	4.7 (0.185)	—	5.00 (0.197)	—	—	—	—	R8
TR250-145	—	6.5 (0.256)	—	11.0 (0.433)	—	4.6 (0.180)	4.7 (0.185)	—	5.00* (0.197)	—	—	—	—	R8
TR250-180U	—	10.4 (0.410)	—	12.6 (0.495)	—	3.6 (0.140)	4.7 (0.185)	—	5.00* (0.197)	—	—	—	—	R8
TR600-150	—	13.5 (0.531)	—	12.6 (0.495)	—	6.0 (0.236)	4.7 (0.185)	—	5.00* (0.197)	—	—	—	—	R8
TR600-160	—	16.0 (0.630)	—	12.6 (0.495)	—	6.0 (0.236)	4.7 (0.185)	—	5.00* (0.197)	—	—	—	—	R8

*Indicates dimension is typical, not minimum.

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Table R4. Dimensions for Radial-leaded Devices in Millimeters (Inches) *continued*

	Dimension													
	A		B		C		D		E		F	H	J	
Part Number	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Typ.**	**Typ.**	**Typ.**	**Figures**
RXE 60V														
RXE005		8.0 (0.32)		8.3 (0.33)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.07 (0.04)	1.0 (0.04)	R9, R15, R16
RXE010	—	7.4 (0.29)	—	11.6 (0.46)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.07 (0.042)	1.0 (0.04)	R10, R15, R16
RXE017	—	7.4 (0.29)	—	11.6 (0.46)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.68 (0.066)	1.7 (0.07)	R10, R15, R16
RXE 72V														
RXE020	—	7.4 (0.29)	—	11.7 (0.46)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.17 (0.046)	1.0 (0.04)	R10, R15, R16
RXE025	—	7.4 (0.29)	—	12.7 (0.50)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.17 (0.046)	1.0 (0.04)	R10, R15, R16
RXE030	—	7.4 (0.29)	—	12.7 (0.50)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.17 (0.046)	1.0 (0.04)	R10, R15, R16
RXE040	—	7.6 (0.30)	—	13.5 (0.53)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.17 (0.046)	1.2 (0.05)	R10, R15, R16
RXE050	—	7.9 (0.31)	—	13.7 (0.54)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.17 (0.046)	1.2 (0.05)	R10, R15, R16
RXE065	—	9.4 (0.37)	—	14.5 (0.57)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.17 (0.046)	1.5 (0.06)	R10, R15, R16
RXE075	—	10.2 (0.40)	—	15.2 (0.60)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.17 (0.046)	1.5 (0.06)	R10, R15, R16
RXE090	—	11.2 (0.44)	—	15.8 (0.62)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.17 (0.046)	1.5 (0.06)	R10, R15, R16
RXE110	—	12.8 (0.50)	—	17.5 (0.69)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.37 (0.054)	1.2 (0.05)	R11, R15, R16
RXE135	—	14.5 (0.57)	—	19.1 (0.75)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.37 (0.054)	1.2 (0.05)	R11, R15, R16
RXE160	—	16.3 (0.64)	—	20.8 (0.82)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.37 (0.054)	1.5 (0.06)	R11, R15, R16
RXE185	—	17.5 (0.69)	—	22.4 (0.88)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.37 (0.054)	1.5 (0.06)	R11, R15, R16
RXE250	—	20.8 (0.82)	—	25.4 (1.00)	—	3.0 (0.12)	7.6 (0.30)	—	9.4 (0.37)	10.9 (0.43)	—	1.37 (0.054)	1.7 (0.07)	R11, R15, R16
RXE300	—	23.9 (0.94)	—	28.6 (1.13)	—	3.0 (0.12)	7.6 (0.30)	—	9.4 (0.37)	10.9 (0.43)	—	1.37 (0.054)	1.7 (0.07)	R11, R15, R16
RXE375	—	27.2 (1.07)	—	31.8 (1.25)	—	3.0 (0.12)	7.6 (0.30)	—	9.4 (0.37)	10.9 (0.43)	—	1.37 (0.054)	1.7 (0.07)	R11, R15, R16
RTE 33V														
RTE120	—	7.4 (0.29)	—	12.2 (0.48)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	0.89 (0.035)	0.8 (0.03)	R12, R15, R16
RTE135	—	7.4 (0.29)	—	14.2 (0.56)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	0.89 (0.035)	0.8 (0.03)	R12, R15, R16
RTE190	—	8.9 (0.35)	—	13.5 (0.53)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	0.89 (0.035)	1.0 (0.04)	R12, R15, R16
RUE 30V														
RUE090	—	7.4 (0.29)	—	12.2 (0.48)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	0.89 (0.035)	0.8 (0.03)	R12, R15, R16
RUE110	—	7.4 (0.29)	—	14.2 (0.56)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	0.89 (0.035)	0.8 (0.03)	R12, R15, R16
RUE135	—	8.9 (0.35)	—	13.5 (0.53)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	0.89 (0.035)	1.0 (0.04)	R12, R15, R16

Table R4. Dimensions for Radial-leaded Devices in Millimeters (Inches) *continued*

	Dimension													
	A		B		C		D		E		F	H	J	
Part Number	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Typ.**	**Typ.**	**Typ.**	**Figures**
RUE *continued* **30V**														
RUE160	—	8.9 (0.35)	—	15.2 (0.60)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	0.89 (0.035)	1.0 (0.04)	R12, R15, R16
RUE185	—	10.2 (0.40)	—	15.7 (0.62)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	0.89 (0.035)	1.0 (0.04)	R12, R15, R16
RUE250	—	11.4 (0.45)	—	18.3 (0.72)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	0.89 (0.035)	1.2 (0.05)	R12, R15, R16
RUE300	—	11.4 (0.45)	—	16.5 (0.65)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.19 (0.047)	1.5 (0.06)	R13, R15, R16
RUE400	—	14.0 (0.55)	—	19.3 (0.76)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	1.19 (0.047)	1.7 (0.07)	R13, R15, R16
RUE500	—	14.0 (0.55)	—	24.1 (0.95)	—	3.0 (0.12)	7.6 (0.30)	—	9.4 (0.37)	10.9 (0.43)	—	1.19 (0.047)	1.0 (0.04)	R13, R15, R16
RUE600	—	16.5 (0.65)	—	24.1 (0.95)	—	3.0 (0.12)	7.6 (0.30)	—	9.4 (0.37)	10.9 (0.43)	—	1.19 (0.047)	1.0 (0.04)	R13, R15, R16
RUE700	—	19.1 (0.75)	—	25.9 (1.02)	—	3.0 (0.12)	7.6 (0.30)	—	9.4 (0.37)	10.9 (0.43)	—	1.19 (0.047)	1.2 (0.05)	R13, R15, R16
RUE800	—	21.6 (0.85)	—	28.4 (1.12)	—	3.0 (0.12)	7.6 (0.30)	—	9.4 (0.37)	10.9 (0.43)	—	1.19 (0.047)	1.5 (0.06)	R13, R15, R16
RUE900	—	24.1 (0.95)	—	29.0 (1.14)	—	3.0 (0.12)	7.6 (0.30)	—	9.4 (0.37)	10.9 (0.43)	—	1.19 (0.047)	1.5 (0.06)	R13, R15, R16
RHE **30V - High Temperature**														
RHE050 New	—	7.4 (0.29)	—	12.7 (0.50)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.21 (0.05)	—	—	—
RHE070 New	—	6.86 (0.27)	—	10.8 (0.425)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	1.24 (0.049)	1.2 (0.05)	R12, R15, R16
RHE100 New	—	9.7 (0.38)	—	13.6 (0.54)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	—
RUSB **16V**														
RUSB090	—	7.4 (0.29)	—	12.2 (0.48)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	0.89 (0.035)	0.8 (0.03)	R12, R15, R16
RUSB110	—	7.4 (0.29)	—	14.2 (0.56)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	0.89 (0.035)	0.8 (0.03)	R12, R15, R16
RUSB135	—	8.9 (0.35)	—	13.5 (0.53)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	0.89 (0.035)	1.0 (0.04)	R12, R15, R16
RUSB160	—	8.9 (0.35)	—	15.2 (0.60)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	0.89 (0.035)	1.0 (0.04)	R12, R15, R16
RUSB185	—	10.2 (0.40)	—	15.7 (0.62)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	0.89 (0.035)	1.0 (0.04)	R12, R15, R16
RUSB250	—	11.4 (0.45)	—	18.3 (0.72)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	0.89 (0.035)	1.2 (0.05)	R12, R15, R16
RGE **16V**														
New RGE250	—	8.9 (0.35)	—	12.8 (0.50)	—	3.0 (0.12)	3.18 (0.13)	6.18 (0.24)	4.3 (0.17)	5.8 (0.23)	1.21 (0.05)	1.24 (0.049)	1.2 (0.05)	R12, R15, R16
RGE300	6.1 (0.24)	7.1 (0.28)	6.1 (0.24)	11.0 (0.43)	2.0 (0.08)	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.21 (0.05)	1.24 (0.049)	1.2 (0.05)	R13, R15, R16
RGE400	7.9 (0.31)	8.9 (0.35)	7.9 (0.31)	12.8 (0.50)	2.0 (0.08)	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.21 (0.05)	1.24 (0.049)	1.4 (0.055)	R13, R15, R16
RGE500	9.4 (0.37)	10.4 (0.41)	9.4 (0.37)	14.3 (0.56)	2.0 (0.08)	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.21 (0.05)	1.24 (0.049)	1.6 (0.06)	R13, R15, R16
RGE600	9.7 (0.38)	10.7 (0.42)	12.2 (0.48)	17.1 (0.67)	2.0 (0.08)	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.21 (0.05)	1.24 (0.049)	1.6 (0.06)	R13, R15, R16

Table R4. Dimensions for Radial-leaded Devices in Millimeters (Inches) *continued*

	Dimension													
	A		B		C		D		E		F	H	J	
Part Number	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Typ.	Typ.	Typ.	Figures
RGE *continued* 16V														
RGE700	10.2 (0.40)	11.2 (0.44)	14.7 (0.58)	19.7 (0.78)	2.0 (0.08)	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.21 (0.05)	1.24 (0.049)	1.7 (0.067)	R13, R15, R16
RGE800	11.7 (0.46)	12.7 (0.50)	16.0 (0.63)	20.9 (0.82)	2.0 (0.08)	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.21 (0.05)	1.24 (0.049)	1.8 (0.07)	R13, R15, R15
RGE900	13.0 (0.51)	14.0 (0.55)	16.8 (0.66)	21.7 (0.85)	2.0 (0.08)	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.21 (0.05)	1.24 (0.049)	2.0 (0.08)	R13, R15, R16
RGE1000	15.5 (0.61)	16.5 (0.65)	21.1 (0.83)	25.2 (0.99)	2.0 (0.08)	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.21 (0.05)	1.24 (0.049)	2.0 (0.08)	R13, R15, R16
RGE1100	16.5 (0.65)	17.5 (0.69)	21.1 (0.83)	26.0 (1.02)	2.0 (0.08)	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	1.24 (0.049)	2.4 (0.09)	R13, R15, R16
RGE1200	16.4 (0.65)	17.5 (0.69)	22.6 (0.89)	28.0 (1.10)	2.3 (0.09)	3.5 (0.14)	7.6 (0.30)	—	9.4 (0.37)	10.9 (0.43)	1.4 (0.06)	1.45 (0.057)	1.5 (0.06)	R13, R15, R16
RGE1400	22.4 (0.88)	23.5 (0.925)	22.6 (0.89)	27.9 (1.10)	2.3 (0.09)	3.5 (0.14)	7.6 (0.30)	—	9.4 (0.37)	10.9 (0.43)	1.4 (0.06)	1.45 (0.057)	1.9 (0.075)	R13, R15, R16
RHE 16V - High Temperature														
New RHE200	—	9.4 (0.37)	14.4 (0.57)	—	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	R10, R15, R16
RHE400	—	11.4 (0.45)	—	18.0 (0.71)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	1.24 (0.049)	1.6 (0.06)	R14, R15, R16
RHE450	—	10.4 (0.41)	—	15.6 (0.61)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	1.24 (0.049)	1.6 (0.06)	R14, R15, R16
RHE600	—	11.2 (0.44)	—	21.0 (0.83)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	1.24 (0.049)	1.7 (0.067)	R14, R15, R16
RHE650	—	12.7 (0.50)	—	22.2 (0.88)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	1.24 (0.049)	1.8 (0.07)	R14, R15, R16
RHE750	—	14.0 (0.55)	—	23.5 (0.93)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	1.24 (0.049)	2.0 (0.08)	R14, R15, R16
New RHE900	—	16.5 (0.65)	—	25.7 (1.01)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	—
RHE1000	—	17.5 (0.69)	—	26.5 (1.04)	—	3.0 (0.12)	7.6 (0.30)	—	9.4 (0.37)	10.9 (0.43)	1.2 (0.05)	1.24 (0.049)	1.5 (0.06)	R14, R15, R16
RHE1300	—	23.5 (0.925)	—	28.7 (1.13)	—	3.6 (0.14)	7.6 (0.30)	—	9.4 (0.37)	10.9 (0.43)	1.4 (0.06)	1.45 (0.057)	1.9 (0.084)	R14, R15, R16
RHE1500	—	23.5 (0.925)	—	28.7 (1.13)	—	3.6 (0.14)	7.6 (0.30)	—	9.4 (0.37)	10.9 (0.43)	1.4 (0.06)	1.45 (0.057)	1.9 (0.084)	R14, R15, R16
RUSB 6V														
RUSB075	—	6.9 (0.27)	—	11.4 (0.45)	—	3.1 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.9 (0.23)	—	0.91 (0.036)	1.0 (0.04)	R10, R15, R16
RUSB120	—	6.9 (0.27)	—	11.7 (0.46)	—	3.1 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.9 (0.23)	—	0.91 (0.036)	1.0 (0.04)	R10, R15, R16
RUSB155	—	6.9 (0.27)	—	11.7 (0.46)	—	3.1 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.9 (0.23)	—	0.91 (0.036)	1.0 (0.04)	R10, R15, R16

4

Figures R17–R23. Typical Time-to-trip Curves at 20°C for Radial-leaded Devices

LVR

A = LVR005

B = LVR008

C = LVR012

D = LVR016

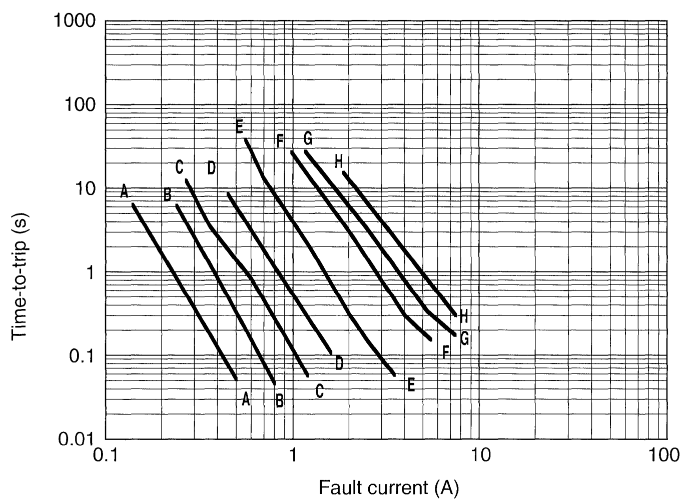
E = LVR025

F = LVR033

G = LVR040

H = LVR055

Figure R17



4

BBR/BBRF

A = BBR550

B = BBR750

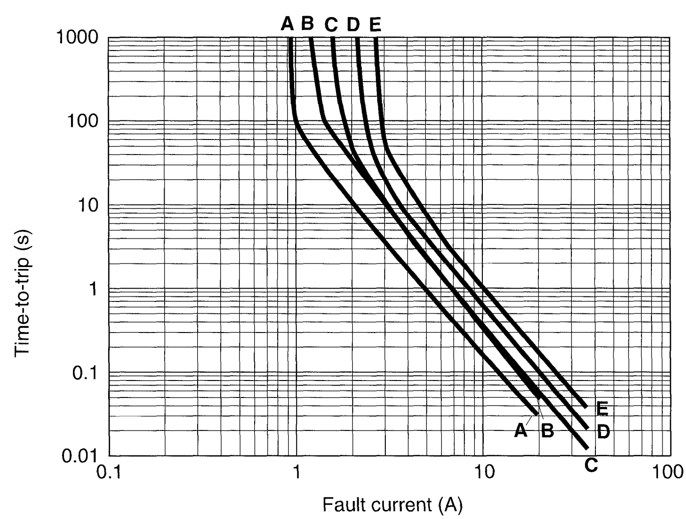
RTE/RTEF

C = RTE120

D = RTE135

E = RTE190

Figure R18

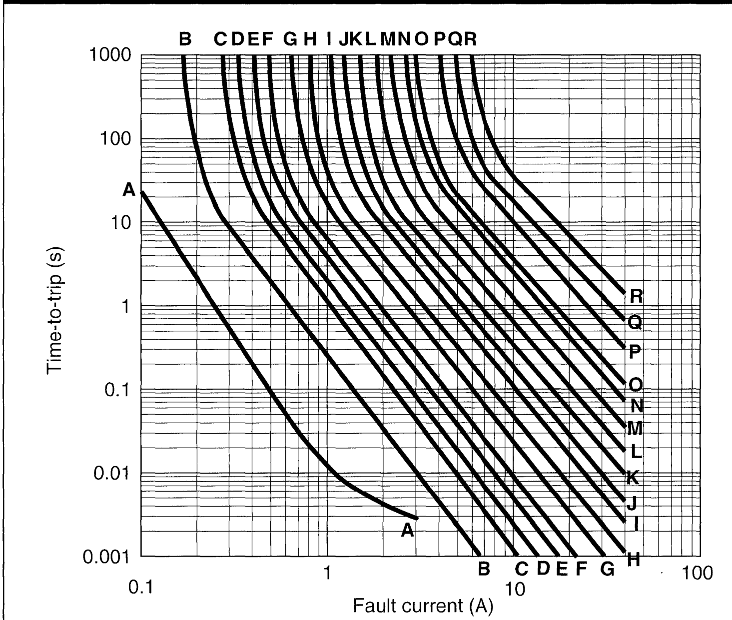


Figures R17–R23. Typical Time-to-trip Curves at 20°C for Radial-leaded Devices

RXE/RXEF

A = RXE005	J = RXE075
B = RXE010	K = RXE090
C = RXE017	L = RXE110
D = RXE020	M = RXE135
E = RXE025	N = RXE160
F = RXE030	O = RXE185
G = RXE040	P = RXE250
H = RXE050	Q = RXE300
I = RXE065	R = RXE375

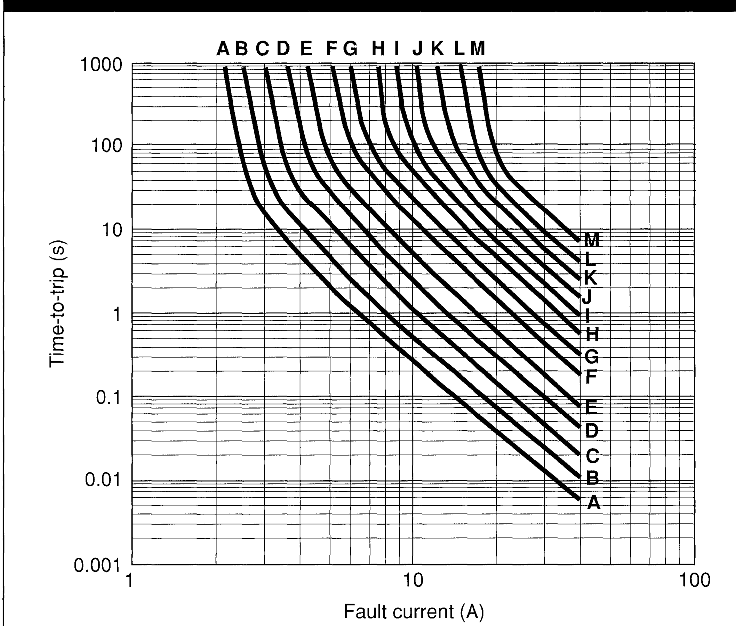
Figure R19



RUE/RUEF

A = RUE090	H = RUE400
B = RUE110	I = RUE500
C = RUE135	J = RUE600
D = RUE160	K = RUE700
E = RUE185	L = RUE800
F = RUE250	M = RUE900
G = RUE300	

Figure R20

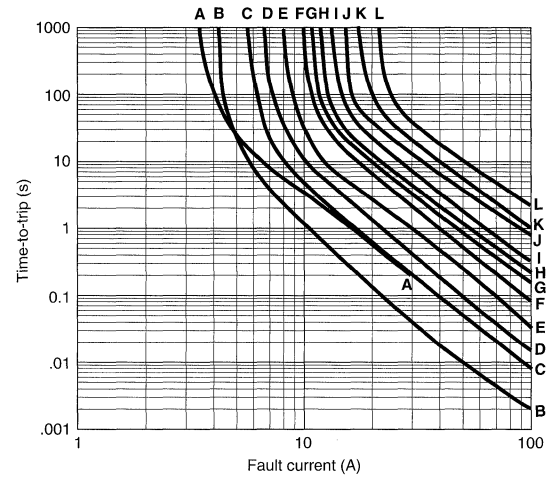


Figures R17–R23. Typical Time-to-trip Curves at 20°C for Radial-leaded Devices *continued*

RGE/RGEF (data at 25°C)

A = RGE250	H = RGE900
B = RGE300	I = RGE1000
C = RGE400	J = RGE1100
D = RGE500	K = RGE1200
E = RGE600	L = RGE1400
F = RGE700	
G = RGE800	

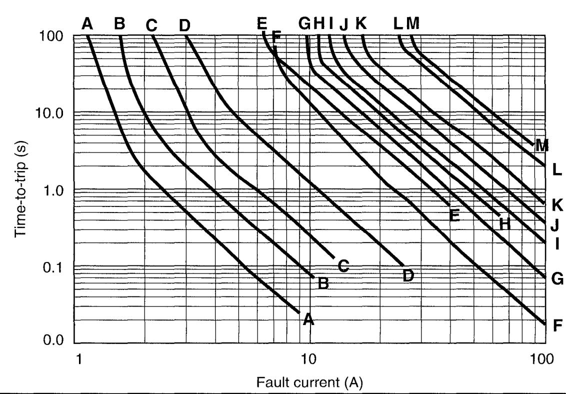
Figure R21



RHE/RHEF (data at 25°C)

A = RHE050	H = RHE650
B = RHE070	I = RHE750
C = RHE100	J = RHE900
D = RHE200	K = RHE1000
E = RHE400	L = RHE1300
F = RHE450	M = RHE1500
G = RHE600	

Figure R22



RUSB/RUSBF

A = RUSB075	F = RUSB155
B = RUSB090	G = RUSB160
C = RUSB110	H = RUSB185
D = RUSB120	I = RUSB250
E = RUSB135	

Figure R23

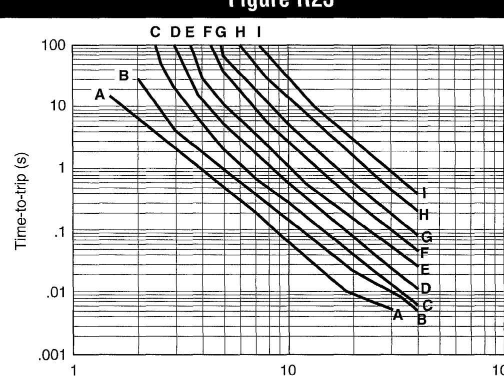


Table R5. Physical Characteristics and Environmental Specifications for Radial-leaded Devices

LVR

Physical Characteristics

Lead material	LVR005-016: Tin-plated copper, 0.205mm² (24 AWG), ø 0.51mm (0.020 in.)
	LVR025-040: Tin-plated copper, 0.32mm² (22 AWG), ø 0.64mm (0.025 in.)
	LVR055: Tin-plated copper, 0.52mm² (20 AWG), ø 0.81mm (0.032 in.)
Soldering characteristics	Solderability per ANSI/J-STD-002 Category 3
Solder heat withstand	per IEC-STD 68-2-20, Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C

Devices are not designed to be placed through a reflow process.

Environmental Specifications

Test	Conditions	Resistance Change
Passive aging	70°C, 1000 hours 85°C, 1000 hours	±5% ±5%
Humidity aging	85°C, 85% RH, 1000 hours	±5%
Thermal shock	85°C, -40°C (10 times)	±5%
Solvent resistance	MIL-STD-202, Method 215F	No change

BBR

Physical Characteristics

Lead material	Tin/lead-plated copper, 0.52mm² (20 AWG), ø 0.81mm (0.032 in.)
Soldering characteristics	Solderability per ANSI/J-STD-002 Category 3
Solder heat withstand	per IEC-STD 68-2-20, Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0

Devices are not designed to be placed through a reflow process.

BBRF

Physical Characteristics

Lead material	Tin-plated copper
Soldering characteristics	Solderability per ANSI/J-STD-002 Category 3
Solder heat withstand	per IEC-STD 68-2-20, Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0

Devices are not designed to be placed through a reflow process.

BBR/BBRF

Environmental Specifications

Test	Conditions	Resistance Change
Passive aging	70°C, 1000 hours 85°C, 1000 hours	±5% ±5%
Humidity aging	85°C, 85% RH, 1000 hours	±5%
Thermal shock	85°C, -40°C (10 times)	±5%
Solvent resistance	MIL-STD-202, Method 215F	No change

RXE

Physical Characteristics

Lead material	RXE005: Tin/lead-plated nickel-copper alloy, 0.128mm² (26 AWG), ø 0.40mm (0.016 in.)
	RXE010: Tin/lead-plated nickel-copper alloy, 0.205mm² (24 AWG), ø 0.51mm (0.020 in.)
	RXE017 to 040: Tin/lead-plated copper-clad steel, 0.205mm² (24 AWG), ø 0.51mm (0.020 in.)
	RXE050 to 090: Tin/lead-plated copper, 0.205mm² (24 AWG), ø 0.51mm (0.020 in.)
	RXE110 to 375: Tin/lead-plated copper, 0.52mm² (20 AWG), ø 0.81mm (0.032 in.)
Soldering characteristics	Solderability per ANSI/J-STD-002 Category 3, except RXE005, RXE010 meet ANSI/J-STD-002 Category 1
Solder heat withstand	RXE017 – RXE025: per IEC-STD 68-2-20, Test Tb, Method 1a, condition a; can withstand 5 seconds at 260°C ± 5°C All other sizes: per IEC-STD 68-2-20, Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0

Devices are not designed to be placed through a reflow process.

Table R5. Physical Characteristics and Environmental Specifications for Radial-leaded Devices *continued*

RXEF
Physical Characteristics

Lead material	RXEF005: Tin-plated nickel-copper alloy, 0.128mm² (26 AWG), ø 0.40mm (0.016 in.)
	RXEF010: Tin-plated nickel-copper alloy, 0.205mm² (24 AWG), ø 0.51mm (0.020 in.)
	RXEF017 to 040: Tin-plated copper-clad steel, 0.205mm² (24 AWG), ø 0.51mm (0.020 in.)
	RXEF050 to 090: Tin-plated copper, 0.205mm² (24 AWG), ø 0.51mm (0.020 in.)
	RXEF110 to 375: Tin-plated copper, 0.52mm² (20 AWG), ø 0.81mm (0.032 in.)
Soldering characteristics	Solderability per ANSI/J-STD-002 Category 3, except RXEF005, RXEF010 meet ANSI/J-STD-002 Category 1
Solder heat withstand	RXEF017 – RXEF025: per IEC-STD 68-2-20, Test Tb, Method 1a, condition a; can withstand 5 seconds at 260°C ± 5°C All other sizes: per IEC-STD 68-2-20, Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0

Devices are not designed to be placed through a reflow process.

RXE/RXEF
Environmental Specifications

Test	Conditions	Resistance Change
Passive aging	-40°C, 1000 hours 85°C, 1000 hours	±5% ±5%
Humidity aging	85°C, 85% RH, 1000 hours	±10%
Thermal shock	85°C, -40°C (10 times)	±10%
Solvent resistance	MIL-STD-202, Method 215F	No change

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RTE
Physical Characteristics

Lead material	Tin/lead-plated copper-clad steel, 0.205mm² (24 AWG), ø 0.40mm (0.016 in.)
Soldering characteristics	Solderability per ANSI/J-STD-002 Category 3
Solder heat withstand	per IEC-STD 68-2-20, Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0

RTEF
Physical Characteristics

Lead material	Tin-plated copper-clad steel, 0.205mm² (24 AWG), ø 0.40mm (0.016 in.)
Soldering characteristics	Solderability per ANSI/J-STD-002 Category 3
Solder heat withstand	per IEC-STD 68-2-20, Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0

RTE/RTEF
Environmental Specifications

Test	Conditions	Resistance Change
Passive aging	70°C, 1000 hours 85°C, 1000 hours	±5% ±5%
Humidity aging	85°C, 85% RH, 1000 hours	±5%
Thermal shock	85°C, -40°C (10 times)	±5%
Solvent resistance	MIL-STD-202, Method 215F	No change

RUE
Physical Characteristics

Lead material	RUE090 to RUE250: Tin/lead-plated copper-clad steel, 0.205mm² (24 AWG) RUE300 to RUE900: Tin/lead-plated copper, 0.52mm² (20 AWG), ø 0.81mm (0.032 in.)
Soldering characteristics	Solderability per ANSI/J-STD-002 Category 3
Solder heat withstand	per IEC-STD 68-2-20, Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0

Devices are not designed to be placed through a reflow process.

Table R5. Physical Characteristics and Environmental Specifications for Radial-leaded Devices *continued*

RUEF
Physical Characteristics

Lead material	RUEF090 to RUEF250: Tin-plated copper-clad steel, 0.205mm² (24 AWG) RUEF300 to RUEF900: Tin-plated copper, 0.52mm² (20 AWG), ø 0.81mm (0.032 in.)
Soldering characteristics	Solderability per ANSI/J-STD-002 Category 3
Solder heat withstand	per IEC-STD 68-2-20, Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0

Devices are not designed to be placed through a reflow process.

RUE/RUEF
Environmental Specifications

Test	Conditions	Resistance Change
Passive aging	70°C, 1000 hours 85°C, 1000 hours	±5% ±5%
Humidity aging	85°C, 85% RH, 1000 hours	±5%
Thermal shock	85°C, -40°C (10 times)	±5%
Solvent resistance	MIL-STD-202, Method 215F	No change

RUSB
Physical Characteristics

Lead material	RUSBF075: Tin/lead-plated nickel-copper alloy, 0.205mm² (24 AWG) ø 0.51 mm/0.020 in. RUSBF090 to RUSB250: Tin-plated copper clad-steel, 0.205mm² (24 AWG) ø 0.51 mm/0.020 in.
Soldering characteristics	Solderability per ANSI/J-STD-002 Category 3 except RUSBF075 meets ANSI/J-STD-002 Category 1
Solder heat withstand	RUSBF120: per IEC 68-2-20, Test Tb, Method 1a, condition a; can withstand 5 seconds at 260°C ± 5°C All others: per IEC 68-2-20, Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0

Devices are not designed to be placed through a reflow process.

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RUSBF
Physical Characteristics

Lead material	RUSBF075: Tin-plated nickel-copper alloy, 0.205mm² (24 AWG) ø 0.51 mm/0.020 in. RUSBF090 to RUSBF250: Tin-plated copper clad-steel, 0.205mm² (24 AWG) ø 0.51 mm/0.020 in.
Soldering characteristics	Solderability per ANSI/J-STD-002 Category 3 except RUSBF075 meets ANSI/J-STD-002 Category 1
Solder heat withstand	RUSBF120: per IEC 68-2-20, Test Tb, Method 1a, condition a; can withstand 5 seconds at 260°C ± 5°C All others: per IEC 68-2-20, Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0

Devices are not designed to be placed through a reflow process.

RUSB/RUSBF
Environmental Specifications

Test	Conditions	Resistance Change
Passive aging	70°C, 1000 hours 85°C, 1000 hours	±5% ±5%
Humidity aging	85°C, 85% RH, 1000 hours	±5%
Thermal shock	85°C, -40°C (10 times)	±5%
Solvent resistance	MIL-STD-202, Method 215F	No change

RGE
Physical Characteristics

Lead material	RGE300 to RGE1100: Tin/lead-plated copper, 0.52mm² (20 AWG) ø 0.81 mm/0.032 in. RGE1200 and RGE1400: Tin/lead-plated copper, 0.82mm² (18 AWG) ø 1.0 mm/0.04 in.
Soldering characteristics	Solderability per ANSI/J-STD 002 Category 3
Solder heat withstand	RGE300K and RGE400: per IEC 68-2-20, Test Tb, Method 1a, condition a; can withstand 5 seconds at 260°C ± 5°C RGE500 to RGE1400: per IEC 68-2-20 Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0

Devices are not designed to be placed through a reflow process.

Table R5. Physical Characteristics and Environmental Specifications for Radial-leaded Devices *continued*

RGEF
Physical Characteristics

Lead material	RGEF300 to RGEF1100: Tin-plated copper, 0.52mm² (20 AWG) ø 0.81 mm/0.032 in. RGEF1200 and RGEF1400: Tin-plated copper, 0.82mm² (18 AWG) ø 1.0 mm/0.04 in.
Soldering characteristics	Solderability per ANSI/J-STD 002 Category 3
Solder heat withstand	RGEF300K and RGEF400: per IEC 68-2-20, Test Tb, Method 1a, condition a; can withstand 5 seconds at 260°C ± 5°C RGEF500 to RGEF1400: per IEC 68-2-20 Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0

Devices are not designed to be placed through a reflow process.

RGE/RGEF
Environmental Specifications

Test	Conditions	Resistance Change
Passive aging	-40°C, 1000 hours 85°C, 1000 hours	± 5% ± 5%
Humidity aging	85°C, 85% RH, 1000 hours	± 5%
Thermal shock	85°C, -40°C (10 times)	± 5%
Solvent resistance	MIL-STD-202, Method 215F	No change

RHE
Physical Characteristics

Lead material	RHEF050 to RHEF400: Tin/lead -plated copper clad steel, 0.205mm² (24 AWG) ø 0.51 mm/0.020 in. RHEF450 to RHEF1000: Tin/lead-plated copper, 0.52mm² (20 AWG) ø 0.81 mm/0.032 in. RHEF1300, RHEF1500: Tin/lead-plated copper, 0.82mm² (18 AWG) ø 1.0 mm/0.04 in.
Soldering characteristics	Solderability per ANSI/J-STD 002 Category 3
Solder heat withstand	Per IEC 68-2-20, Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0

Devices are not designed to be placed through a reflow process.

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RHEF
Physical Characteristics

Lead material	RHEF050 to RHEF400: Tin-plated copper clad steel, 0.205mm² (24 AWG) ø 0.51 mm/0.020 in. RHEF450 to RHEF1000: Tin-plated copper, 0.52mm² (20 AWG) ø 0.81 mm/0.032 in. RHEF1300, RHEF1500: Tin-plated copper, 0.82mm² (18 AWG) ø 1.0 mm/0.04 in.
Soldering characteristics	Solderability per ANSI/J-STD 002 Category 3
Solder heat withstand	Per IEC 68-2-20, Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0

Devices are not designed to be placed through a reflow process.

RHE/RHEF
Environmental Specifications

Test	Conditions	Resistance Change
Passive aging	70°C, 1000 hours 85°C, 1000 hours	± 5% ± 5%
Humidity aging	85°C, 85% RH, 1000 hours	± 5%
Thermal shock	125°C, -40°C (10 times)	± 5%
Solvent resistance	MIL-STD-202, Method 215F	No change

Devices are not designed to be placed through a reflow process.

Notes:

Storage conditions: 40°C max., 70% RH max.; devices should remain in original sealed bags prior to use. Devices may not meet specified values if these storage conditions are exceeded.
For the TR device series, see the Telecommunications and Networking section.

Agency recognitions for Radial-leaded Devices

UL	File # E74889
CSA	File # CA78165C
TÜV	Certificate number available on request (per IEC 60730-1).

Table R6. Packaging and Marking Information for Radial-leaded Devices

Part Number	Bag Quantity	Tape and Reel Quantity	Ammo Pack Quantity	Standard Package Quantity	Part Marking	Agency Recognition
LVR 240V$_{AC}$						
LVR005K	500	—	—	10,000	L005	UL,CSA, TÜV
LVR005K-2	—	500	—	10,000	L005	UL,CSA, TÜV
LVR005S	500	—	—	10,000	L005	UL,CSA, TÜV
LVR005S-2	—	500	—	10,000	L005	UL,CSA, TÜV
LVR008K	500	—	—	10,000	L008	UL,CSA, TÜV
LVR008K-2	—	500	—	10,000	L008	UL,CSA, TÜV
LVR008S	500	—	—	10,000	L008	UL,CSA, TÜV
LVR008S-2	—	500	—	10,000	L008	UL,CSA, TÜV
LVR012K	500	—	—	10,000	L012	UL,CSA, TÜV
LVR012K-2	—	500	—	10,000	L012	UL,CSA, TÜV
LVR012S	500	—	—	10,000	L012	UL,CSA, TÜV
LVR012S-2	—	500	—	10,000	L012	UL,CSA, TÜV
LVR016K	500	—	—	10,000	L016	UL,CSA, TÜV
LVR016K-2	—	500	—	10,000	L016	UL,CSA, TÜV
LVR016S	500	—	—	10,000	L016	UL,CSA, TÜV
LVR016S-2	—	500	—	10,000	L016	UL,CSA, TÜV
LVR025K	500	—	—	10,000	L025	UL,CSA, TÜV
LVR025K-2	—	500	—	10,000	L025	UL,CSA, TÜV
LVR025S	500	—	—	10,000	L025	UL,CSA, TÜV
LVR025S-2	—	500	—	10,000	L025	UL,CSA, TÜV
LVR033S	500	—	—	10,000	L033	UL,CSA, TÜV
LVR033S-2	—	500	—	10,000	L033	UL,CSA, TÜV
LVR033K	500	—	—	10,000	L033	UL,CSA, TÜV
LVR033K-2	—	500	—	10,000	L033	UL,CSA, TÜV
LVR040S	500	—	—	10,000	L040	UL,CSA, TÜV
LVR040S-2	—	500	—	10,000	L040	UL,CSA, TÜV
LVR040K	500	—	—	10,000	L040	UL,CSA, TÜV
LVR040K-2	—	500	—	10,000	L040	UL,CSA, TÜV
LVR055K	500	—	—	10,000	L055	Pending
LVR055S	500	—	—	10,000	L055	Pending
BBR 99V$_{AC}$						
BBR550	500	—	—	10,000	B550	UL, CSA
BBR550-2	—	1,500	—	7,500	B550	UL, CSA
BBR750	500	—	—	10,000	B750	UL, CSA
BBR750-2	—	1,500	—	7,500	B750	UL, CSA
TR250, TR600 60/600V						
TR250-080U	500	1,500	—	10,000/7,500	08	UL, CSA, TÜV
TR250-120	500	1,500	—	10,000/7,500	20	UL, CSA, TÜV
TR250-145	500	1,500	—	10,000/7,500	45	UL, CSA, TÜV
TR250-180U	500	1,500	—	10,000/7,500	80	UL, CSA, TÜV
TR600-150	500	600	—	10,000/3,000	150	UL, CSA
TR600-160	500	600	—	10,000/3,000	160	UL, CSA
RXE 60V						
RXE005	500	—	—	10,000	—	UL, CSA, TÜV
RXE010	500	—	—	10,000	X010	UL, CSA, TÜV
RXE010-2	—	3,000	—	15,000	X010	UL, CSA, TÜV

Table R6. Packaging and Marking Information for Radial-leaded Devices *continued*

Part Number	Bag Quantity	Tape and Reel Quantity	Ammo Pack Quantity	Standard Package Quantity	Part Marking	Agency Recognition
RXE 60V ***continued***						
RXE010-AP	—	—	2,000	10,000	X010	UL, CSA, TÜV
RXE017	500	—	—	10,000	X017	UL, CSA, TÜV
RXE017-2	—	2,500	—	12,500	X017	UL, CSA, TÜV
RXE017-AP	—	—	2,000	10,000	X017	UL, CSA, TÜV
RXE 72V						
RXE020	500	—	—	10,000	X020	UL, CSA, TÜV
RXE020-2	—	3,000	—	15,000	X020	UL, CSA, TÜV
RXE020-AP	—	—	2,000	10,000	X020	UL, CSA, TÜV
RXE025	500	—	—	10,000	X025	UL, CSA, TÜV
RXE025-2	—	3,000	—	15,000	X025	UL, CSA, TÜV
RXE025-AP	—	—	2,000	10,000	X025	UL, CSA, TÜV
RXE030	500	—	—	10,000	X030	UL, CSA, TÜV
RXE030-2	—	3,000	—	15,000	X030	UL, CSA, TÜV
RXE030-AP	—	—	2,000	10,000	X030	UL, CSA, TÜV
RXE040	500	—	—	10,000	X040	UL, CSA, TÜV
RXE040-2	—	3,000	—	15,000	X040	UL, CSA, TÜV
RXE040-AP	—	—	2,000	10,000	X040	UL, CSA, TÜV
RXE050	500	—	—	10,000	X050	UL, CSA, TÜV
RXE050-2	—	3,000	—	15,000	X050	UL, CSA, TÜV
RXE050-AP	—	—	2,000	10,000	X050	UL, CSA, TÜV
RXE065	500	—	—	10,000	X065	UL, CSA, TÜV
RXE065-2	—	3,000	—	15,000	X065	UL, CSA, TÜV
RXE065-AP	—	—	2,000	10,000	X065	UL, CSA, TÜV
RXE075	500	—	—	10,000	X075	UL, CSA, TÜV
RXE075-2	—	3,000	—	15,000	X075	UL, CSA, TÜV
RXE075-AP	—	—	2,000	10,000	X075	UL, CSA, TÜV
RXE090	500		—	10,000	X090	UL, CSA, TÜV
RXE090-2	—	3,000	—	15,000	X090	UL, CSA, TÜV
RXE090-AP	—	—	2,000	10,000	X090	UL, CSA, TÜV
RXE110	500	—	—	10,000	X110	UL, CSA, TÜV
RXE110-2	—	1,500	—	7,500	X110	UL, CSA, TÜV
RXE110-AP	—	—	1,000	5,000	X110	UL, CSA, TÜV
RXE135	500	—	—	10,000	X135	UL, CSA, TÜV
RXE135-2	—	1,500	—	7,500	X135	UL, CSA, TÜV
RXE135-AP	—	—	1,000	5,000	X135	UL, CSA, TÜV
RXE160	500	—	—	10,000	X160	UL, CSA, TÜV
RXE160-2	—	1,500	—	7,500	X160	UL, CSA, TÜV
RXE160-AP	—	—	1,000	5,000	X160	UL, CSA, TÜV
RXE185	500	—	—	10,000	X185	UL, CSA, TÜV
RXE185-2	—	1,500	—	7,500	X185	UL, CSA, TÜV
RXE185-AP	—	—	1,000	5,000	X185	UL, CSA, TÜV
RXE250	250	—	—	5,000	X250	UL, CSA, TÜV
RXE250-2	—	1,000	—	5,000	X250	UL, CSA, TÜV
RXE250-AP	—	—	1,000	5,000	X250	UL, CSA, TÜV
RXE300	250	—	—	5,000	X300	UL, CSA, TÜV
RXE300-2	—	1,000	—	5,000	X300	UL, CSA, TÜV

Table R6. Packaging and Marking Information for Radial-leaded Devices *continued*

Part Number	Bag Quantity	Tape and Reel Quantity	Ammo Pack Quantity	Standard Package Quantity	Part Marking	Agency Recognition
RXE 72V *continued*						
RXE300-AP	—		1,000	5,000	X300	UL, CSA, TÜV
RXE375	250			5,000	X375	UL, CSA, TÜV
RTE 33V						
RTE120	500	—	—	10,000	T120	UL, CSA, TÜV
RTE120-2	—	3,000	—	15,000	T120	UL, CSA, TÜV
RTE120-AP	—	—	2,000	10,000	T120	UL, CSA, TÜV
RTE135	500	—	—	10,000	T135	UL, CSA, TÜV
RTE135-2	—	3,000	—	15,000	T135	UL, CSA, TÜV
RTE135-AP	—	—	2,000	10,000	T135	UL, CSA, TÜV
RTE190	500	—	—	10,000	T190	UL, CSA, TÜV
RTE190-2	—	3,000	—	15,000	T190	UL, CSA, TÜV
RTE190-AP	—	—	2,000	10,000	T190	UL, CSA, TÜV
RUE 30V						
RUE090	500	—	—	10,000	U090	UL, CSA, TÜV
RUE090-2	—	3,000	—	15,000	U090	UL, CSA, TÜV
RUE090-AP	—	—	2,000	10,000	U090	UL, CSA, TÜV
RUE110	500	—	—	10,000	U110	UL, CSA, TÜV
RUE110-2	—	3,000	—	15,000	U110	UL, CSA, TÜV
RUE110-AP	—	—	2,000	10,000	U110	UL, CSA, TÜV
RUE135	500	—	—	10,000	U135	UL, CSA, TÜV
RUE135-2	—	3,000	—	15,000	U135	UL, CSA, TÜV
RUE135-AP	—	—	2,000	10,000	U135	UL, CSA, TÜV
RUE160	500	—	—	10,000	U160	UL, CSA, TÜV
RUE160-2	—	3,000	—	15,000	U160	UL, CSA, TÜV
RUE160-AP	—	—	2,000	10,000	U160	UL, CSA, TÜV
RUE185	500	—	—	10,000	U185	UL, CSA, TÜV
RUE185-2	—	3,000	—	15,000	U185	UL, CSA, TÜV
RUE185-AP	—	—	2,000	10,000	U185	UL, CSA, TÜV
RUE250	500	—	—	10,000	U250	UL, CSA, TÜV
RUE250-2	—	3,000	—	15,000	U250	UL, CSA, TÜV
RUE250-AP	—	—	2,000	10,000	U250	UL, CSA, TÜV
RUE300	500	—	—	10,000	U300	UL, CSA, TÜV
RUE300-2	—	2,500	—	12,500	U300	UL, CSA, TÜV
RUE300-AP	—	—	1,000	5,000	U300	UL, CSA, TÜV
RUE400	500	—	—	10,000	U400	UL, CSA, TÜV
RUE400-2	—	1,500	—	7,500	U400	UL, CSA, TÜV
RUE400-AP	—	—	1,000	5,000	U400	UL, CSA, TÜV
RUE500	250	—	—	5,000	U500	UL, CSA, TÜV
RUE500-2	—	1,500	—	7,500	U500	UL, CSA, TÜV
RUE500-AP	—	—	1,000	5,000	U500	UL, CSA, TÜV
RUE600	250	—	—	5,000	U600	UL, CSA, TÜV
RUE600-AP	—	—	1,000	5,000	U600	UL, CSA, TÜV
RUE700	250	—	—	5,000	U700	UL, CSA, TÜV
RUE800	250	—	—	5,000	U800	UL, CSA, TÜV
RUE900	250	—	—	5,000	U900	UL, CSA, TÜV

Table R6. Packaging and Marking Information for Radial-leaded Devices *continued*

Part Number	Bag Quantity	Tape and Reel Quantity	Ammo Pack Quantity	Standard Package Quantity	Part Marking	Agency Recognition
RHE 30V - High Temperature						
RHE050	500	—	—	10,000	H0.5	UL, CSA, TÜV
RHE070	500	—	—	10,000	H0.7	UL, CSA, TÜV
RHE070-2						UL, CSA, TÜV
RHE100	500	—	—	10,000	H1.0	UL, CSA, TÜV
RHE100-2	—	3,000	—	15,000	H1.0	UL, CSA, TÜV
RUSB, RGE 16V						
RUSB090	500	—	—	10,000	R090	UL, CSA, TÜV
RUSB090-2	—	3,000	—	15,000	R090	UL, CSA, TÜV
RUSB090-AP	—	—	2,000	10,000	R090	UL, CSA, TÜV
RUSB110	500	—	—	10,000	R110	UL, CSA, TÜV
RUSB110-2	—	3,000	—	15,000	R110	UL, CSA, TÜV
RUSB110-AP	—	—	2,000	10,000	R110	UL, CSA, TÜV
RUSB135	500	—	—	10,000	R135	UL, CSA, TÜV
RUSB135-2	—	3,000	—	15,000	R135	UL, CSA, TÜV
RUSB135-AP	—	—	2,000	10,000	R135	UL, CSA, TÜV
RUSB155	500	—	—	10,000	R155	UL, CSA, TÜV
RUSB160	500	—	—	10,000	R160	UL, CSA, TÜV
RUSB160-2	—	3,000	—	15,000	R160	UL, CSA, TÜV
RUSB160-AP	—	—	2,000	10,000	R160	UL, CSA, TÜV
RUSB185	500	—	—	10,000	R185	UL, CSA, TÜV
RUSB185-2	—	3,000	—	15,000	R185	UL, CSA, TÜV
RUSB185-AP	—	—	2,000	10,000	R185	UL, CSA, TÜV
RUSB250	500	—	—	10,000	R250	UL, CSA, TÜV
RUSB250-2	—	3,000	—	15,000	R250	UL, CSA, TÜV
RUSB250-AP	—	—	2,000	10,000	R250	UL, CSA, TÜV
RGE 16V						
RGE250	500	—	—	10,000	G250	UL, CSA, TÜV
RGE300	500	—	—	10,000	G300	UL, CSA, TÜV
RGE300-2	—	2,500	—	12,500	G300	UL, CSA, TÜV
RGE300-AP	—	—	2,000	10,000	G300	UL, CSA, TÜV
RGE400	500	—	—	10,000	G400	UL, CSA, TÜV
RGE400-2	—	2,500	—	12,500	G400	UL, CSA, TÜV
RGE400-AP	—	—	2,000	10,000	G400	UL, CSA, TÜV
RGE500	500	—	—	10,000	G500	UL, CSA, TÜV
RGE500-2	—	2,000	—	10,000	G500	UL, CSA, TÜV
RGE500-AP	—	—	2,000	10,000	G500	UL, CSA, TÜV
RGE600	500	—	—	10,000	G600	UL, CSA, TÜV
RGE600-2	—	2,000	—	10,000	G600	UL, CSA, TÜV
RGE600-AP	—	—	2,000	10,000	G600	UL, CSA, TÜV
RGE700	500	—	—	10,000	G700	UL, CSA, TÜV
RGE700-2	—	1,500	—	7,500	G700	UL, CSA, TÜV
RGE700-AP	—	—	1,500	7,500	G700	UL, CSA, TÜV
RGE800	500	—	—	10,000	G800	UL, CSA, TÜV
RGE800-2	—	1,000	—	5,000	G800	UL, CSA, TÜV
RGE800-AP	—	—	1,000	5,000	G800	UL, CSA, TÜV
RGE900	500	—	—	10,000	G900	UL, CSA, TÜV
RGE900-2	—	1,000	—	5,000	G900	UL, CSA, TÜV
RGE900-AP	—	—	1,000	5,000	G900	UL, CSA, TÜV
RGE1000	250	—	—	5,000	G1000	UL, CSA, TÜV

Table R6. Packaging and Marking Information for Radial-leaded Devices *continued*

Part Number	Bag Quantity	Tape and Reel Quantity	Ammo Pack Quantity	Standard Package Quantity	Part Marking	Agency Recognition
RGE 16V *continued*						
RGE1000-2	—	1,000	—	5,000	G1000	UL, CSA, TÜV
RGE1000-AP	—	—	1,000	5,000	G1000	UL, CSA, TÜV
RGE1100	250	—	—	5,000	G1100	UL, CSA, TÜV
RGE1100-2	—	1,000	—	5,000	G1100	UL, CSA, TÜV
RGE1100-AP	—	—	1,000	5,000	G1100	UL, CSA, TÜV
RGE1200	250	—	—	5,000	G1200	UL, CSA, TÜV
RGE1200-2	—	1,000	—	5,000	G1200	UL, CSA, TÜV
RGE1200-AP	—	—	1,000	5,000	G1200	UL, CSA, TÜV
RGE1400	250	—	—	5,000	G1400	UL, CSA, TÜV
RGE1400-2	—	1,000	—	5,000	G1400	UL, CSA, TÜV
RGE1400-AP	—	—	1,000	5,000	G1400	UL, CSA, TÜV
RHE 16V - High Temperature						
RHE200	500	—	—	10,000	H2.5	UL, CSA, TÜV
RHE200-2	—	2,500	—	12,500	H2.5	UL, CSA, TÜV
RHE400	500	—	—	10,000	H4	UL, CSA, TÜV
RHE400-2	—	1,500	—	7,500	H4	UL, CSA, TÜV
RHE400-AP	—	—	1,500	7,500	H4.5	UL, CSA, TÜV
RHE450	500	—	—	10,000	H4.5	UL, CSA, TÜV
RHE450-2	—	1,500	—	7,500	H4.5	UL, CSA, TÜV
RHE450-AP	—	—	1,500	7,500	H4.5	UL, CSA, TÜV
RHE600	500	—	—	10,000	H6	UL, CSA, TÜV
RHE600-2	—	1,500	—	7,500	H6	UL, CSA, TÜV
RHE600-AP	—	—	1,500	7,500	H6	UL, CSA, TÜV
RHE650	500	—	—	10,000	H6.5	UL, CSA, TÜV
RHE750	500	—	—	10,000	H7.5	UL, CSA, TÜV
RHE750-2	—	1,000	—	5,000	H7.5	UL, CSA, TÜV
RHE750-AP	—	—	1,000	5,000	H7.5	UL, CSA, TÜV
RHE900	250	—	—	5,000	H9	UL, CSA, TÜV
RHE900-2	—	1,000	—	5,000	H9	UL, CSA, TÜV
RHE900-AP	—	—	1,000	5,000	H9	UL, CSA, TÜV
RHE1000	250	—	—	5,000	H10	UL, CSA, TÜV
RHE1000-2	—	1,000	—	5,000	H10	UL, CSA, TÜV
RHE1000-AP	—	—	1,000	5,000	H10	UL, CSA, TÜV
RHE 16V						
RHE1300	250	—	—	5,000	H13	UL, CSA, TÜV
RHE1300-2	—	1,000	—	5,000	H13	UL, CSA, TÜV
RHE1300-AP	—	—	1,000	5,000	H13	UL, CSA, TÜV
RHE1500	250	—	—	5,000	H15	UL, CSA, TÜV
RHE1500-2	—	1,000	—	5,000	H15	UL, CSA, TÜV
RHE1500-AP	—	—	1,000	5,000	H15	UL, CSA, TÜV
RUSB 6V						
RUSB075	500	—	—	10,000	R075	UL, CSA, TÜV
RUSB075-2	—	3,000	—	15,000	R075	UL, CSA, TÜV
RUSB075-AP	—	—	2,500	12,500	R075	UL, CSA, TÜV
RUSB120	500	—	—	10,000	R120	UL, CSA, TÜV
RUSB120-2	—	3,000	—	15,000	R120	UL, CSA, TÜV
RUSB120-AP	—	—	2,000	10,000	R120	UL, CSA, TÜV
RUSB155	500	—	—	10,000	R155	UL, CSA, TÜV

Part Numbering System

RUE 250 U 2

- **2**:
  - Blank = Packaged in bags
  - – 1 = 25.4mm (1.0 inch) minimum lead length
  - – 2 = Tape and reel
  - – AP = Ammo pack
  - – X.X = Special lead cut length (inches)
- **U**: Modifier
  - K = Standard kinked lead
  - B = Special kinked lead
  - S = Straight lead
  - U = Uncoated device
- **250**: Hold current indicator
- **RUE**: Product series - An “F” at the end of product series indicates Pb-free version of product.

TR250 –120 –RA –B–0.5 –2

- **–2**: 2 = Tape and reel packaging
- **–B–0.5**: Bxx = Resistance matched (Optional)
- **–RA**: Rx = Resistance range (Optional)
- **–120**: Hold current (mA)
- **TR250**: Product series

Part Marking System

Side 1

⨯ 16 V

- **16 V**: Voltage Rating
- **⨯**: Raychem circuit protection system symbol

G □□□□

- **□□□□**: Part ID - (current rating - 135 = 1.35A, 1400 = 14A, 010 = 0.1A)
- **G**: Product Family (G = RGE, H = RHE, X = RXE, U = RUE, L = LVR, T = RTE, R = RUSB)

Side 2

— — — —

- Date code/batch number

- Country of origin for assembly

Table R7. Tape and Reel Specifications for Radial-leaded Devices

RXE and BBR devices are available in tape and reel packaging per EIA468–B/IEC60286–2 standards. See Figures R24 and R25 for details.

Description	EIA Mark	Dimension (mm)	Tolerance
Carrier tape width	W	18	-0.5/+1.0
Hold-down tape width	W_4	11	Minimum
Top distance between tape edges	W_6	3	Maximum
Sprocket hole position	W_5	9	-0.5/+0.75
Sprocket hole diameter	D_0	4	± 0.2
Abscissa to plane (straight lead) RXE110 to RXE375	H	18.5	± 2.5
Abscissa to plane (kinked lead) RXE010 to RXE090, BBR550, BBR750	H_0	16.0	± 0.5
Abscissa to top RXE010 to RXE090, BBR550, BBR750	H_1	32.2	Maximum
Abscissa to top* RXE110 to RXE375	H_1	47.5	Maximum
Overall width with lead protrusion RXE010 to RXE090, BBR550, BBR750	C_1	43.2	Maximum
Overall width with lead protrusion* RXE110 to RXE375	C_1	58	Maximum
Overall width without lead protrusion RXE010 to RXE090, BBR550, BBR750	C_2	42.5	Maximum
Overall width without lead protrusion* RXE110 to RXE375	C_2	57	Maximum
Lead protrusion	L_1	1.0	Maximum
Protrusion of cut-out	L	11.0	Maximum
Protrusion beyond hold-down tape	l_2	Not specified	—
Sprocket hole pitch	P_0	12.7	± 0.3
Device pitch RXE010 to RXE090, BBR550, BBR750	—	12.7	± 0.3
Device pitch RXE110 to RXE375	—	25.4	± 0.61
Pitch tolerance	—	20 consecutive	± 1
Tape thickness	t	0.9	Maximum
Overall tape and lead thickness RXE010 to RXE090	t_1	1.5	Maximum
Overall tape and lead thickness RXE110 to RXE375, BBR550, BBR750*	t_1	2.3	Maximum
Splice sprocket hole alignment	—	0	± 0.3
Body lateral deviation	Δh	0	± 1.0
Body tape plane deviation	Δp	0	± 1.3
Ordinate to adjacent component lead RXE010 to RXE090, BBR550, BBR750	P_1	3.81	± 0.7
Ordinate to adjacent component lead RXE110 to RXE375	P_1	7.62	± 0.7
Lead spacing* RXE010 to RXE185, BBR550, BBR750	F	5.08	+0.75/-0.5
Lead spacing* RXE250 to RXE375	F	10.2	+0.75/-0.5
Reel width RXE010 to RXE090	w_2	56.0	Maximum
Reel width* RXE110 to RXE375	w_2	63.5	Maximum
Reel diameter	a	370.0	Maximum
Space between flanges less device	w_1	4.75	± 3.25
Arbor hold diameter	c	26.0	± 12.0
Core diameter*	n	91.0	Maximum
Box	—	64/372/362	Maximum
Consecutive missing places	—	None	—
Empty places per reel	—	0.1%	Maximum

*Differs from EIA specification.

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Table R7. Tape and Reel Specifications for Radial-leaded Devices *continued*

RUE, RTE and RUSB devices are available in tape and reel packaging per EIA468–B/IEC60286–2 standards. See Figures R24 and R25 for details.

Description	EIA Mark	Dimension (mm)	Tolerance
Carrier tape width	W	18	-0.5/+1.0
Hold-down tape width	W_4	11	Minimum
Top distance between tape edges	W_6	3	Maximum
Sprocket hole position	W_5	9	-0.5/+0.75
Sprocket hole diameter	D_0	4	± 0.2
Abscissa to plane (straight lead)* RUE300 to RUE900	H	18.5	± 2.5
Abscissa to plane (kinked lead) RUSB075 to RUSB250, RUE090 to RUE250, RTE120 to RTE190	H_o	16.0	± 0.5
Abscissa to top RUSB075 to RUSB250, RUE090 to RUE300, RTE120 to RTE190	H_1	32.2	Maximum
Abscissa to top* RUE400 to RUE900	H_1	45.0	Maximum
Overall width w/lead protrusion RUSB075 to RUSB250, RUE090 to RUE300, RTE120 to RTE190	C_1	43.2	Maximum
Overall width w/ lead protrusion RUE400 to RUE900	C_1	56	Maximum
Overall width w/o lead protrusion RUSB075 to RUSB250, RUE090 to RUE300, RTE120 to RTE190	C_2	42.5	Maximum
Overall width w/o lead protrusion RUE400 to RUE900	C_2	56	Maximum
Lead protrusion	L_1	1.0	Maximum
Protrusion of cut-out	L	11	Maximum
Protrusion beyond hold-down tape	l_2	Not specified	—
Sprocket hole pitch	P_0	12.7	± 0.3
Device pitch RUSB075 to RUSB250, RUE090 to RUE300, RTE120 to RTE190	—	12.7	± 0.3
Device pitch RUE400 to RUE900	—	25.4	± 0.6
Pitch tolerance	—	20 consecutive	± 1
Tape thickness	t	0.9	Maximum
Overall tape and lead thickness RUSB075 to RUSB250, RUE090 to RUE250, RTE120 to RTE190	t_1	1.5	Maximum
Overall tape and lead thickness* RUE300 to RUE900	t_1	2.3	Maximum
Splice sprocket hole alignment	—	0	± 0.3
Body lateral deviation	Δh	0	± 1.0
Body tape plane deviation	Δp	0	± 1.3
Ordinate to adjacent component lead RUSB075 to RUSB250, RUE090 to RUE300, RTE120 to RTE190	P_1	3.81	± 0.7
Ordinate to adjacent component lead RUE400 to RUE900	P_1	7.62	± 0.7
Lead spacing* RUSB075 to RUSB250, RUE090 to RUE400, RTE120 to RTE190	F	5.08	+0.75/-0.5
Lead spacing* RUE500 to RUE900	F	10.2	+0.75/-0.5
Reel width RUE090 to RUE400, RUSB075 to RUSB250, RTE120 to RTE190	w_2	56.0	Maximum
Reel width RUE500* to RUE900	w_2	63.5	Maximum
Reel diameter	a	370.0	Maximum
Space between flanges less device	w_1	4.75	± 3.25
Arbor hold diameter	c	26.0	± 12.0
Core diameter*	n	91.0	Maximum
Box	—	64/372/362	Maximum
Consecutive missing places	—	None	—
Empty places per reel	—	0.1%	Maximum

*Differs from EIA specification.

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Table R7. Tape and Reel Specifications for Radial-leaded Devices *continued*

RGE and RHE devices are available in tape and reel packaging per EIA468–B/IEC60286–2 standards. See Figures R24 and R25 for details.

Dimension Description	EIA Mark	Dimension (mm)	Tolerance
Carrier tape width	W	18	-0.5/+1.0
Hold-down tape width	W_4	11	Minimum
Top distance between tape edges	W_6	3	Maximum
Sprocket hole position	W_5	9	-0.5/+0.75
Sprocket hole diameter	D_0	4	± 0.2
Abscissa to plane (straight lead) RGE250 to RGE1400	H	18.5	± 2.5
Abscissa to plane (kinked lead) RHE050 to RHE1500	H_0	16.0	± 0.5
Abscissa to top RGE250 to RGE600, RHE050 to RHE450	H_1	32.2	Maximum
Abscissa to top* RGE700 to RGE1400, RHE600 to RHE1500	H_1	45.0	Maximum
Overall width w/lead protrusion RGE250 to RGE600, RHE050 to RHE450	C_1	43.2	Maximum
Overall width w/lead protrusion RGE700 to RGE1400, RHE600 to RHE1500	C_1	55	Maximum
Overall width w/o lead protrusion RGE250 to RGE600, RHE050 to RHE450	C_2	42.5	Maximum
Overall width w/o lead protrusion RGE700 to RGE1400, RHE600 to RHE1500	C_2	54	Maximum
Lead protrusion	L_1	1.0	Maximum
Protrusion of cut-out	L	11	Maximum
Protrusion beyond hold-down tape	I_2	Not specified	—
Sprocket hole pitch	P_0	12.7	± 0.3
Device pitch RGE250 to RGE700, RHE050 to RHE600	—	25.4	± 0.61
Device pitch RGE800 to RGE1400, RHE650 to RHE1500	—	25.4	± 0.6
Pitch tolerance	—	20 consecutive	± 1
Tape thickness	t	0.9	Maximum
Overall tape and lead thickness* RGE250 to RGE1100, RHE050 to RHE1000	t_1	2.0	Maximum
Overall tape and lead thickness* RGE1200 to RGE1400, RHE1300, RHE1500	t_1	2.3	Maximum
Splice sprocket hole alignment	—	0	± 0.3
Body lateral deviation	Δh	0	± 1.0
Body tape plane deviation	Δp	0	± 1.3
Ordinate to adjacent component lead RGE300 to RGE1100, RHE400 to RHE750	P_1	3.81	± 0.7
Ordinate to adjacent component lead RGE1200 to RGE1400, RHE1000 to RHE1500	P_1	7.62	± 0.7
Lead spacing* RGE250 to RGE1100, RHE050 to RHE900	F	5.08	+0.75 /-0.5
Lead spacing* RGE1200 to RGE1400, RHE1000 to RHE1500	F	10.2	+ 0.75/-0.5
Reel width RGE250 to RGE600, RHE050 to RHE450	w_2	56.0	Maximum
Reel width* RGE600 to RGE1400 & RHE600 to RHE1500	w_2	63.5	Maximum
Reel diameter	a	370.0	Maximum
Space between flanges less device*	w_1	4.75	± 3.25
Arbor hold diameter	c	26.0	± 12.0
Core diameter*	n	91.0	Maximum
Box	—	64/372/362	Maximum
Consecutive missing places	—	None	—
Empty places per reel	—	0.1%	Maximum

*Differs from EIA specification.

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Figure R24. EIA Referenced Taped Component Dimensions for Radial-leaded Devices

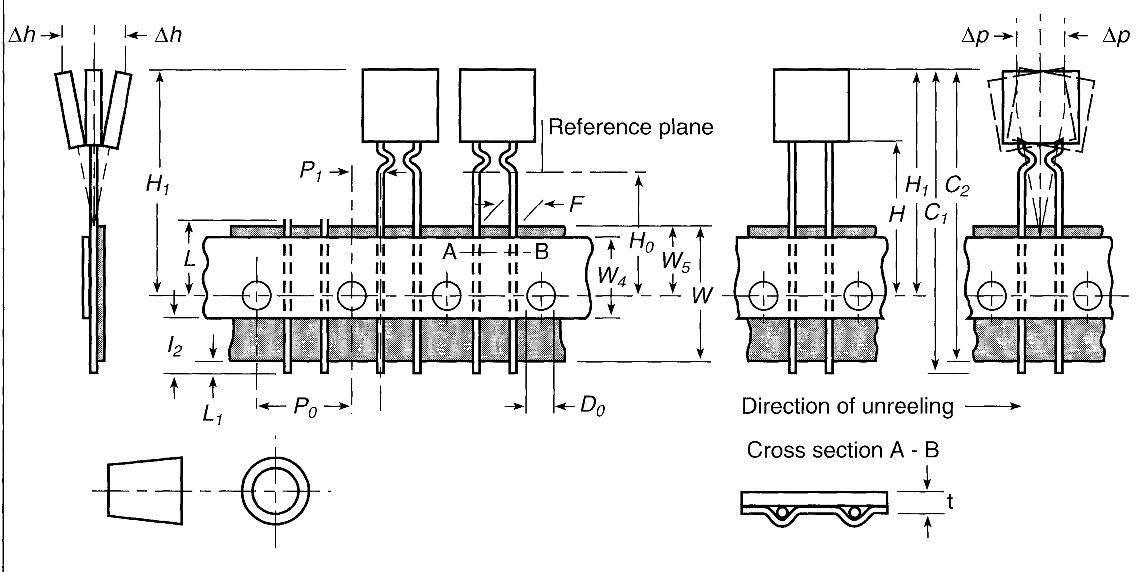
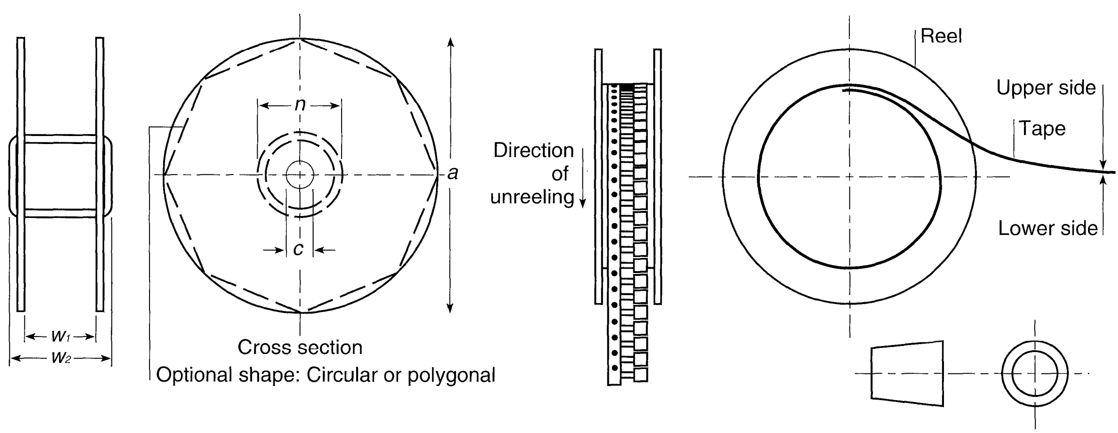


Figure R25. EIA Referenced Reel Dimensions for Radial-leaded Devices



Latest Information

- Please visit us at www.circuitprotection.com or contact your local representative for the latest information.
- The information in this Databook contains some preliminary information. Raychem Circuit Protection, a division of Tyco Electronics, reserves the right to change any of the specifications without notice. In addition, Tyco Electronics reserves the right to make changes—without notification to Buyer—to materials or processing that do not affect compliance with any applicable specification.

⚠ WARNING:

- Operation beyond the maximum ratings or improper use may result in device damage and possible electrical arcing and flame.
- The devices are intended for protection against occasional overcurrent or overtemperature fault conditions and should not be used when repeated fault conditions or prolonged trip events are anticipated.
- Contamination of the PPTC material with certain silicon based oils or some aggressive solvents can adversely impact the perfomance of the devices.
- Device performance can be impacted negatively if devices are handled in a manner inconsistent with recommended electronic, thermal, and mechanical procedures for electronic components.
- Operation in circuits with a large inductance can generate a circuit voltage ($L\, ^{di}/_{dt}$) above the rated voltage of the PolySwitch resettable device.

PolySwitch Automotive
Resettable Devices

Raychem has provided PPTC resettable devices in the automotive industry for over twenty years. Until recently, the products sold by Raychem to this industry were either custom products (TD and Chip series devices) or our standard commercial versions of PPTC resettable devices. With the advent of QS-9000 and our continued involvement in the automotive industry, we were asked to develop automotive-specific versions of our PPTC resettable devices. The result of that work is the four device series (AHS, ASMD, AHR and AGR) featured in this section (as well as adding other products to the automotive qualification on an ongoing basis). These products are qualified and sold under our PS400 specification which is derived from AEC-Q200, the standard for electronic components used in the automotive industry. The key difference of these products is the rigorous additional testing these devices have successfully passed to meet the demanding environmental conditions that can be found in automotive applications, and the addition of new specification values which characterize the products' performance after being subjected to these specified environmental and electrical stress conditions.

Benefits:
- Many product choices give engineers more design flexibility
- Compatible with high volume electronics assembly
- Assists in meeting regulatory requirements
- Higher voltage ratings allow use in new applications

Features:
- Wide range of resettable devices for the automotive industry
- Current ratings from 0.3A to 15A
- Voltage ratings from 15V to 60V
- Meets automotive industry standards
- Fast time-to-trip
- Low resistance

Applications:
- Electronic control modules
- Automotive small and medium motors
- Junction boxes
- Lamp protection
- Power outlet protection
- Powered antennae
- Telematics powered components protection
- HVAC and climate control

Devices in this section are grouped by:
Form Factor, Product Series, Hold Current

Step 1. Determine the circuit's operating parameters.

Fill in the following information about the circuit:

Maximum ambient operating temperature ____________

Normal operating current ____________

Maximum operating voltage
(i.e. AGR400 is $16V_{MAX}$.) ____________

Maximum interrupt current ____________

Step 2. Select the PolySwitch device that will accommodate the circuit's maximum ambient temperature and normal operating current.

Look across the top of Table A2 to find the temperature that most closely matches the circuit's maximum operating temperature. Look down that column to find the value equal to or greater than the circuit's normal operating current. Now look to the far left of that row to find the part number for the PolySwitch device that will best accommodate the circuit. Devices in this section are grouped by form factor, therefore your operating current requirement may be found in more than one product grouping.

The thermal derating curves located in Figures A1 and A2 are the normalized representations of the data in Table A2.

Step 3. Compare the selected device's maximum electrical ratings with the circuit's maximum operating voltage and maximum interrupt current.

Look down the first column of Table A3 to find the part number you selected in Step 2. Look to the right in that row to find the device's maximum operating voltage (V_{MAX}) and maximum interrupt current (I_{MAX}) Ensure that V_{MAX} and I_{MAX} are greater than or equal to the circuit's maximum operating voltage and maximum interrupt current.

Step 4. Determine time-to-trip.

Time-to-trip is the amount of time it takes for a device to switch to a high-resistance state once a fault current has been applied across the device. Identifying the PolySwitch device's time-to-trip is important in order to provide the desired protection capabilities. If the device you choose trips too fast, undesired or nuisance tripping will occur. If the device trips too slowly, the components being protected may be damaged before the device switches to a high-resistance state.

Refer to the typical time-to-trip curves for each of the PolySwitch devices found in Figures A8-A11.

If the PolySwitch device's time-to-trip is too fast or too slow for the circuit, go back to Step 2 and choose an alternate device.

Step 5. Verify ambient operating conditions.

Ensure that your application's minimum and maximum ambient temperatures are within the operating temperature of -40°C to 85°C (-40°C to 125°C for AHR, AHS series devices).

Step 6. Verify the PolySwitch device dimensions.

Using dimensions in Table A4, compare the dimensions of the PolySwitch device you selected with the application's space considerations.

Table A1. Product Series – Current Rating, Voltage Rating/Typical Resistance for Automotive Devices

	AGR	AHR	AHS	ASMD		
Voltage Rating	**16V**	**16V**	**16V**	**15V**	**30V**	**60V**
Hold Current (A)						
0.30	—	—	—	—	—	0.23Ω
0.50	—	—	—	—	—	0.90Ω
0.75	—	—	—	—	0.60Ω	
0.80	—	—	0.25Ω	—	—	—
1.00	—	—	—	—	0.30Ω	—
1.25	—	—	—	0.16Ω	—	—
1.50	—	—	—	0.16Ω	—	—
1.60	—	—	0.10Ω	—	—	—
2.00	—	—	—	0.09Ω	—	—
2.50	—	—	—	0.06Ω	—	—
4.00	0.030Ω	—	—	—	—	—
4.50	—	0.029Ω	—	—	—	—
5.00	0.0192Ω	—	—	—	—	—
6.00	0.0145Ω	0.018Ω	—	—	—	—
6.50	—	0.014Ω	—	—	—	—
7.00	0.0105Ω	—	—	—	—	—
7.50	—	0.012Ω	—	—	—	—
8.00	0.0086Ω	—	—	—	—	—
9.00	0.0070Ω	0.010Ω	—	—	—	—
10.00	0.0056Ω	0.0083Ω	—	—	—	—
11.00	0.0050Ω	—	—	—	—	—
12.00	0.0046Ω	—	—	—	—	—
13.00	—	0.0055Ω	—	—	—	—
14.00	0.0040Ω	—	—	—	—	—
15.00	—	0.0048Ω	—	—	—	—

Table A2. Thermal Derating for Automotive Devices [Hold Current (A) at Ambient Temperature (°C)]

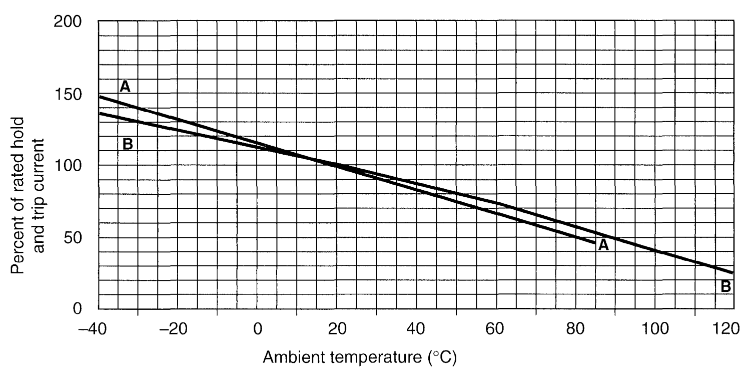
Part Number	Maximum Ambient Temperature -40°C	-20°C	0°C	20°C	25°C	40°C	50°C	60°C	70°C	85°C	125°C
AGR (AGRF for Pb-free version of product) **16V—Leaded**											
AGR400	5.9	5.3	4.8	4.1	4.0	3.5	3.2	2.8	2.5	1.9	—
AGR500	7.3	6.6	6.0	5.2	5.0	4.4	4.0	3.6	3.1	2.4	—
AGR600	8.8	8.0	7.2	6.2	6.0	5.2	4.8	4.2	3.8	2.8	—
AGR700	10.3	9.3	8.4	7.3	7.0	6.2	5.6	5.0	4.4	3.3	—
AGR800	11.7	10.7	9.6	8.3	8.0	6.9	6.4	5.6	5.1	3.7	—
AGR900	13.2	11.9	10.7	9.4	9.0	7.9	7.2	6.4	5.6	4.2	—
AGR1000	14.7	13.3	12.0	10.3	10.0	8.7	8.0	7.0	6.3	4.7	—
AGR1100	16.1	14.6	13.1	11.5	11.0	9.7	8.8	7.8	6.9	5.2	—
AGR1200	17.6	16.0	14.4	12.4	12.0	10.4	9.6	8.4	7.6	5.6	—
AGR1400	20.5	18.7	16.8	14.5	14.0	12.1	11.2	9.8	8.9	6.5	—
AHR (High Temperature) (AHRF for Pb-free version of product) **16V—Leaded**											
AHR450	6.1	5.6	5.1	4.6	4.5	4.0	3.6	3.3	3.0	2.5	1.1
AHR600	8.2	7.5	6.8	6.2	6.0	5.3	4.9	4.4	4.0	3.3	1.5
AHR650	8.8	8.1	7.4	6.7	6.5	5.7	5.3	4.8	4.3	3.6	1.6
AHR750	10.2	9.4	8.6	7.7	7.5	6.6	6.1	5.6	5.0	4.1	1.9
AHR1000	13.6	12.5	11.4	10.3	10.0	8.8	8.1	7.4	6.6	5.5	2.5
AHR1300	17.7	16.3	14.8	13.4	13.0	11.4	10.5	9.6	8.6	7.2	3.3
AHS (High Temperature) 16V—Surface-mount											
AHS080-2018	1.20	1.04	0.90	0.80	0.77	0.68	0.62	0.60	0.53	0.46	0.26
AHS160	2.15	1.96	1.78	1.60	1.55	1.42	1.33	1.24	1.15	1.01	0.64
ASMD 15-60V—Surface-mount											
ASMD030	0.35	0.31	0.27	0.23	0.22	0.19	0.17	0.15	0.13	0.11	—
ASMD050	0.59	0.53	0.46	0.39	0.37	0.33	0.29	0.26	0.23	0.18	—
ASMD075	0.91	0.81	0.71	0.60	0.58	0.50	0.45	0.40	0.35	0.28	—
ASMD100	1.37	1.22	1.06	0.90	0.86	0.76	0.68	0.60	0.52	0.41	—
ASMD125	1.58	1.40	1.23	1.04	1.00	0.87	0.78	0.70	0.60	0.48	—
ASMD150	1.93	1.70	1.50	1.27	1.22	1.07	0.95	0.85	0.74	0.58	—
ASMD200	2.63	2.34	2.04	1.73	1.66	1.45	1.30	1.16	1.00	0.80	—
ASMD250	3.00	2.66	2.32	1.97	1.89	1.65	1.48	1.32	1.14	0.91	—

Figures A1-A2. Thermal Derating Curves for Automotive Devices

A = AGR/AGRF

B = AHR/AHRF

Figure A1



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A = ASMD

B = AHS

Figure A2

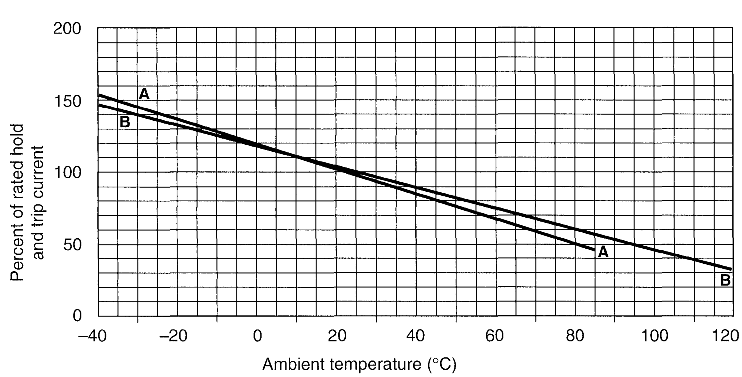

Table A3. Electrical Characteristics for Automotive Devices

Part Number	I_H (A) @ R_{1MAX}	I_H (A) @ R_{aMAX}	I_T (A)	V_{MAX} (V_{DC})	I_{MAX} (A)	$P_{D\ TYP}$ (W)	Max. Time-to-trip (A)	Max. Time-to-trip (s)	R_{MIN} (Ω)	R_{1MAX} (Ω)	R_{aMAX} (Ω)	Figures for Dimensions
AGR (AGRF for Pb-free version of product) **16V–Leaded**												
AGR400	4.0	3.0	7.6	16	100	2.5	20	2.0	0.0186	0.061	0.085	A3, A6, A7
AGR500	5.0	4.3	9.4	16	100	2.7	25	2.5	0.0140	0.034	0.048	A3, A6, A7
AGR600	6.0	5.3	10.7	16	100	2.8	30	3.5	0.0095	0.028	0.032	A3, A6, A7
AGR700	7.0	6.5	13.2	16	100	3.0	35	4.0	0.0066	0.020	0.022	A3, A6, A7
AGR800	8.0	7.6	15.0	16	100	3.2	40	5.5	0.0049	0.0175	0.0181	A3, A6, A7
AGR900	9.0	8.6	16.5	16	100	3.4	45	6.0	0.0041	0.0135	0.0140	A3, A6, A7
AGR1000	10.0	9.6	18.5	16	100	3.6	50	7.0	0.0034	0.0102	0.0106	A3, A6, A7
AGR1100	11.0	10.5	20.3	16	100	3.7	55	7.5	0.0033	0.0089	0.0093	A3, A6, A7
AGR1200	12.0	11.5	22.1	16	100	4.2	60	8.0	0.0030	0.0086	0.0091	A3, A6, A7
AGR1400	14.0	13.0	27.3	16	100	4.6	70	9.0	0.0022	0.0064	0.0067	A3, A6, A7
AHR (AHRF for Pb-free version of product) **16V–Leaded (High Temperature)**												
AHR450	4.5	4.5	8.7	16	100	3.6	22.5	4.0	0.0170	0.054	0.054	A3, A6, A7
AHR600	6.0	6.0	12.0	16	100	4.1	30.0	6.5	0.0100	0.032	0.032	A3, A6, A7
AHR650	6.5	6.5	13.7	16	100	4.3	32.5	7.0	0.0090	0.026	0.026	A3, A6, A7
AHR750	7.5	7.5	14.8	16	100	4.5	37.5	8.0	0.0074	0.022	0.022	A3, A6, A7
AHR1000	10.0	10.0	20.5	16	100	5.3	50	10.5	0.0051	0.015	0.015	A3, A6, A7
AHR1300	13.0	13.0	27.0	16	100	6.9	65	15.0	0.0034	0.010	0.010	A3, A6, A7
AHS **16V–Surface-mount (High Temperature)**												
AHS080-2018	0.80	0.80	2.00	16	70	1.5	8.0	9.0	0.130	0.550	0.550	A4
AHS160	1.60	1.60	3.20	16	70	2.1	8.0	15.0	0.050	0.150	0.150	A5
ASMD **15-60V–Surface-mount**												
ASMD030	0.23	0.23	0.59	60	10	1.1	1.15	12.0	0.98	4.800	4.800	A5
ASMD050	0.39	0.39	0.98	60	10	1.1	1.95	20.0	0.29	1.400	1.400	A5
ASMD075	0.60	0.60	1.48	30	40	1.1	3.00	20.0	0.29	1.000	1.000	A5
ASMD100	0.90	0.90	2.16	30	40	1.1	4.50	20.0	0.098	0.480	0.480	A5
ASMD125	1.04	1.04	2.46	15	40	1.1	5.20	20.0	0.057	0.250	0.250	A5
ASMD150	1.27	1.27	2.95	15	40	1.2	6.35	25.0	0.049	0.250	0.250	A5
ASDM200	1.73	1.73	3.93	15	40	1.2	8.65	30.0	0.05	0.120	0.120	A5
ASMD250	1.97	1.97	5.00	15	40	1.2	9.85	30.0	0.035	0.085	0.085	A5

Notes:

I_H = Hold current: maximum current device will pass without interruption in 25°C unless otherwise specified (20°C for ASMD).

I_T = Trip current: minimum current that will switch the device from low resistance to high resistance in 25°C still air unless otherwise specified.

V_{MAX} = Maximum voltage device can withstand without damage at rated current.

I_{MAX} = Maximum fault current device can withstand without damage at rated voltage.

P_D = Power dissipated from device when in the tripped state in 25°C still air unless otherwise specified.

R_{1MAX} = Maximum resistance of device when measured one hour post reflow (surface-mount device) or one hour post trip (radial leaded device) at 25°C unless otherwise specified.

R_{aMIN} = Minimum functional resistance of device after being subjected to the stresses described in PS400 at 25°C unless otherwise specified.

R_{aMAX} = Maximum functional resistance of device after being subjected to the stresses described in PS400 at 25°C unless otherwise specified.

R_{MIN} = Minimum resistance of device as supplied at 25°C unless otherwise specified.

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Figures A3–A7. Physical Description for Dimensions for Automotive Devices

Figure A3

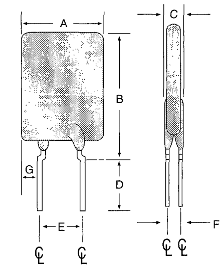

Figure A4

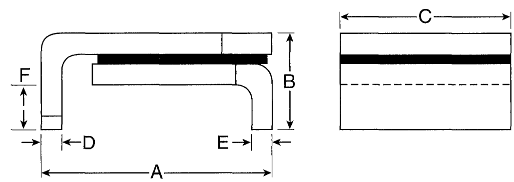

Figure A5

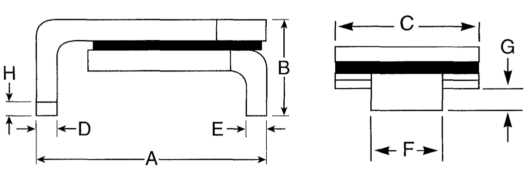

Figure A6

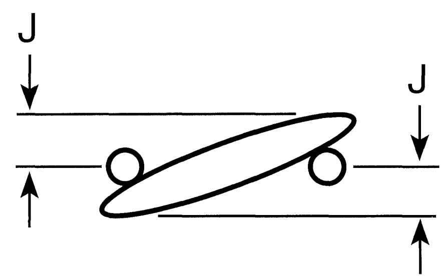

Figure A7

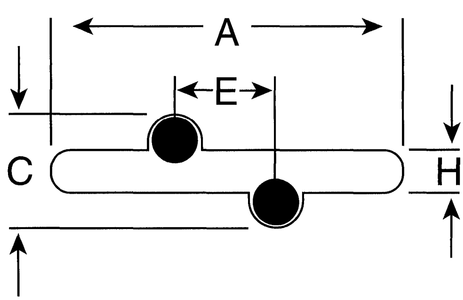

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Table A4. Dimensions for Automotive Devices in Millimeters (Inches)

Part Number	Dimension A Min.	A Max.	B Min.	B Max.	C Min.	C Max.	D Min.	D Max.	E Min.	E Max.	F Typ.	F Max.	G Min.	G Max.	H Typ.	J Max.	Figures
AGR (AGRF for Pb-free version of product) **16V—Leaded**																	
AGR400	—	8.9 (0.35)	—	14.1 (0.56)	—	3.0 (0.12)	7.6 (0.3)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.15)	—	—	3.05 (0.120)	1.24 (0.049)	1.4 (0.06)	A3, A6, A7
AGR500	—	10.4 (0.41)	—	15.6 (0.61)	—	3.0 (0.12)	7.6 (0.3)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	—	—	3.94 (0.155)	1.24 (0.049)	1.6 (0.06)	A3, A6, A7
AGR600	—	10.7 (0.42)	—	18.4 (0.73)	—	3.0 (0.12)	7.6 (0.3)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	—	—	4.07 (0.160)	1.24 (0.049)	1.6 (0.06)	A3, A6, A7
AGR700	—	11.2 (0.44)	—	21.0 (0.73)	—	3.0 (0.12)	7.6 (0.3)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	—	—	4.49 (0.177)	1.24 (0.049)	1.7 (0.07)	A3, A6, A7
AGR800	—	12.7 (0.50)	—	22.2 (0.88)	—	3.0 (0.12)	7.6 (0.3)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	—	—	5.08 (0.200)	1.24 (0.049)	1.8 (0.07)	A3, A6, A7
AGR900	—	14.0 (0.55)	—	23.0 (0.91)	—	3.0 (0.12)	7.6 (0.3)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	—	—	5.69 (0.224)	1.24 (0.049)	2.0 (0.08)	A3, A6, A7
AGR1000	—	16.51 (0.65)	—	25.7 (1.01)	—	3.0 (0.12)	7.6 (0.3)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	—	—	6.96 (0.274)	1.24 (0.049)	2.0 (0.08)	A3, A6, A7
AGR1100	—	17.5 (0.69)	—	26.5 (1.04)	—	3.0 (0.12)	7.6 (0.3)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	—	—	7.47 (0.294)	1.24 (0.049)	2.4 (0.09)	A3, A6, A7
AGR1200	—	17.5 (0.69)	—	28.8 (1.14)	—	3.5 (0.14)	7.6 (0.3)	—	9.4 (0.37)	10.9 (0.43)	1.4 (0.06)	—	—	4.83 (0.190)	1.45 (0.057)	1.5 (0.06)	A3, A6, A7
AGR1400	—	23.5 (0.925)	—	28.7 (1.13)	—	3.5 (0.14)	7.6 (0.3)	—	9.4 (0.37)	10.9 (0.43)	1.4 (0.06)	—	—	7.82 (0.308)	1.45 (0.057)	1.9 (0.07)	A3, A6, A7
AHR (High Temperature) (AHRF for Pb-free version of product) **16V—Leaded**																	
AHR450	—	10.4 (0.41)	—	15.6 (0.61)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	—	—	3.94 (0.155)	1.24 (0.049)	1.6 (0.06)	A3, A6, A7
AHR600	—	11.2 (0.44)	—	21.0 (0.73)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	—	—	4.49 (0.177)	1.24 (0.049)	1.7 (0.067)	A3, A6, A7
AHR650	—	12.7 (0.50)	—	22.2 (0.88)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	—	—	5.08 (0.200)	1.24 (0.049)	1.8 (0.07)	A3, A6, A7
AHR750	—	14.0 (0.55)	—	23.5 0.93)	—	3.0 (0.14)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	1.2 (0.05)	—	—	5.69 (0.224)	1.24 (0.049)	2.0 (0.08)	A3, A6, A7
AHR1000	—	17.5 (0.69)	—	26.5 (1.04)	—	3.0 (0.12)	7.6 (0.30)	—	9.4 (0.37)	10.9 (0.43)	1.2 (0.05)	—	—	7.47 (0.294)	1.24 (0.049)	1.5 (0.06)	A3, A6, A7
AHR1300	—	23.5 (0.925)	—	28.7 (1.13)	—	3.5 (0.14)	7.6 (0.30)	—	9.4 (0.37)	10.9 (0.43)	1.4 (0.06)	—	—	7.82 (0.308)	1.45 (0.057)	1.9 (0.08)	A3, A6, A7

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Table A4. Dimensions for Automotive Devices in Millimeters (Inches) *continued*

Part Number	Dimension A Min.	A Max.	B Min.	B Max.	C Min.	C Max.	D Min.	D Max.	E Min.	E Max.	F Min.	F Max.	G Min.	G Max.	H Min.	H Max.	Figures
AHS (High Temperature) 16V—Surface-mount																	
AHS080-2018	4.72 (0.186)	5.44 (0.214)	—	1.52 (0.060)	4.22 (0.166)	4.93 (0.194)	0.25 (0.010)	0.36 (0.014)	0.25 (0.010)	0.36 (0.014)	0.30 (0.012)	0.46 (0.018)	—	—	—	—	A4
AHS160	8.00 (0.315)	9.40 (0.370)	—	3.00 (0.118)	6.0 (0.24)	6.71 (0.264)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	3.68 (0.145)	3.94 (0.155)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)		A5
ASMD 15-60V—Surface-mount																	
ASMD030	6.73 (0.265)	7.98 (0.314)	—	3.18 (0.125)	4.8 (0.19)	5.44 (0.214)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	2.16 (0.085)	2.41 (0.095)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	—	A5
ASMD050	6.73 (0.265)	7.98 (0.314)	—	3.18 (0.125)	4.8 (0.19)	5.44 (0.214)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	2.16 (0.085)	2.41 (0.095)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	—	A5
ASMD075	6.73 (0.265)	7.98 (0.314)	—	3.18 (0.125)	4.8 (0.19)	5.44 (0.214)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	2.16 (0.085)	2.41 (0.095)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	—	A5
ASMD100	6.73 (0.265)	7.98 (0.314)	—	3.00 (0.118)	4.8 (0.19)	5.44 (0.214)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	2.16 (0.085)	2.41 (0.095)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	—	A5
ASMD125	6.73 (0.265)	7.98 (0.314)	—	3.00 (0.118)	4.8 (0.19)	5.44 (0.214)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	2.16 (0.085)	2.41 (0.095)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	—	A5
ASMD150	8.00 (0.315)	9.40 (0.370)	—	3.00 (0.118)	6.0 (0.24)	6.71 (0.264)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	3.68 (0.145)	3.94 (0.155)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	—	A5
ASMD200	8.00 (0.315)	9.40 (0.370)	—	3.00 (0.118)	6.0 (0.24)	6.71 (0.264)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	3.68 (0.145)	3.94 (0.155)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	—	A5
ASMD250	8.00 (0.315)	9.40 (0.370)	—	3.00 (0.118)	6.0 (0.24)	6.71 (0.264)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	3.68 (0.145)	3.94 (0.155)	0.66 (0.026)	1.37 (0.054)	0.43 (0.017)	—	A5

Figures A8–A11. Typical Time-to-trip at 25°C for Automotive Devices

AGR/AGRF

A = AGR400

B = AGR500

C = AGR600

D = AGR700

E = AGR800

F = AGR900

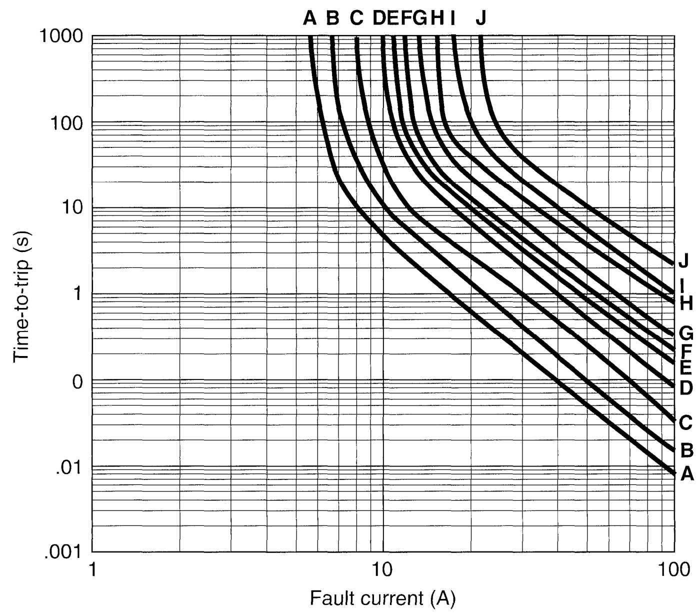
G = AGR1000

H = AGR1100

I = AGR1200

J = AGR1400

Figure A8



AHR/AHRF

A = AHR450

B = AHR600

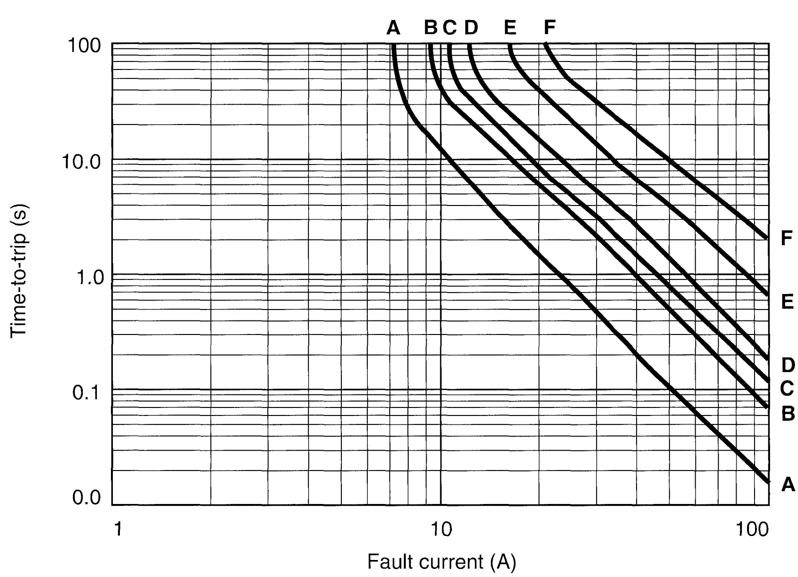
C = AHR650

D = AHR750

E = AHR1000

F = AHR1300

Figure A9



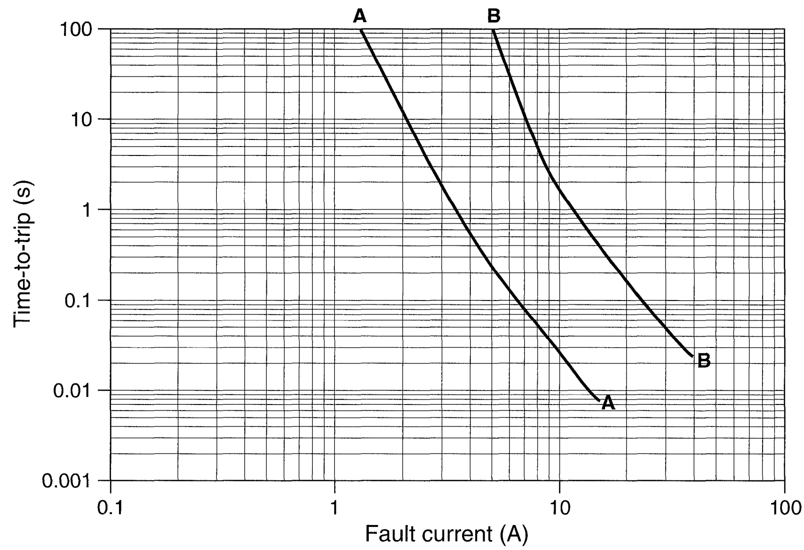
Figures A8–A11. Typical Time-to-trip at 25°C for Automotive Devices *continued*

AHS

A = AHS080-2018

B = AHS160

Figure A10



4

ASMD

A = ASMD030

B = ASMD050

C = ASMD075

D = ASMD100

E = ASMD125

F = ASMD150

G = ASMD200

H = ASMD250

Figure A11

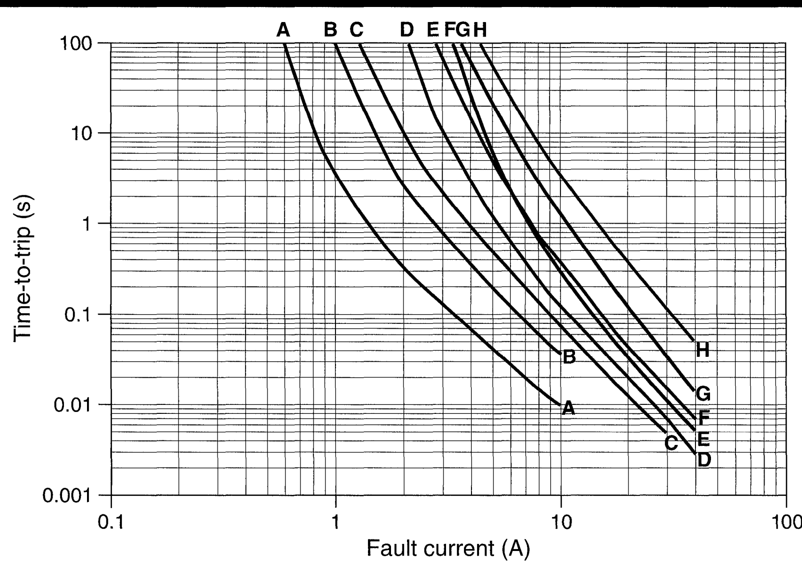


Table A5. Physical Characteristics and Environmental Specifications for Automotive Devices

AGR
Physical characteristics

Lead material	AGR400 to AGR1000: Tin/Lead Plated Copper, 0.52mm^2 (20AWG) ø 0.8 mm/0.032in
	AGR1200 to AGR1400: Tin/Lead Plated Copper, 0.82mm^2 (18AWG) ø 1.0mm/0.040in
Soldering characteristics	Solderability per ANSI/J-STD-002 Category 3
Solder heat withstand	AGR400: per IEC68-2-20 Test Tb, method 1a, condition a: can withstand 5 seconds at 260˚C ± 5˚C AGR500-AGR1400: per IEC68-2-20 Test Tb, method 1a, condition b: can withstand 10 seconds at 260˚C ± 5˚C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0
See PS400 for other physical characteristics	

*Devices are not designed to be placed through a reflow process.

AGRF
Physical characteristics

Lead material	AGRF400 to AGRF1000: Tin plated copper, 0.52mm^2 (20AWG) ø 0.8 mm/0.032in
	AGRF1200 to AGRF1400: Tin plated copper, 0.82mm^2 (18AWG) ø 1.0mm/0.040in
Soldering characteristics	Solderability per ANSI/J-STD-002 Category 3
Solder heat withstand	AGR400: per IEC68-2-20 Test Tb, method 1a, condition a: can withstand 5 seconds at 260˚C ± 5˚C AGR500-AGR1400: per IEC68-2-20 Test Tb, method 1a, condition b: can withstand 10 seconds at 260˚C ± 5˚C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0
See PS400 for other physical characteristics	

*Devices are not designed to be placed through a reflow process.

AGR/AGRF
Environmental specifications

Test	Conditions	Resistance Change
Passive aging	70°C, 1000 hours	±5%
	85°C, 1000 hours	±5%
Humidity aging	85°C, 85% RH, 1000 hours	±5%
Thermal shock	85°C, -40°C (10 times)	±5%
Solvent resistance	MIL-STD-202, Method 215F	No change
See PS400 for other environmental specifications		

AHR
Physical characteristics

Lead material	AHR450 to AHR1000: Tin/lead-plated Copper 0.52mm^2 (20 AWG), ø 0.81mm/0.032in
	AHR1300: Tin lead-plated copper 0.82mm^2 (18AWG),. ø 1.0mm/0.04 in
Soldering characteristics	Solderability per ANSI/J-STD 002 Category 3
Solder heat withstand	per IEC 68-2-20, Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0 requirements
See PS400 for other physical specifications	

*Devices are not designed to be placed through a reflow process.

AHRF
Physical characteristics

Lead material	AHR450 to AHR1000: Tin-plated Copper 0.52mm^2 (20 AWG), ø 0.81mm/0.032in
	AHR1300: Tin-plated copper 0.82mm^2 (18AWG),. ø 1.0mm/0.04 in
Soldering characteristics	Solderability per ANSI/J-STD 002 Category 3
Solder heat withstand	per IEC 68-2-20, Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0 requirements
See PS400 for other physical specifications	

*Devices are not designed to be placed through a reflow process.

Table A5. Physical Characteristics and Environmental Specifications for Automotive Devices *continued*

AHR/AHRF
Environmental specifications

Test	Conditions	Resistance Change
Passive aging	70°C, 1000 hours	±5%
	85°C, 1000 hours	±5%
Humidity aging	85°C, 85% RH, 1000 hours	±5%
Thermal shock	125°C, -40°C (10 times)	±5%
Solvent resistance	MIL-STD-202, Method 215F	No change
See PS400 for other environmental specifications		

ASMD
Physical characteristics

Terminal pad material	98%+ Tin-plated Brass
Soldering characteristics	Solderability per ANSI-J-STD-002 Category 1
Solder heat withstand	per IEC-STD 68-2-20, Test Tb, Section 5, Method 1A
Flammability resistance	per IEC 695-2-2 Needle flame test for 20 seconds
Recommended storage conditions	40˚C max, 70% RH max; devices may not meet specified ratings if storage conditions are exceeded
See PS400 for other physical characteristics	

Environmental specifications

Test	Conditions	Resistance Change
Passive aging	60°C, 1000 hours	±3% typical
	85°C, 1000 hours	±5% typical
Humidity aging	85°C, 85% RH, 100 hours	±1.2% typical
Thermal shock	85°C, -40°C (20 times) 125˚C, -55˚C (10 times)	-33% typical -33% typical
Solvent resistance	Freon Trichloroethane Hydrocarbons	No change No change No change
See PS400 for other environmental specifications		

AHS
Physical characteristics

Lead material	Tin-plated brass to MIL-T-10727B
Soldering characteristics	Solderability per ANSI-J-STD-002 Category 1
Solder heat withstand	per IEC-STD 68-2-20, Test Tb, Section 5, Method 1A
Flammability	per IEC 695-2-2 Needle flame test for 20 seconds
See PS400 for other physical characteristics	

Environmental specifications

Test	Conditions	Resistance Change
Passive aging	70°C, 1000 hours	±3% Typical
	85°C, 1000 hours	±5% Typical
Humidity aging	85°C, 85% RH, 1000 hours	±1.2% Typical
Thermal shock	125°C, -40°C (20 times)	-33% Typical
Solvent resistance	Freon Trichloroethane Hydrocarbons	No change No change No change
See PS400 for other environmental specifications		

Table A6. Packaging and Marking Information for Radial-leaded Automotive Devices

Part Number	Bag Quantity	Tape & Reel Quantity	Ammo Pack Quantity	Standard Package Quantity	Part Marking	Agency Recognition
AGR Leaded						
AGR400	500	—	—	10,000	G4	*
AGR400-2	—	2,500	—	12,500	G4	*
AGR400-AP	—	—	2,000	10,000	G4	*
AGR500	500	—	—	10,000	G5	*
AGR500-2	—	2,000	—	10,000	G5	*
AGR500-AP	—	—	2,000	10,000	G5	*
AGR600	500	—	—	10,000	G6	*
AGR600-2	—	2,000	—	10,000	G6	*
AGR600-AP	—	—	2,000	10,000	G6	*
AGR700	500	—	—	10,000	G7	*
AGR700-2	—	1,500	—	7,500	G7	*
AGR700-AP	—	—	1,500	7,500	G7	*
AGR800	500	—	—	10,000	G8	*
AGR800-2	—	1,000	—	5,000	G8	*
AGR800-AP	—	—	1,000	5,000	G8	*
AGR900	500	—	—	10,000	G9	*
AGR900-2	—	1,000	—	5,000	G9	*
AGR900-AP	—	—	1,000	5,000	G9	*
AGR1000	250	—	—	5,000	G10	*
AGR1000-2	—	1,000	—	5,000	G10	*
AGR1000-AP	—	—	1,000	5,000	G10	*
AGR1100	250	—	—	5,000	G11	*
AGR1100-2	—	1,000	—	5,000	G11	*
AGR1100-AP	—	—	1,000	5,000	G11	*
AGR1200	250	—	—	5,000	G12	*
AGR1200-2	—	1,000	—	5,000	G12	*
AGR1200-AP	—	—	1,000	5,000	G12	*
AGR1400	250	—	—	5,000	G14	*
AGR1400-2	—	1,000	—	5,000	G14	*
AGR1400-AP	—	—	1,000	5,000	G14	*

*These devices have been designed for use in automotive applications. For commercial alternatives to these product series please see the Radial-leaded or Surface-mount section of this Databook.

Table A6. Packaging and Marking Information for Radial-leaded Automotive Devices *continued*

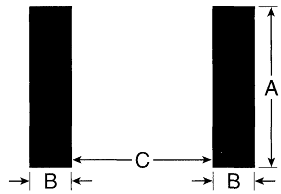
Part Number	Bag Quantity	Tape & Reel Quantity	Ammo Pack Quantity	Standard Package Quantity	Part Marking	Agency Recognition
AHR (High Temperature) Leaded						
AHR450	500	—	—	10,000	H4.5	*
AHR450-2	—	1,500		7,500	H4.5	*
AHR450-AP	—	—	1,500	7,500	H4.5	*
AHR600	500	—	—	10,000	H6	*
AHR600-2	—	1,500	—	7,500	H6	*
AHR600-AP	—	—	1,500	7,500	H6	*
AHR650	500	—	—	10,000	H6.5	*
AHR650-2	—	1,500	—	7,500	H6.5	*
AHR650-AP	—	—	1,500	7,500	H6.5	*
AHR750	500	—	—	10,000	H7.5	*
AHR750-2	—	1,000	—	5,000	H7.5	*
AHR750-AP	—	—	1,000	5,000	H7.5	*
AHR1000	250	—	—	5,000	H10	*
AHR1000-2	—	1,000	—	5,000	H10	*
AHR1000-AP	—	—	1,000	5,000	H10	*
AHR1300	250	—	—	5,000	H13	*
AHR1300-2	—	1,000	—	5,000	H13	*
AHR1300-AP	—	—	1,000	5,000	H13	*

Table A7. Packaging and Marking Information for Surface-mount Automotive Devices

				Recommended Pad Layouts [mm (in) See Figure A12]			
Part Number	**Tape & Reel Quantity**	**Standard Package Quantity**	**Part Marking**	**Dimension A (min*/nom)**	**Dimension B (nom)**	**Dimension C (nom)**	**Agency Recognition**
AHS (High Temperature)							
AHS080-2018	4,000	20,000	H08	4.6 (0.18)	1.5 (0.09)	3.4 (0.134)	*
AHS160	1,500	7,500	160	4.6 (0.18)	2.3 (0.09)	6.1 (0.240)	*
ASMD							
ASMD030	2,000	10,000	030	3.1 (0.12)	2.3 (0.09)	5.1 (0.201)	*
ASMD050	2,000	10,000	050	3.1 (0.12)	2.3 (0.09)	5.1 (0.201)	*
ASMD075	2,000	10,000	075	3.1 (0.12)	2.3 (0.09)	5.1 (0.201)	*
ASMD100	2,000	10,000	100	3.1 (0.12)	2.3 (0.09)	5.1 (0.201)	*
ASMD125	2,000	10,000	125	3.1 (0.12)	2.3 (0.09)	5.1 (0.201)	*
ASMD150	1,500	7,500	150	4.6 (0.18)	2.3 (0.09)	6.1 (0.240)	*
ASMD200	1,500	7,500	200	4.6 (0.18)	2.3 (0.09)	6.1 (0.240)	*
ASMD250	1,500	7,500	250	4.6 (0.18)	2.3 (0.09)	6.1 (0.240)	*

*These devices have been designed for use in automotive applications. For commercial alternatives to these product series please see the Radial-leaded or Surface-mount section of this Databook.

Figure A12. Recommended Pad Layout for Automotive Devices



Part Numbering System for Automotive Devices

AGR 800 -2

- -2: Packaging option
  (Blank) = Bulk
  2 = Tape and reel packaging
  AP = Ammo pack
- 800: Hold current indicator
- AGR: Product series – An "F" at the end of the series indicates Pb-free version of product

AHS 080 -2

- -2: 2 = Tape and reel packaging
- 080: Hold current indicator
- AHS: Product series

Part Marking System for Radial-leaded Automotive Devices

Side 1

16

- 16: Voltage Rating (Volts)
- Raychem circuit protection system symbol

G □□□□

- □□□□: Part ID - (current rating - 7 = 7A, 4.5 = 4.5A, 13 = 13A)
- G: Product Family (G = AGR, H = AHR)

Side 2

_ _ _ _

- Date code/batch number

____

- Country of origin for assembly

Part Marking System for Surface-mount Automotive Devices

□□□□

- □□□□: Part ID - (current rating - 125 = 1.25A, 0.30 = 300mA, 250 = 2.5A)
- Raychem circuit protection system symbol

_ _ _ _

- Date code/batch number

Table A8. Tape and Reel Specifications for Automotive Devices

AGR and AHR devices are available in tape and reel packaging per EIA468-B/IEC286-2 and EIA 481-2 standards. See Figures A13 and A14 for details.

Description	EIA Mark	Dimensions (mm)	Tolerance
Carrier tape width	W	18.0	-0.5/+1.0
Hold down tape width	W_4	11.0	Minimum
Top distance between tape edges	W_6	3.0	Maximum
Sprocket hole position	W_5	9.0	-0.5/+0.75
Sprocket hole diameter	D_0	4.0	±0.2
Abscissa to plane	H_0	16.0	±0.5
Abscissa to top AGR500 to AGR600 & AHR450	H_1	32.2	Maximum
Abscissa to top AGR700 to AGR1400 & AHR600 to AHR1300*	H_1	45.0	Maximum
Overall width w/lead protrusion AGR400 to AGR600 & AHR450	C_1	43.2	Maximum
Overall width w/lead protrusion AGR700 to AGR1400 & AHR600 to AHR1300	C_1	55.0	Maximum
Overall width w/o lead protrusion AGR400 to AGR600 & AHR450	C_2	42.5	Maximum
Overall width w/o lead protrusion AGR700 to AGR1400 & AHR600 to AHR1300	C_2	54.0	Maximum
Lead protrusion	L_1	1.0	Maximum
Protrusion of cut-out	L	11.0	Maximum
Protrusion beyond hold-down tape	l_2	Not specified	—
Sprocket hole pitch	P_0	12.7	±0.3
Device pitch AGR400 to AGR700, AHR450 to AHR600	—	12.7	±0.3
Device pitch AGR800 to AGR1400, AHR650 to AHR1300	—	25.4	±0.6
Pitch tolerance	—	20 consec.	±0.1
Tape thickness	t	0.9	Maximum
Overall tape and lead thickness AGR400 to AGR1100, AHR450 to AHR1000*	t_1	2.0	Maximum
Overall tape and lead thickness AGR1200 to AGR1400, AHR1300*	t_1	2.3	Maximum
Splice sprocket hole alignment	—	0	±0.3
Body lateral deviation	Dh	0	±1.0
Body tape plane deviation	Dp	0	±1.3
Ordinate to adjacent component lead AGR400 to AGR1100, AHR450 to AHR750	P1	3.81	±0.7
Ordinate to adjacent component lead AGR1200 to AGR1400, AHR1000 to AHR1300	P_1	7.62	±0.7
Lead spacing AGR400 to AGR1100, AHR450 to AHR750*	F	5.08	±0.75/-0.5
Lead spacing AGR1200 to AGR1400, AHR1000 to AHR1300*	F	10.2	±0.75/-0.5
Reel width AGR400 to AGR600 & AHR450	w_2	56.0	Maximum
Reel width AGR700 to AGR1400, AHR600 to AHR1300*	w_2	63.5	Maximum
Reel diameter	a	370.0	Maximum
Space between flanges less device*	w_1	4.75	±3.25
Arbor hold diameter	c	26.0	±12.0
Core diameter*	n	91.0	Maximum
Box	—	64/372/362	Maximum
Consecutive missing places	—	None	—
Empty places per reel	—	0.1%	Maximum

* Differs from EIA specification

Figure A13. EIA Referenced Taped Component Dimensions for AGR, AHR

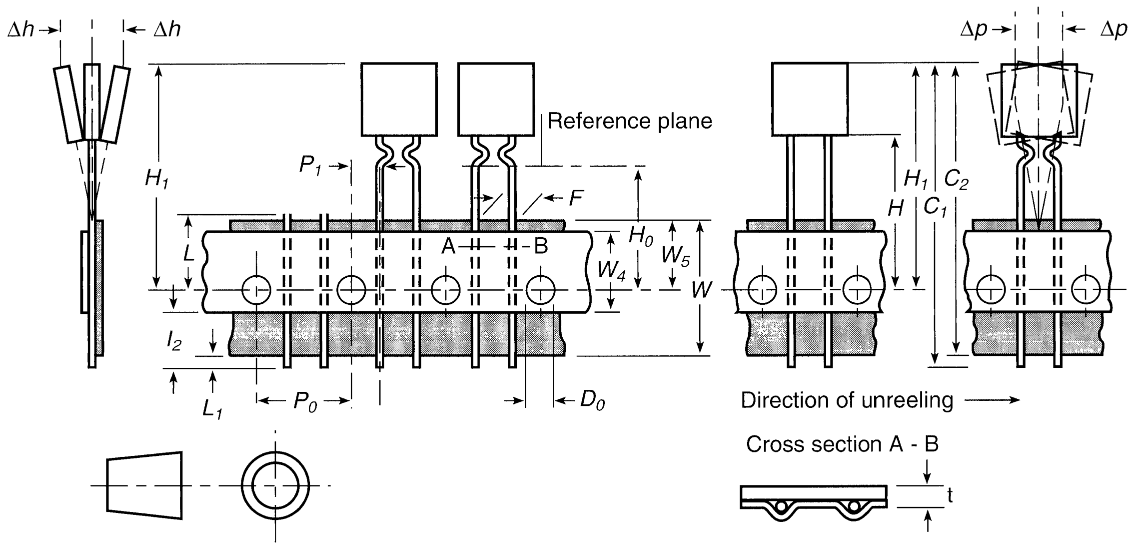


Figure A14. EIA Referenced Taped Component Dimensions for AHR, AGR

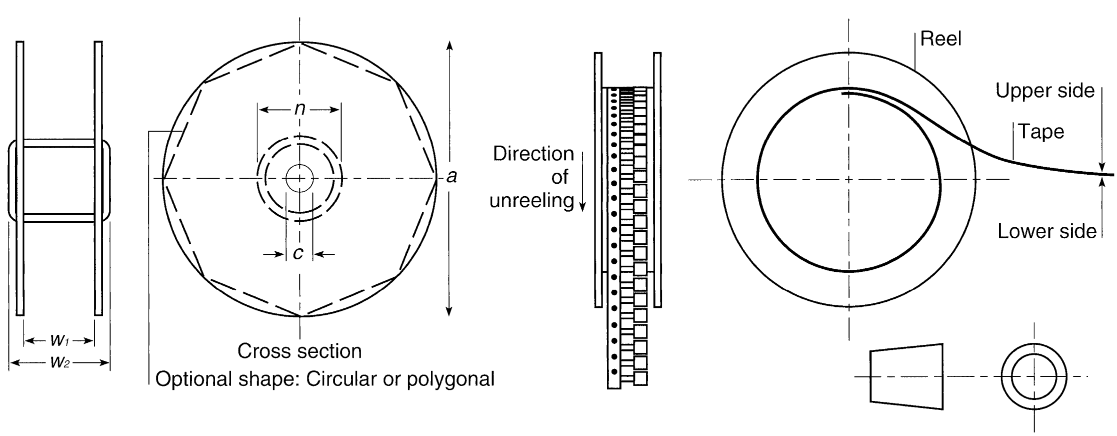


Table A8. Tape and Reel Specifications for Automotive Devices *continued*

AHS and ASMD devices are available in tape and reel packaging per EIA 468-2 standards. See Figures A15 and A16 for details.

Description	EIA Mark	Dimensions (mm)	Tolerance
Carrier tape width	W	16.0	± 0.3
Sprocket hole pitch	P_0	4.0	± 0.10
Embossed cavity pitch (ASMD030 to ASMD125 & AHS080)	P_1	8.0	± 0.10
Embossed cavity pitch (ASMD150 to ASMD250 & AHS160)	P_1	12.0	± 0.10
Ordinate to embossed cavity center	P_2	2.0	± 0.10
Embossed cavity length (inside) (AHS080)	A_0	5.11	± 0.15
Embossed cavity length (inside) (ASMD030 to ASMD125 & AHS160)	A_0	5.6	± 0.23
Embossed cavity length (inside) (ASDM150 to ASMD250)	A_0	6.9	± 0.23
Embossed cavity width (inside) (AHS080)	B_0	5.6	± 0.23
Embossed cavity width (inside) (ASMD030 to ASMD125)	B_0	8.1	± 0.15
Embossed cavity width (inside) (ASMD150 to ASMD250)	B_0	9.6	± 0.15
Embossed cavity length (outside)	B_1 max.	12.1	—
Sprocket hole diameter	D_0	1.5	+ 0.1, -0
Abscissa to embossed cavity center	F	7.5	± 0.10
Sprocket hole location	E_1	1.75	± 0.10
Sprocket hole location (across embossed cavity)	E_2 min.	14.25	—
Carrier tape thickness	T max.	0.6	—
Cover tape thickness	T_1 max.	0.1	—
AHS080	K_0	1.8	± 0.15
ASMD100, ASMD125	K_0	3.2	± 0.15
ASMD150 to 250	K_0	3.4	± 0.15
Embossed cavity depth (inside)	K_0	—	± 0.15
Leader min.	—	400	—
Trailer min.	—	160	—
Reel diameter	A max.	609	—
Core diameter	N min.	50	—
Reel width measured at inside hub	W_1	16.4	+ 2.0, -0
Reel width measured at outside hub	W_2 max.	22.4	—

4

Figure A15. EIA Referenced Taped Component Dimensions for AHS and ASMD Devices

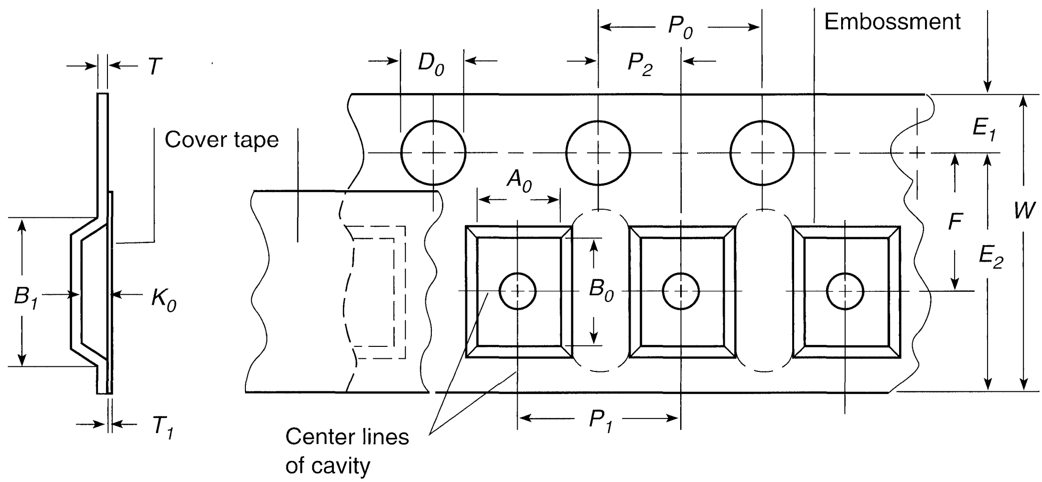
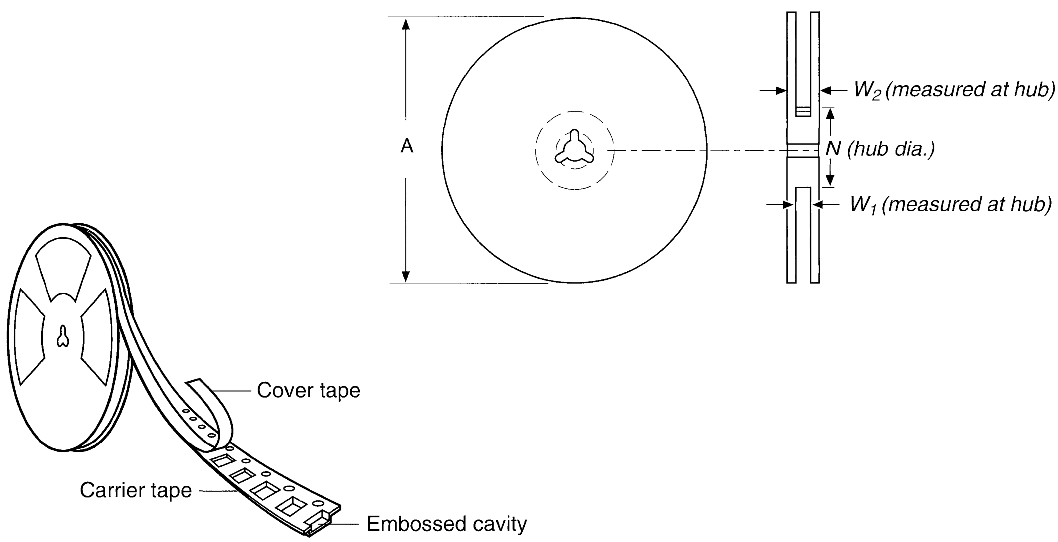


Figure A16. EIA Referenced Reel Dimensions for AHS and ASMD Devices



Latest Information

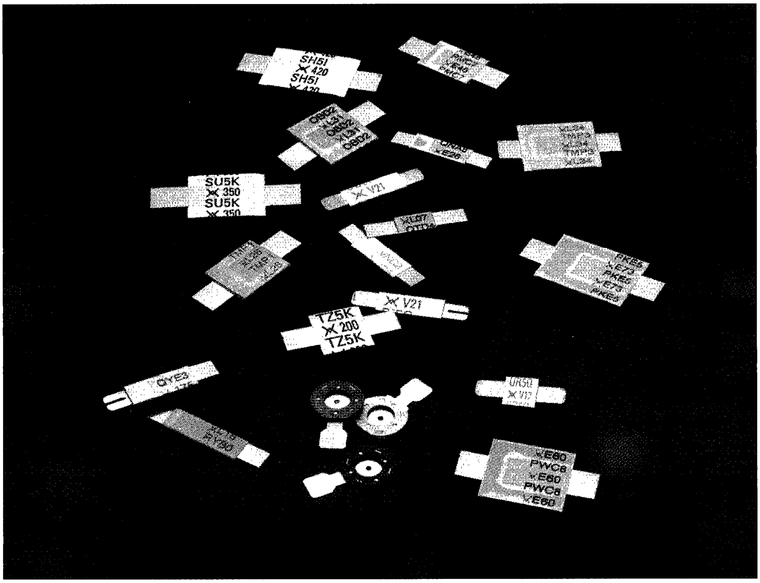
- Please visit us at www.circuitprotection.com or contact your local representative for the latest information.
- The information in this Databook contains some preliminary information. Raychem Circuit Protection, a division of Tyco Electronics reserves the right to change any of the specifications without notice. In addition, Tyco Electronics reserves the right to make changes—without notification to Buyer—to materials or processing that do not affect compliance with any applicable specification.

⚠ WARNING:

- Operation beyond the maximum ratings or improper use may result in device damage and possible electrical arcing and flame.
- The devices are intended for protection against occasional overcurrent or overtemperature fault conditions and should not be used when repeated fault conditions or prolonged trip events are anticipated.
- Contamination of the PPTC material with certain silicon based oils or some aggressive solvents can adversely impact the performance of the devices.
- Device performance can be impacted negatively if devices are handled in a manner inconsistent with recommended electronic, thermal, and mechanical procedures for electronic components.
- Operation in circuit with a large inductance can generate a circuit voltage ($L\ ^{di}/_{dt}$) above the rated voltage of the PolySwitch resettable device.

PolySwitch Strap Battery
Resettable Devices

Raychem Circuit Protection, pioneer of polymeric PTC resettable devices, has developed several material platforms specifically tailored to help protect battery applications. Each of these material platforms offers different performance characteristics, allowing the engineer greater design flexibility. Raychem Circuit Protection's battery protection family includes SRP, LTP, LR4, VTP, VLP, and VLR series, disc, and special application strap devices.



Benefits:
- Many material platforms and device form factors give engineers more design flexibility
- Compatible with high-volume electronics assembly
- Assists in meeting regulatory requirements
- Low resistance devices increase battery operating time

Features:
- Lead free versions of all devices are available upon request
- Broad range of resettable devices available
- Current ratings from 0.7A to 14.1A
- Voltage ratings from 12V to 30V
- Agency recognition, UL, CSA, TÜV
- Fast time-to-trip
- Low resistance

Applications:
- Mobile phone battery packs
- Cordless phone battery packs
- Mobile radio packs
- Computer battery packs
- Camcorder battery packs
- PDA battery packs

Devices in this section are grouped by:

Activation Temperature, Device Series, Hold Current

Step 1. Determine the circuit's operating parameters.

Fill in the following information about the circuit:

Maximum ambient operating temperature ________________

Normal operating current ________________

Maximum operating voltage
(i.e., VTP210G is 16V max.) ________________

Maximum interrupt current ________________

Step 2. Select the PolySwitch device that will accommodate the circuit's maximum ambient temperature and normal operating current.

Look across the top of Table B2 to find the temperature that most closely matches the circuit's maximum operating temperature. Look down the column to find the value equal to or greater than the circuit's normal operating current. Now look to the far left of that row to find the part number for the PolySwitch strap device that will best accommodate the circuit. Devices in this section are grouped by typical activation temperature; therefore, your operating current requirement may be found in more than one grouping.

The thermal derating curves located in Figure B3 are the normalized representations of the data in Table B2.

Step 3. Compare the selected device's electrical ratings with the circuit's maximum operating voltage and maximum interrupt current.

Look down the first column of Table B3 to find the part number you selected in Step 2. Look to the right in that row to find the device's maximum operating voltage (V_{MAX}) and maximum interrupt current (I_{MAX}). Ensure that V_{MAX} and I_{MAX} are greater than or equal to the circuits maximum operating voltage and maximum interrupt current.

Step 4. Determine time-to-trip.

Time-to-trip is the amount of time it takes for a device to switch to a high-resistance state once a fault current has been applied across the device. Identifying the PolySwitch device's time-to-trip is important in order to provide the desired protection capabilities. If the device you choose trips too fast, undesired or nuisance tripping will occur. If the device trips too slowly, the components being protected may be damaged before the device switches to a high resistance state.

Selection Guide for Strap Battery Devices

Figures B19-25 show the typical time-to-trip at 20°C for each of the PolySwitch devices.

If the PolySwitch device time-to-trip is too fast or too slow for the circuit, go back to Step 2 and choose an alternate device.

Step 5. Match Thermal Cut-Off to Cell Chemistry.

Thermal cut-off is the temperature at which a PolySwitch device will trip when sourced with a specific current. Figure B1 demonstrates how the resistance-versus-temperature characteristics of various PolySwitch strap device series differ by use of different material platforms. Figure B2 shows the thermal cut-off behavior for each strap battery series device. Actual device performance can vary depending on the application environment, and users should independently test and evaluate each product in their application. Thermally sensitive cell chemistries such as Li-ion and NiMH typically use devices with lower thermal cut-off, which can provide enhanced thermal protection (VLR, VLP, and VTP series). Less sensitive chemistries, like NiCd, typically use devices with higher thermal cut-off temperatures (LR4, SRP series).

Step 6. Verify ambient operating conditions.

Ensure that your application's minimum and maximum ambient temperatures are within the operating temperature range of -40°C to 85°C (except for VLR series, which is -40°C to 70°C).

Step 7. Verify the PolySwitch device dimensions.

Using dimensions in Table B4, compare the dimensions of the PolySwitch device you selected with the application's space considerations.

Figure B1. Resistance vs. Temperature

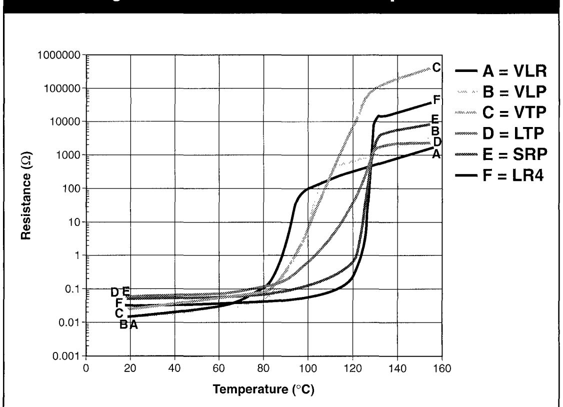
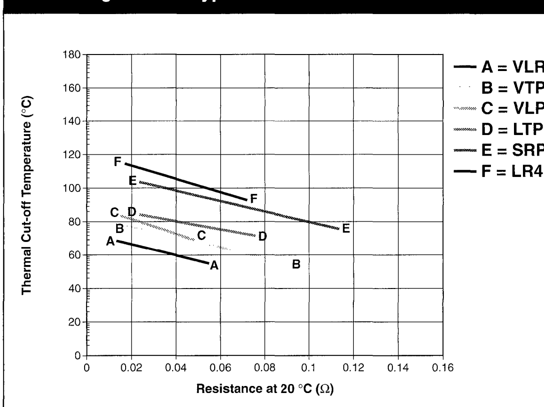


Figure B2. Typical Thermal Cut-Off at 1 A



Protection Application Selection Guide for Strap Battery Devices

The guide below lists PolySwitch devices which are typically used in these applications. The following pages contain the specifications for the part numbers recommended below. Once a device is selected, the user should evaluate and test each product for its intended application.

		PolySwitch Resettable Devices—Key Device Selection Criteria		
Protection Application	**Additional Comments**	**Installation Method**	**Lowest Resistance**	**Lowest Thermal Cut-off**
Mobile phone battery packs	NiMH	Cylindrical (AAA cell)	VLP210 TAC170-09	VTP170
		Flexprint	miniSMDE190	—
		Prismatic	VLP270 VTP210G LR4-260	VLR230
	Li-ion	Flexprint	miniSMDE190	—
		Surface Mount	refer to Surface Mount section of this Databook	
		Prismatic	VLP270 VTP210G	VLR175
Cordless phone battery packs	NiMH	Cylindrical	VLP210 TAC170-09 SRP175	VTP170
Mobile radio packs	NiMH	Cylindrical	LR4-380 SRP350	LTP340
Computer battery packs	NiMH	Cylindrical	LR4-900	—
	Li-ion	Cylindrical	LR4-1410	—
		Prismatic	Consult local Rep	Consult local Rep
Camcorder battery packs	NiMH or Li-ion	Prismatic	VLP270 LR4-380	VTP210G —
PDA	Li-ion	Prismatic	VLP220 VTP175	VLR175 —
Power tools (charge line)	NiCd or NiMH	Cylindrical	custom LR4	custom VTP

Table B1. Product Series – Current Rating, Voltage Rating/Typical Resistance for Strap Battery Devices

	VLR	VLP	VTP	LTP	SRP	LR4	TAC		miniSMDE
Hold Current (A)	Typical Activation Temperature								
	85°C	90°C	90°C	110°C	125°C	125°C	110°C	125°C	110°C
0.70	—	—	—	15V/0.15Ω	—	—	—	—	—
1.00	—	—	—	24V/0.100Ω	—	—	15V/0.120Ω	—	—
1.10	—	—	16V/0.054Ω	—	—	—	—	—	—
1.20	—	—	—	—	15V/0.123Ω	—	—	—	—
1.70	12V/0.025Ω	—	16V/0.041Ω	—	—	15V/0.061Ω	—	15V/0.074Ω	—
1.75	12V/0.024Ω	—	16V/0.040Ω	—	15V/0.070Ω	—	—	—	—
1.80	—	—	—	24V/0.054Ω	—	—	—	—	—
1.90	—	—	—	24V/0.044Ω	—	15V/0.056Ω	—	—	16V/0.032Ω
2.00	—	—	16V/0.031Ω	—	30V/0.045Ω	—	—	—	—
2.10	—	16V/0.024Ω	16V/0.024Ω	—	—	—	—	15V/0.049Ω	—
2.20	—	16V/0.023Ω	—	—	—	—	—	—	—
2.30	12V/0.015Ω	—	—	—	—	—	—	—	—
2.40	—	—	16V/0.020Ω	—	—	—	—	—	—
2.60	—	—	—	24V/0.034Ω	—	15V/0.031Ω	—	—	—
2.70	—	16V/0.015Ω	—	—	—	—	—	—	—
3.00	—	—	—	24V/0.023Ω	—	—	—	—	—
3.40	—	—	—	24V/0.022Ω	—	—	—	—	—
3.50	—	—	—	—	30V/0.024Ω	—	—	—	—
3.80	—	—	—	—	—	15V/0.020Ω	—	—	—
4.20	—	—	—	—	30V/0.018Ω	—	—	—	—
4.50	—	—	—	—	—	20V/0.016Ω	—	—	—
5.50	—	—	—	—	—	20V/0.013Ω	—	—	—
6.00	—	—	—	—	—	20V/0.011Ω	—	—	—
7.30	—	—	—	—	—	20V/0.009Ω	—	—	—
8.80	—	—	—	—	—	20V/0.085Ω	—	—	—
9.00	—	—	—	—	—	20V/0.008Ω	—	—	—
13.00	—	—	—	—	—	20V/0.006Ω	—	—	—
14.10	—	—	—	—	—	20V/0.004Ω	—	—	—

Table B2. Thermal Derating for Strap Battery Devices [Hold Current (A) at Ambient Temperature (°C)]

	Maximum Ambient Temperature										
Part Number	-40°C Amps	-20°C	0°C	20°C	25°C	40°C	50°C	60°C	70°C	80°C	85°C
85°C Typical Activation VLR†											
VLR170	3.5	2.9	2.4	1.84	1.7	1.2	1.0	0.7	0.3	—	—
VLR170L	3.5	2.9	2.4	1.84	1.7	1.2	1.0	0.7	0.3	—	—
VLR170U	3.5	2.9	2.4	1.84	1.7	1.2	1.0	0.7	0.3	—	—
VLR170UF	3.5	2.9	2.4	1.84	1.7	1.2	1.0	0.7	0.3	—	—
VLR175	3.5	2.9	2.4	1.87	1.75	1.3	1.0	0.8	0.3	—	—
VLR175L	3.5	2.9	2.4	1.87	1.75	1.3	1.0	0.8	0.3	—	—
VLR175UF	3.5	2.9	2.4	1.87	1.75	1.3	1.0	0.8	0.3	—	—
VLR230	5.0	4.2	3.4	2.52	2.3	1.7	1.3	0.9	0.4	—	—
VLR230-C36	5.0	4.2	3.4	2.52	2.3	1.7	1.3	0.9	0.4	—	—
VLR230S	5.0	4.2	3.4	2.52	2.3	1.7	1.3	0.9	0.4	—	—
VLR230SU	5.0	4.2	3.4	2.52	2.3	1.7	1.3	0.9	0.4	—	—
VLR230U	5.0	4.2	3.4	2.52	2.3	1.7	1.3	0.9	0.4	—	—

† = Product electrical characteristics determined at 25°C

Table B2. Thermal Derating for Strap Battery Devices [Hold Current (A) at Ambient Temperature (°C)] *continued*

Part Number	Maximum Ambient Temperature -40°C Amps	-20°C	0°C	20°C	25°C	40°C	50°C	60°C	70°C	80°C	85°C
90°C Typical Activation VLP†											
VLP210	4.3	3.6	2.9	2.31	2.1	1.6	1.3	1.0	0.6	0.3	0.1
VLP220	4.5	3.8	3.0	2.45	2.2	1.7	1.4	1.1	0.7	0.3	0.1
VLP270	5.6	4.7	4.0	3.05	2.7	2.2	1.7	1.4	0.9	0.4	0.1

† = Product electrical characteristics determined at 25°C

Part Number	-40°C	-20°C	0°C	20°C	25°C	40°C	50°C	60°C	70°C	80°C	85°C
90°C Typical Activation VTP†											
VTP110	2.0	1.7	1.4	1.02	1.1	0.8	0.6	0.5	0.3	0.2	0.1
VTP170	3.2	2.7	2.2	1.80	1.7	1.3	1.0	0.8	0.5	0.3	0.1
VTP170SS	3.2	2.7	2.2	1.80	1.7	1.3	1.0	0.8	0.5	0.3	0.1
VTP170X	3.2	2.7	2.2	1.80	1.7	1.3	1.0	0.8	0.5	0.3	0.1
VTP170XS	3.2	2.7	2.2	1.80	1.7	1.3	1.0	0.8	0.5	0.3	0.1
VTP175	3.2	2.7	2.2	1.84	1.75	1.3	1.0	0.8	0.5	0.3	0.1
VTP175L	3.2	2.7	2.2	1.84	1.75	1.3	1.0	0.8	0.5	0.3	0.1
VTP175U	3.2	2.7	2.2	1.84	1.75	1.3	1.0	0.8	0.5	0.3	0.1
VTP200G	3.7	3.2	2.6	2.12	2.0	1.5	1.2	0.9	0.5	0.3	0.1
VTP200U	3.7	3.2	2.6	2.12	2.0	1.5	1.2	0.9	0.5	0.3	0.1
VTP210G	4.1	3.5	2.9	2.26	2.1	1.6	1.3	1.0	0.7	0.4	0.1
VTP210L	4.1	3.5	2.9	2.26	2.1	1.6	1.3	1.0	0.7	0.4	0.1
VTP210S	4.1	3.5	2.9	2.26	2.1	1.6	1.3	1.0	0.7	0.4	0.1
VTP210SF	4.1	3.5	2.9	2.26	2.1	1.6	1.3	1.0	0.7	0.4	0.1
VTP210SL	4.1	3.5	2.9	2.26	2.1	1.6	1.3	1.0	0.7	0.4	0.1
VTP210SL-19.2/5.8	4.1	3.5	2.9	2.26	2.1	1.6	1.3	1.0	0.7	0.4	0.1
VTP210SS	4.1	3.5	2.9	2.26	2.1	1.6	1.3	1.0	0.7	0.4	0.1
VTP210ULD	4.1	3.5	2.9	2.26	2.1	1.6	1.3	1.0	0.7	0.4	0.1
VTP240	4.4	3.7	3.1	2.54	2.4	1.8	1.5	1.2	0.9	0.5	0.1

† = Product electrical characteristics determined at 25°C

Part Number	-40°C	-20°C	0°C	20°C	25°C	40°C	50°C	60°C	70°C	80°C	85°C
110°C Typical Activation LTP											
LTP070	1.1	1.0	0.8	0.7	0.65	0.5	0.4	0.3	0.2	0.2	0.1
LTP070S	1.1	1.0	0.8	0.7	0.65	0.5	0.4	0.3	0.2	0.2	0.1
LTP100	1.8	1.6	1.4	1.0	0.99	0.8	0.7	0.6	0.4	0.3	0.2
LTP100S	1.8	1.6	1.4	1.0	0.99	0.8	0.7	0.6	0.4	0.3	0.2
LTP100SL	1.8	1.6	1.4	1.0	0.99	0.8	0.7	0.6	0.4	0.3	0.2
LTP100SS	1.8	1.6	1.4	1.0	0.99	0.8	0.7	0.6	0.4	0.3	0.2
LTP180	3.1	2.6	2.2	1.8	1.67	1.3	1.1	0.9	0.6	0.4	0.3
LTP180L	3.1	2.6	2.2	1.8	1.67	1.3	1.1	0.9	0.6	0.4	0.3
LTP180S	3.1	2.6	2.2	1.8	1.67	1.3	1.1	0.9	0.6	0.4	0.3
LTP190	3.3	2.8	2.4	1.9	1.79	1.4	1.2	1.1	0.7	0.5	0.4
LTP260	4.3	3.7	3.1	2.6	2.42	1.9	1.6	1.4	1.1	0.8	0.6
LTP300	5.1	4.4	3.7	3.0	2.82	2.3	1.9	1.6	1.2	0.9	0.7
LTP340	5.5	4.7	4.0	3.4	3.17	2.6	2.2	1.9	1.5	1.1	0.9

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Table B2. Thermal Derating for Strap Battery Devices [Hold Current (A) at Ambient Temperature (°C)] *continued*

	Maximum Ambient Temperature										
Part Number	-40°C Amps	-20°C	0°C	20°C	25°C	40°C	50°C	60°C	70°C	80°C	85°C
miniSMDE											
miniSMDE190	3.0	2.6	2.2	1.9	1.74	1.4	1.2	1.1	0.7	0.5	0.4
TAC											
TAC100-09	1.6	1.4	1.2	1.0	0.92	0.7	0.6	0.5	0.4	0.2	0.2
125°C Typical Activation LR4											
LR4-170U	2.5	2.2	2.0	1.7	1.64	1.4	1.3	1.2	1.0	0.9	0.8
LR4-190	2.8	2.5	2.3	1.9	1.86	1.6	1.5	1.4	1.2	1.1	1.0
LR4-190S	2.8	2.5	2.3	1.9	1.86	1.6	1.5	1.4	1.2	1.1	1.0
LR4-260	3.8	3.4	3.1	2.6	2.54	2.2	2.0	1.9	1.7	1.4	1.3
LR4-260S	3.8	3.4	3.1	2.6	2.54	2.2	2.0	1.9	1.7	1.4	1.3
LR4-380	5.4	4.9	4.4	3.8	3.64	3.3	3.0	2.8	2.5	2.3	2.1
LR4-380X	5.4	4.9	4.4	3.8	3.64	3.3	3.0	2.8	2.5	2.3	2.1
LR4-450	6.5	5.8	5.3	4.5	4.38	3.9	3.6	3.3	2.9	2.6	2.4
LR4-550	7.6	6.9	6.2	5.5	5.32	4.7	4.3	4.0	3.6	3.2	3.0
LR4-600	8.7	7.8	7.1	6.0	5.86	5.2	4.7	4.4	3.9	3.4	3.2
LR4-600X	8.7	7.8	7.1	6.0	5.86	5.2	4.7	4.4	3.9	3.4	3.2
LR4-730	10.5	9.5	8.6	7.3	7.13	6.3	5.7	5.4	4.7	4.2	4.0
LR4-880SS	12.3	11.0	9.8	8.8	8.3	7.4	6.8	6.2	5.5	4.8	4.5
LR4-900	12.7	11.4	10	9.0	8.5	7.5	6.8	6.2	5.5	4.9	4.5
LR4-1300SS	17.9	16.2	14.5	13.0	12.4	11.1	10.3	9.5	8.6	7.7	7.2
LR4-1410	19.9	17.8	15.7	14.1	13.3	11.8	10.8	9.7	8.7	7.7	7.2
SRP											
SRP120	1.9	1.7	1.5	1.2	1.17	1.0	0.9	0.8	0.6	0.5	0.4
SRP120L	1.9	1.7	1.5	1.2	1.17	1.0	0.9	0.8	0.6	0.5	0.4
SRP120S	1.9	1.7	1.5	1.2	1.17	1.0	0.9	0.8	0.6	0.5	0.4
SRP175	2.5	2.2	2.0	1.75	1.68	1.4	1.3	1.2	1.0	0.9	0.8
SRP175L	2.5	2.2	2.0	1.75	1.68	1.4	1.3	1.2	1.0	0.9	0.8
SRP175S	2.5	2.2	2.0	1.75	1.68	1.4	1.3	1.2	1.0	0.9	0.8
SRP175SS	2.5	2.2	2.0	1.75	1.68	1.4	1.3	1.2	1.0	0.9	0.8
SRP200	3.1	2.8	2.5	2.0	1.97	1.7	1.5	1.4	1.2	1.0	0.9
SRP350	5.3	4.8	4.3	3.5	3.44	3.0	2.7	2.5	2.1	1.8	1.7
SRP420	6.3	5.7	5.1	4.2	4.11	3.6	3.3	3.0	2.6	2.2	2.1
TAC											
TAC170-09	2.4	2.2	2.0	1.7	1.67	1.5	1.4	1.3	1.1	1.0	1.0
TAC210	2.8	2.6	2.3	2.1	2.03	1.7	1.6	1.5	1.3	1.2	1.1

Figure B3. Thermal Derating

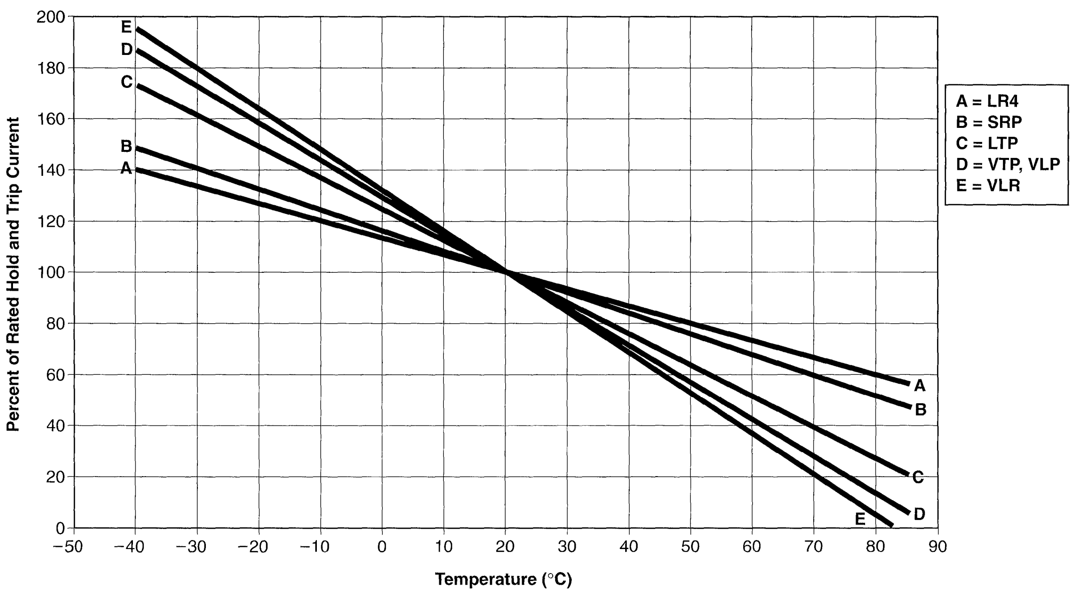


Table B3. Product Electrical Characteristics for Strap Battery Devices

Part Number		I_H (A)	I_T (A)	V_{MAX} (V_{DC})	I_{MAX} (A)	$P_{D\ TYP}$ (W)	Max. Time-to-Trip (A)	Max. Time-to-Trip (s)	R_{MIN} (Ω)	R_{TYP} (Ω)	R_{MAX} (Ω)	$R_{Tripped\ TYP}$ (Ω)	$R_{1\ MAX}$ (Ω)	Figure for Dimensions
85°C Typical Activation VLR														
VLR170	†	1.7	4.1	12	100	1.4	8.5	5.0	0.018	0.025	0.032	0.050	0.064	B5
VLR170L	†	1.7	4.1	12	100	1.4	8.5	5.0	0.018	0.025	0.032	0.050	0.064	B5
VLR170U	†	1.7	4.1	12	100	1.4	8.5	5.0	0.018	0.025	0.032	0.050	0.064	B8
VLR170UF	†	1.7	4.1	12	100	1.4	8.5	5.0	0.018	0.025	0.032	0.050	0.064	B8
VLR175	†	1.75	4.2	12	100	1.4	8.75	5.0	0.017	0.024	0.031	0.048	0.062	B5
VLR175L	†	1.75	4.2	12	100	1.4	8.75	5.0	0.017	0.024	0.031	0.048	0.062	B5
VLR175UF	†	1.8	4.2	12	100	1.4	8.75	5.0	0.017	0.024	0.031	0.048	0.620	B8
VLR230	†	2.3	5.0	12	100	1.4	10.0	5.0	0.012	0.015	0.018	0.030	0.036	B5
VLR230-C36	†	2.3	5.0	12	100	1.4	10.0	5.0	0.012	0.015	0.018	0.030	0.036	B5
VLR230S	†	2.3	5.0	12	100	1.4	10.0	5.0	0.012	0.015	0.018	0.030	0.036	B6
VLR230SU	†	2.3	5.0	12	100	1.4	10.0	5.0	0.012	0.015	0.018	0.030	0.036	B6
VLR230U	†	2.3	5.0	12	100	1.4	10.0	5.0	0.012	0.015	0.018	0.030	0.036	B8
90°C Typical Activation VLP														
VLP210	†	2.1	5.0	16	60	0.8	10.5	5.0	0.018	0.024	0.030	0.048	0.060	B4
VLP220	†	2.1	5.3	16	60	0.8	11.0	5.0	0.017	0.023	0.029	0.046	0.058	B5
VLP270	†	2.7	6.5	16	60	1.2	13.5	5.0	0.012	0.015	0.018	0.030	0.036	B5
90°C Typical Activation VTP														
VTP110	†	1.1	2.7	16	100	0.7	7.0	5.0	0.038	0.054	0.070	0.108	0.140	B8
VTP170	†	1.7	3.4	16	100	1.0	8.5	5.0	0.030	0.041	0.052	0.082	0.105	B4

Table B3. Product Electrical Characteristics for Strap Battery Devices *continued*

Part Number	I_H (A)	I_T (A)	V_{MAX} (V_{DC})	I_{MAX} (A)	$P_{D\ TYP}$ (W)	Max. Time-to-Trip (A)	Max. Time-to-Trip (s)	R_{MIN} (Ω)	R_{TYP} (Ω)	R_{MAX} (Ω)	$R_{Tripped\ TYP}$ (Ω)	$R_{1\ MAX}$ (Ω)	Figure for Dimensions
90°C Typical Activation													
VTP *continued*													
VTP170X †	1.7	3.4	16	100	0.7	8.5	5.0	0.030	0.041	0.052	0.082	0.105	B5
VTP170XS †	1.7	3.4	16	100	0.7	8.5	5.0	0.030	0.041	0.052	0.082	0.105	B6
VTP175 †	1.75	3.6	16	100	0.8	8.75	5.0	0.029	0.040	0.051	0.080	0.102	B5
VTP175L †	1.75	3.6	16	100	0.8	8.75	5.0	0.029	0.040	0.051	0.080	0.102	B5
VTP175U †	1.75	3.6	16	100	0.8	8.75	5.0	0.029	0.040	0.051	0.080	0.102	B8
VTP200G †	2.0	4.7	16	100	0.9	10.0	5.0	0.022	0.031	0.039	0.062	0.078	B5
VTP200U †	2.0	4.7	16	100	0.9	10.0	5.0	0.022	0.031	0.039	0.062	0.078	B8
VTP210G †	2.1	4.7	16	100	1.2	10.0	5.0	0.018	0.024	0.030	0.048	0.060	B5
VTP210L †	2.1	4.7	16	100	1.2	10.0	5.0	0.018	0.024	0.030	0.048	0.060	B5
VTP210S †	2.1	4.7	16	100	1.2	10.0	5.0	0.018	0.024	0.030	0.048	0.060	B6
VTP210SF †	2.1	4.7	16	100	1.2	10.0	5.0	0.018	0.024	0.030	0.048	0.060	B6
VTP210SL †	2.1	4.7	16	100	1.2	10.0	5.0	0.018	0.024	0.030	0.048	0.060	B6
VTP210SL-19.2/5.8 †	2.1	4.7	16	100	1.2	10.0	5.0	0.018	0.024	0.030	0.048	0.060	B6
VTP210SS †	2.1	4.7	16	100	1.2	10.0	5.0	0.018	0.024	0.030	0.048	0.060	B7
VTP210ULD †	2.1	4.7	16	100	1.2	10.0	5.0	0.018	0.024	0.030	0.048	0.060	B8
VTP240 †	2.4	5.9	16	100	1.2	12.0	5.0	0.014	0.020	0.026	0.040	0.052	B5
110°C Typical Activation													
LTP													
LTP070	0.7	1.45	15	100	0.7	3.5	5.0	0.100	0.150	0.200	0.300	0.340	B9
LTP070S	0.7	1.45	15	100	0.7	3.5	5.0	0.100	0.150	0.200	0.300	0.340	B10
LTP100	1.0	2.50	24	100	0.9	5.0	7.0	0.070	0.100	0.130	0.200	0.260	B9
LTP100S	1.0	2.50	24	100	0.9	5.0	7.0	0.070	0.100	0.130	0.200	0.260	B10
LTP100SL	1.0	2.50	24	100	0.9	5.0	7.0	0.070	0.100	0.130	0.200	0.260	B10
LTP100SS	1.0	2.50	24	100	0.9	5.0	7.0	0.070	0.100	0.130	0.200	0.260	B11
LTP180	1.8	3.80	24	100	1.0	9.0	2.9	0.040	0.054	0.068	0.108	0.120	B9
LTP180L	1.8	3.80	24	100	1.0	9.0	2.9	0.040	0.054	0.068	0.108	0.120	B9
LTP180S	1.8	3.80	24	100	1.0	9.0	2.9	0.040	0.054	0.068	0.108	0.120	B10
LTP190	1.9	4.20	24	100	1.9	10.0	3.0	0.030	0.044	0.057	0.088	0.100	B9
LTP260	2.6	5.20	24	100	1.3	13.0	5.0	0.025	0.034	0.042	0.068	0.076	B9
LTP300	3.0	6.30	24	100	1.7	15.0	4.0	0.015	0.023	0.031	0.046	0.055	B9
LTP340	3.4	6.80	24	100	1.6	17.0	5.0	0.016	0.022	0.027	0.044	0.050	B9
miniSMDE													
miniSMDE190	1.9	3.8	16	100	1.5	10.0	2.0	0.024	0.032	0.040	0.060	0.080*	B18
TAC													
TAC100-09	1.0	2.4	15	50	1.2	5.0	5.0	0.085	0.120	0.155	0.240	0.300	B12
125°C Typical Activation													
LR4													
LR4-170U	1.7	3.4	15	100	0.8	8.5	5.0	0.044	0.061	0.078	0.089	0.114	B15
LR4-190	1.9	3.9	15	100	0.8	9.5	5.0	0.039	0.056	0.072	0.079	0.102	B13
LR4-190S	1.9	3.9	15	100	0.8	9.5	5.0	0.039	0.056	0.072	0.079	0.102	B14
LR4-260	2.6	5.8	15	100	1.0	13.0	5.0	0.020	0.031	0.042	0.046	0.063	B13
LR4-260S	2.6	5.8	15	100	1.0	13.0	5.0	0.020	0.031	0.042	0.046	0.063	B14
LR4-380	3.8	8.3	15	100	1.2	19.0	5.0	0.013	0.020	0.026	0.028	0.037	B13
LR4-380X	3.8	8.3	15	100	1.2	19.0	5.0	0.013	0.020	0.026	0.028	0.037	B13
LR4-450	4.5	8.9	20	100	1.4	22.5	5.0	0.011	0.016	0.020	0.022	0.028	B13
LR4-550	5.5	10.5	20	100	2.0	27.5	5.0	0.009	0.013	0.016	0.018	0.022	B13
LR4-600	6.0	11.7	20	100	1.7	30.0	5.0	0.007	0.011	0.014	0.015	0.019	B13

Table B3. Product Electrical Characteristics for Strap Battery Devices *continued*

Part Number	I_H (A)	I_T (A)	V_{MAX} (V_{DC})	I_{MAX} (A)	$P_{D\,TYP}$ (W)	Max. Time-to-Trip (A)	Max. Time-to-Trip (s)	R_{MIN} (Ω)	R_{TYP} (Ω)	R_{MAX} (Ω)	$R_{Tripped\,TYP}$ (Ω)	$R_{1\,MAX}$ (Ω)	Figure for Dimensions
125°C Typical Activation LR4 *continued*													
LR4-600X	6.0	11.7	20	100	1.7	30.0	5.0	0.0075	0.012	0.014	0.015	0.019	B13
LR4-730	7.3	14.1	20	100	1.9	30.0	5.0	0.006	0.009	0.012	0.011	0.015	B13
LR4-880SS	8.8	16.0	20	100	2.0	44.0	5.0	0.0065	0.0085	0.0105	0.012	0.0145	B14
LR4-900	9.0	16.7	20	100	3.0	45.0	5.0	0.006	0.008	0.010	0.011	0.014	B13
LR4-1300SS	13.0	21.2	20	100	2.2	50.0	10.0	0.004	0.006	0.007	0.008	0.009	B14
LR4-1410	14.1	26.2	20	100	2.2	70.0	5.0	0.003	0.004	0.005	0.060	0.007	B13
SRP													
SRP120	1.2	2.7	15	100	0.8	6.0	5.0	0.085	0.123	0.160	0.170	0.220	B9
SRP120L	1.2	2.7	15	100	0.8	6.0	5.0	0.085	0.123	0.160	0.170	0.220	B9
SRP120S	1.2	2.7	15	100	0.8	6.0	5.0	0.085	0.123	0.160	0.170	0.220	B16
SRP175	1.75	3.8	15	100	0.9	8.75	5.0	0.050	0.070	0.090	0.093	0.120	B9
SRP175L	1.75	3.8	15	100	0.9	8.75	5.0	0.050	0.070	0.090	0.093	0.120	B9
SRP175S	1.75	3.8	15	100	0.9	8.75	5.0	0.050	0.070	0.090	0.093	0.120	B16
SRP175SS	1.75	3.8	15	100	0.9	8.75	5.0	0.050	0.070	0.090	0.093	0.120	B17
SRP200	2.0	4.4	30	100	1.6	10.0	4.0	0.030	0.045	0.060	0.075	0.100	B9
SRP350	3.5	6.3	30	100	1.9	20.0	3.0	0.017	0.024	0.031	0.040	0.050	B9
SRP420	4.2	7.6	30	100	2.2	20.0	6.0	0.012	0.018	0.024	0.030	0.040	B9
TAC													
TAC170-09	1.7	3.7	15	50	1.2	8.5	5.0	0.05	0.074	0.098	0.106	0.140	B12
TAC210	2.1	4.7	15	50	1.3	10.5	5.0	0.035	0.049	0.062	0.089	0.113	B12

Notes:

I_H = Hold current: maximum current device will pass without interruption in 20°C still air unless otherwise specified.

I_T = Trip current: minimum current that will switch the device from low resistance to high resistance in 20°C still air unless otherwise specified.

V_{MAX} = Maximum voltage device can withstand without damage at rated current.

I_{MAX} = Maximum fault current device can withstand without damage at rated voltage.

P_D = Power dissipated from device when in the tripped state in 20°C still air unless otherwise specified.

R_{MIN} = Minimum resistance of device as supplied at 20°C unless otherwise specified.

R_{TYP} = Typical resistance of device as supplied at 20°C unless otherwise specified.

$R_{Tripped\,Typ}$ = Typical resistance, measured at 20°C unless otherwise specified, of device one hour after being tripped the first time.

R_{MAX} = Maximum resistance of device as supplied at 20°C unless otherwise specified.

† = Product electrical characteristics determined at 25°C.

* = R_1max value for this device is the maximum resistance of the device at 20°C one hour after reflow.

4

Figures B4–B18. Physical Description for Dimensions

Figure B4

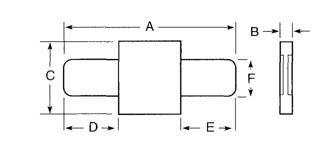


Figure B5

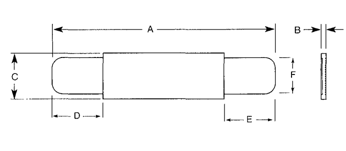


Figure B6

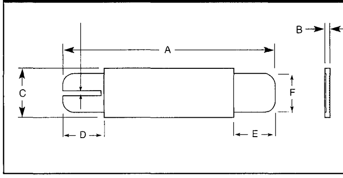


Figure B7

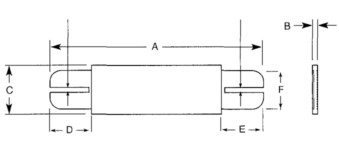


Figure B8

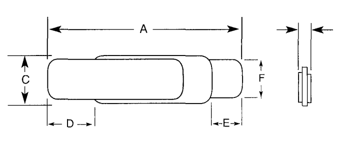


Figure B9

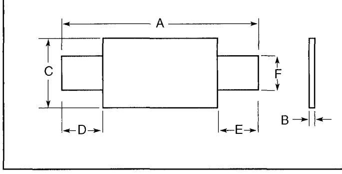


Figure B10

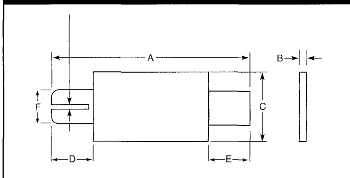


Figure B11

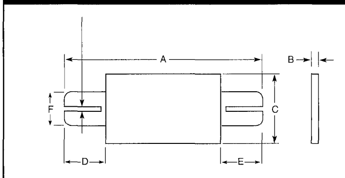


Figure B12

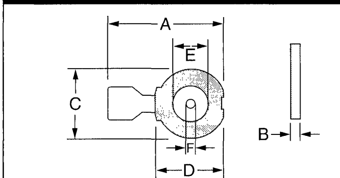


Figure B13

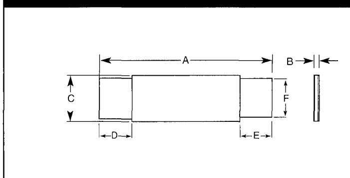


Figure B14

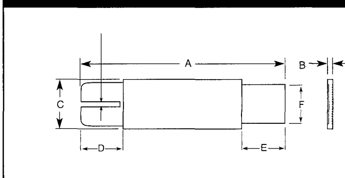


Figure B15

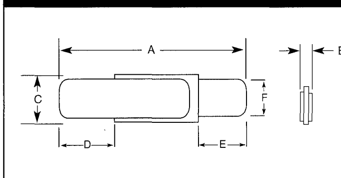


Figure B16

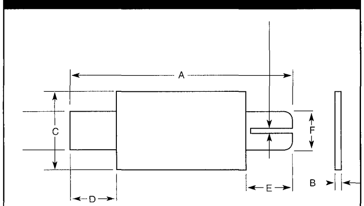


Figure B17

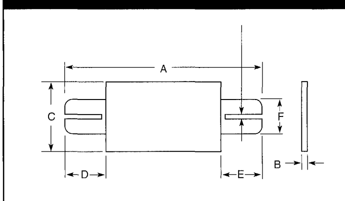
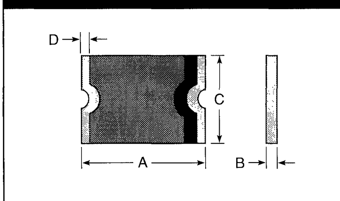


Figure B18



Note: All slit parts are 0.5mm x 4.0mm nom. (0.02 in x 0.16 in)

Table B4. Dimensions for Strap Battery Devices in Millimeters (Inches)

	Dimension												
	A		B		C		D		E		F		
Part Number	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Figure
85°C Typical Activation VLR													
VLR170	20.8	23.2	—	0.8	3.5	3.9	4.5	6.5	4.5	6.5	2.4	2.6	B5
	(0.82)	(0.91)	—	(0.03)	(0.14)	(0.15)	(0.18)	(0.26)	(0.18)	(0.26)	(0.09)	(0.10)	—
VLR170L	38.8	41.2	—	0.8	3.5	3.9	8.7	10.3	18.7	20.3	2.4	2.6	B5
	(1.53)	(1.62)	—	(0.03)	(0.14)	(0.15)	(0.34)	(0.41)	(0.74)	(0.80)	(0.09)	(0.10)	—
VLR170U	20.8	23.2	—	0.7	3.5	3.7	5.3	6.7	5.3	6.7	2.4	2.6	B8
	(0.82)	(0.91)	—	(0.03)	(0.14)	(0.15)	(0.21)	(0.26)	(0.21)	(0.26)	(0.09)	(0.10)	—
VLR170UF	20.8	23.2	—	0.07	3.5	3.7	5.3	6.7	5.3	6.7	2.4	2.6	B8
	(0.81)	(0.91)	—	(0.03)	(0.14)	(0.15)	(0.21)	(0.26)	(0.21)	(0.26)	(0.09)	(0.10)	—
VLR175	23.0	24.5	—	0.8	2.9	3.3	4.7	7.2	3.8	5.4	2.4	2.6	B5
	(0.91)	(0.96)	—	(0.03)	(0.11)	(0.13)	(0.19)	(0.28)	(0.15)	(0.21)	(0.09)	(0.10)	—
VLR175L	29.3	31.7	—	0.8	2.9	3.3	5.2	6.8	10.0	12.5	2.4	2.6	B5
	(1.15)	(1.25)	—	(0.03)	(0.11)	(0.13)	(0.21)	(0.27)	(0.39)	(0.49)	(0.09)	(0.10)	—
VLR175UF	23.0	24.5	—	0.7	2.9	3.1	5.2	7.5	4.3	5.7	2.4	2.6	B8
	(0.91)	(0.96)	—	(0.03)	(0.11)	(0.12)	(0.20)	(0.30)	(0.17)	(0.22)	(0.09)	(0.10)	—
VLR230	20.9	23.1	—	0.8	4.9	5.3	4.1	5.8	4.1	5.8	3.9	4.1	B5
	(0.82)	(0.91)	—	(0.03)	(0.19)	(0.21)	(0.16)	(0.23)	(0.16)	(0.23)	(0.15)	(0.16)	—
VLR230-C36	25.3	27.7	—	0.8	3.5	3.9	3.5	5.7	3.5	5.7	2.9	3.1	B13
	(0.10)	(1.09)	—	(0.03)	(0.14)	(0.15)	(0.14)	(0.22)	(0.14)	(0.22)	(0.11)	(0.12)	—
VLR230S	20.9	23.1	—	0.8	4.9	5.3	4.1	5.8	4.1	5.8	3.9	4.1	B6
	(0.82)	(0.91)	—	(0.03)	(0.19)	(0.21)	(0.16)	(0.23)	(0.16)	(0.23)	(0.15)	(0.16)	—
VLR230SU	20.9	23.1	—	0.7	4.9	5.1	4.1	6.0	4.1	6.0	3.9	4.1	B6
	(0.82)	(0.91)	—	(0.03)	(0.19)	(0.20)	(0.16)	(0.24)	(0.16)	(0.24)	(0.15)	(0.16)	—
VLR230U	20.9	23.1	—	0.7	4.9	5.1	4.1	6.0	4.1	6.0	3.9	4.1	B8
	(0.82)	(0.91)	—	(0.03)	(0.19)	(0.20)	(0.16)	(0.24)	(0.16)	(0.24)	(0.15)	(0.16)	—
90°C Typical Activation VLP													
VLP210	15.4	17.5	0.6	0.8	6.9	7.3	4.0	6.2	4.0	6.2	3.9	4.1	B4
	(0.606)	(0.689)	(0.02)	(0.03)	(0.27)	(.287)	(0.157)	(0.244)	(0.157)	(0.244)	(0.15)	(0.16)	—
VLP220	21.1	23.3	0.6	0.8	3.5	3.9	5.1	6.8	5.1	6.8	2.9	3.1	B5
	(0.83)	(0.92)	(0.02)	(0.03)	(0.13)	(0.15)	(0.20)	(0.27)	(0.20)	(0.27)	(0.11)	(0.12)	—
VLP270	20.9	23.1	0.6	0.8	4.9	5.3	4.1	5.8	4.1	5.8	3.9	4.1	B5
	(0.82)	(0.91)	(0.02)	(0.03)	(0.19)	(0.21)	(0.16)	(0.23)	(0.16)	(0.23)	(0.15)	(0.16)	—
90°C Typical Activation VTP													
VTP110	23.6	25.6	—	0.7	2.7	2.9	7.0	8.0	7.0	8.0	2.3	2.5	B8
	(0.93)	(1.01)	—	(0.03)	(0.11)	(0.11)	(0.28)	(0.32)	(0.28)	(0.32)	(0.09)	(0.10)	—
VTP170	15.4	17.5	0.5	0.8	7.0	7.4	4.0	6.2	4.0	6.2	3.9	4.1	B4
	(0.606)	(0.689)	(0.02)	(0.03)	(0.275)	(0.292)	(0.157)	(0.244)	(0.157)	(0.244)	(0.15)	(0.16)	—
VTP170SS	15.4	17.5	0.5	0.8	7.0	7.4	4.0	6.2	4.0	6.2	3.9	4.1	B11
	(0.606)	(0.689)	(0.02)	(0.03)	(0.275)	(0.292)	(0.157)	(0.244)	(0.157)	(0.244)	(0.154)	(0.161)	—
VTP170X	20.9	22.9	0.5	0.8	4.9	5.3	6.0	8.6	6.0	8.6	3.9	4.1	B5
	(0.82)	(0.90)	(0.02)	(0.03)	(0.19)	(0.21)	(0.23)	(0.34)	(0.23)	(0.34)	(0.15)	(0.16)	—
VTP170XS	20.9	22.9	0.5	0.8	4.9	5.3	6.0	8.6	6.0	8.6	3.9	4.1	B6
	(0.82)	(0.90)	(0.02)	(0.03)	(0.19)	(0.21)	(0.23)	(0.34)	(0.23)	(0.34)	(0.15)	(0.16)	—
VTP175	21.2	23.2	—	0.8	3.5	3.9	4.6	6.6	4.6	6.6	2.9	3.1	B5
	(0.83)	(0.91)	—	(0.03)	(0.14)	(0.15)	(0.18)	(0.26)	(0.18)	(0.26)	(0.11)	(0.12)	—
VTP175L	25.8	28.2	—	0.8	3.5	3.9	5.7	7.3	8.7	10.3	2.4	2.6	B5
	(1.02)	(1.11)	—	(0.03)	(0.13)	(0.15)	(0.22)	(0.29)	(0.34)	(0.41)	(0.09)	(0.10)	—
VTP175U	21.2	23.2	—	0.7	3.5	3.7	5.6	6.8	5.6	6.8	2.9	3.1	B8
	(0.83)	(0.91)	—	(0.03)	(0.13)	(0.15)	(0.22)	(0.27)	(0.22)	(0.27)	(0.11)	(0.12)	—

Table B4. Dimensions for Strap Battery Devices in Millimeters (Inches) *continued*

Part Number	Dimension A Min.	A Max.	B Min.	B Max.	C Min.	C Max.	D Min.	D Max.	E Min.	E Max.	F Min.	F Max.	Figure
90°C Typical Activation VTP *continued*													
VTP200G	20.9	23.1	—	0.8	4.1	4.5	3.0	4.8	3.0	4.8	2.9	3.1	B5
	(0.82)	(0.91)	—	(0.03)	(0.16)	(0.18)	(0.11)	(0.19)	(0.11)	(0.19)	(0.11)	(0.12)	—
VTP200U	20.9	23.1	—	0.7	4.1	4.3	4.0	5.4	4.0	5.4	2.9	3.1	B8
	(0.82)	(0.91)	—	(0.03)	(0.16)	(0.17)	(0.16)	(0.21)	(0.16)	(0.21)	(0.11)	(0.12)	—
VTP210G	20.9	23.1	0.6	0.8	4.9	5.3	4.1	5.8	4.1	5.8	3.9	4.1	B5
	(0.82)	(0.91)	(0.02)	(0.03)	(0.19)	(0.21)	(0.16)	(0.23)	(0.16)	(0.23)	(0.15)	(0.16)	—
VTP210L	24.0	26.0	0.6	0.8	4.9	5.3	5.0	7.1	5.0	7.1	3.9	4.1	B5
	(0.94)	(1.02)	(0.02)	(0.03)	(0.19)	(0.21)	(0.20)	(0.28)	(0.20)	(0.28)	(0.15)	(0.16)	—
VTP210S	20.9	23.1	0.6	0.8	4.9	5.3	4.1	5.8	4.1	5.8	3.9	4.1	B6
	(0.82)	(0.91)	(0.02)	(0.03)	(0.19)	(0.21)	(0.16)	(0.28)	(0.16)	(0.23)	(0.15)	(0.16)	—
VTP210SF	20.9	23.1	0.6	0.8	4.9	5.3	4.1	5.8	4.1	5.8	3.9	4.1	B6
	(0.82)	(0.91)	(0.02)	(0.03)	(0.19)	(0.21)	(0.16)	(0.23)	(0.16)	(0.23)	(0.15)	(0.16)	—
VTP210SL	29.0	32.0	0.6	0.8	4.9	5.3	3.5	5.8	12.5	14.5	3.9	4.1	B6
	(1.14)	(1.26)	(0.02)	(0.03)	(0.19)	(0.21)	(0.13)	(0.23)	(0.49)	(0.57)	(0.15)	(0.16)	—
VTP210SL-19.2/5.8	34.0	37.0	—	0.8	4.9	5.3	16.8	19.2	4.1	5.8	3.9	4.1	B6
	(1.33)	(1.46)	—	(0.03)	(0.19)	(0.21)	(0.66)	(0.76)	(0.16)	(0.23)	(0.15)	(0.16)	—
VTP210SS	20.9	23.1	0.6	0.8	4.9	5.3	4.1	5.8	4.1	5.8	3.9	4.1	B7
	(0.82)	(0.91)	(0.02)	(0.03)	(0.19)	(0.21)	(0.16)	(0.23)	(0.16)	(0.23)	(0.15)	(0.16)	—
VTP210ULD	22.8	25.2	—	0.8	4.9	5.1	7.8	9.2	2.9	4.1	2.9	3.1	B8
	(0.89)	(1.00)	—	(0.03)	(0.19)	(0.20)	(0.30)	(0.37)	(0.11)	(0.17)	(0.11)	(0.13)	—
VTP240	23.8	26.2	—	0.8	4.9	5.3	3.5	5.7	3.5	5.7	3.9	4.1	B5
	(0.93)	(1.03)	—	(0.03)	(0.19)	(0.21)	(0.13)	(0.23)	(0.13)	(0.23)	(0.15)	(0.16)	—
110°C Typical Activation LTP													
LTP070	19.9	22.1	0.7	1.2	4.9	5.2	5.5	7.5	5.5	7.5	3.9	4.1	B9
	(0.783)	(0.870)	(0.027)	(0.048)	(0.192)	(0.205)	(0.216)	(0.296)	(0.216)	(0.296)	(0.153)	(0.162)	—
LTP070S	19.9	22.1	0.7	1.2	4.9	5.2	5.5	7.5	5.5	7.5	3.9	4.1	B10
	(0.783)	(0.870)	(0.027)	(0.048)	(0.192)	(0.205)	(0.216)	(0.296)	(0.216)	(0.296)	(0.153)	(0.162)	—
LTP100	20.9	23.1	0.6	1.0	4.9	5.2	4.1	5.5	4.1	5.5	3.9	4.1	B9
	(0.82)	(0.91)	(0.02)	(0.04)	(0.19)	(0.20)	(0.16)	(0.22)	(0.16)	(0.22)	(0.15)	(0.16)	—
LTP100S	20.9	23.1	0.6	1.0	4.9	5.2	4.1	5.5	4.1	5.5	3.9	4.1	B10
	(0.82)	(0.91)	(0.02)	(0.04)	(0.19)	(0.20)	(0.16)	(0.22)	(0.16)	(0.22)	(0.15)	(0.16)	—
LTP100SL	29.0	32.0	0.6	1.0	4.9	5.2	3.5	5.5	12.5	14.5	3.9	4.1	B10
	(1.14)	(1.26)	(0.02)	(0.04)	(0.19)	(0.20)	(0.13)	(0.22)	(0.49)	(0.57)	(0.15)	(0.16)	—
LTP100SS	20.9	23.1	0.6	1.0	4.9	5.2	4.1	5.5	4.1	5.5	3.9	4.1	B11
	(0.82)	(0.91)	(0.02)	(0.04)	(0.19)	(0.20)	(0.16)	(0.22)	(0.16)	(0.22)	(0.15)	(0.16)	—
LTP180	24.0	26.0	0.6	1.0	4.9	5.2	4.1	5.5	4.1	5.5	3.9	4.1	B9
	(0.94)	(1.02)	(0.02)	(0.04)	(0.19)	(0.20)	(0.16)	(0.22)	(0.16)	(0.22)	(0.15)	(0.16)	—
LTP180L	35.5	37.5	0.6	1.0	4.9	5.2	9.7	11.0	9.7	11.0	3.9	4.1	B9
	(1.40)	(1.48)	(0.02)	(0.04)	(0.19)	(0.20)	(0.38)	(0.44)	(0.38)	(0.44)	(0.15)	(0.16)	—
LTP180S	24.0	26.0	0.6	1.0	4.9	5.2	4.1	5.5	4.1	5.5	3.9	4.1	B10
	(0.94)	(1.02)	(0.02)	(0.04)	(0.19)	(0.20)	(0.16)	(0.22)	(0.16)	(0.22)	(0.15)	(0.16)	—
LTP190	21.3	23.4	0.5	1.1	10.2	11.0	5.0	7.6	5.0	7.6	4.8	5.4	B9
	(0.84)	(0.92)	(0.02)	(0.04)	(0.40)	(0.43)	(0.20)	(0.30)	(0.20)	(0.30)	(0.19)	(0.21)	—
LTP260	24.0	26.0	0.6	1.0	10.8	11.9	5.0	7.0	5.0	7.0	5.9	6.1	B9
	(0.94)	(1.02)	(0.02)	(0.04)	(0.43)	(0.47)	(0.20)	(0.28)	(0.20)	(0.28)	(0.23)	(0.24)	—
LTP300	28.4	31.8	0.5	1.1	13.0	13.5	6.3	8.9	6.3	8.9	6.0	6.6	B9
	(1.12)	(1.25)	(0.02)	(0.04)	(0.51)	(0.53)	(0.25)	(0.35)	(0.25)	(0.35)	(0.24)	(0.26)	—
LTP340	24.0	26.0	0.6	1.0	14.8	15.9	4.0	5.0	4.0	5.0	5.9	6.1	B9
	(0.94)	(1.02)	(0.02)	(0.04)	(0.58)	(0.63)	(0.16)	(0.20)	(0.16)	(0.20)	(0.23)	(0.24)	—

Table B4. Dimensions for Strap Battery Devices in Millimeters (Inches) *continued*

	Dimension												
	A		B		C		D		E		F		
Part Number	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Figure
miniSMDE													
miniSMDE190	11.15	11.51	0.33	0.53	4.83	5.33	0.51	1.02	—	—	—	—	B18
	(0.439)	(0.453)	(0.013)	(0.021)	(0.19)	(0.21)	(0.02)	(0.04)	—	—	—	—	—
TAC													
TAC100-09	16.5	17.5	—	0.9	9.5	10.5	9.4	10.0	5.0	5.2	0.8	1.2	B12
	(0.65)	(0.69)	—	(0.036)	(0.37)	(0.45)	(0.37)	(0.040)	(0.19)	(0.21)	(0.03)	(0.05)	—
125°C Typical Activation													
LR4													
LR4-170U	19.0	21.0	0.5	0.7	3.8	4.0	5.3	6.5	5.3	6.5	2.9	3.1	B15
	(0.75)	(0.83)	(0.02)	(0.03)	(0.15)	(0.16)	(0.21)	(0.26)	(0.21)	(0.26)	(0.11)	(0.12)	—
LR4-190	19.9	22.1	0.6	1.0	4.9	5.5	5.5	7.5	5.5	7.5	3.9	4.1	B13
	(0.78)	(0.87)	(0.02)	(0.04)	(0.19)	(0.22)	(0.22)	(0.30)	(0.22)	(0.30)	(0.15)	(0.16)	—
LR4-190S	19.9	22.1	0.6	1.0	4.9	5.5	5.5	7.5	5.5	7.5	3.9	4.1	B14
	(0.78)	(0.87)	(0.02)	(0.04)	(0.19)	(0.22)	(0.22)	(0.30)	(0.22)	(0.30)	(0.15)	(0.16)	—
LR4-260	20.9	23.1	0.6	1.0	4.9	5.5	4.1	5.5	4.1	5.5	3.9	4.1	B13
	(0.82)	(0.91)	(0.02)	(0.04)	(0.19)	(0.22)	(0.16)	(0.22)	(0.16)	(0.22)	(0.15)	(0.16)	—
LR4-260S	20.9	23.1	0.6	1.0	4.9	5.5	4.1	5.5	4.1	5.5	3.9	4.1	B14
	(0.82)	(0.91)	(0.02)	(0.04)	(0.19)	(0.22)	(0.16)	(0.22)	(0.16)	(0.22)	(0.15)	(0.16)	—
LR4-380	24.0	26.0	0.6	1.0	6.9	7.5	4.1	5.5	4.1	5.5	4.9	5.1	B13
	(0.94)	(1.02)	(0.02)	(0.04)	(0.27)	(0.30)	(0.16)	(0.22)	(0.16)	(0.22)	(0.19)	(0.20)	—
LR4-380X	32.2	35.8	0.6	1.0	4.9	5.5	5.5	7.5	5.5	7.5	3.9	4.1	B13
	(1.27)	(1.41)	(0.02)	(0.04)	(0.19)	(0.22)	(0.22)	(0.30)	(0.22)	(0.30)	(0.15)	(0.16)	—
LR4-450	24.0	26.0	0.6	1.0	9.9	10.5	5.3	6.7	5.3	6.7	5.9	6.1	B13
	(0.94)	(1.02)	(0.02)	(0.04)	(0.41)	(0.39)	(0.21)	(0.26)	(0.21)	(0.26)	(0.23)	(0.24)	—
LR4-550	35.0	37.0	0.6	1.0	6.9	7.5	5.3	6.7	5.3	6.7	4.9	5.1	B13
	(1.38)	(1.46)	(0.02)	(0.04)	(0.27)	(0.30)	(0.21)	(0.26)	(0.21)	(0.26)	(0.19)	(0.20)	—
LR4-600	24.0	26.0	0.6	1.0	13.9	14.5	4.1	5.5	4.1	5.5	5.9	6.1	B13
	(0.95)	(1.02)	(0.02)	(0.04)	(0.55)	(0.57)	(0.16)	(0.22)	(0.16)	(0.22)	(0.23)	(0.24)	—
LR4-600X	40.5	42.7	0.06	1.0	6.9	7.5	5.2	6.8	5.2	6.8	4.9	5.1	B13
	(1.59)	(1.68)	(0.02)	(0.04)	(0.27)	(0.30)	(0.20)	(0.27)	(0.20)	(0.27)	(0.19)	(0.20)	—
LR4-730	27.1	29.1	0.6	1.0	13.9	14.5	4.1	5.5	4.1	5.5	5.9	6.1	B13
	(1.06)	(1.15)	(0.02)	(0.04)	(0.54)	(0.57)	(0.16)	(0.22)	(0.16)	(0.22)	(0.23)	(0.24)	—
LR4-880S	62.8	65.2	0.6	1.0	7.9	8.5	10.0	12.0	10.0	12.0	5.9	6.1	B17
	(2.47)	(2.57)	(0.02)	(0.04)	(0.31)	(0.33)	(0.39)	(0.47)	(0.39)	(0.47)	(0.23)	(0.24)	—
LR4-900	45.4	47.6	0.9	1.3	7.9	8.5	4.6	6.2	4.6	6.2	5.9	6.1	B13
	(1.79)	(1.87)	(0.04)	(0.05)	(0.31)	(0.33)	(0.18)	(0.24)	(0.18)	(0.24)	(0.23)	(0.24)	—
LR4-1300SS	61.5	66.5	0.9	1.3	9.4	10.0	5.0	7.5	5.0	7.5	5.9	6.1	B17
	(0.42)	(2.62)	(0.04)	(0.05)	(0.37)	(0.39)	(0.20)	(0.30)	(0.20)	(0.30)	(0.23)	(0.24)	—
LR4-1410	58.0	60.0	0.9	1.3	13.4	14.0	4.2	5.8	4.2	5.8	5.9	6.1	B13
	(2.28)	(2.36)	(0.04)	(0.05)	(0.53)	(0.55)	(0.17)	(0.23)	(0.17)	(0.23)	(0.23)	(0.24)	—
SRP													
SRP120	19.9	22.1	0.6	1.0	4.9	5.2	5.5	7.5	5.5	7.5	3.9	4.1	B9
	(0.78)	(0.87)	(0.02)	(0.04)	(0.19)	(0.20)	(0.22)	(0.30)	(0.22)	(0.30)	(0.15)	(0.16)	—
SRP120L	24.9	27.1	0.6	1.0	4.9	5.2	5.5	7.5	10.5	12.5	3.9	4.1	B9
	(0.98)	(1.07)	(0.02)	(0.04)	(0.19)	(0.20)	(0.22)	(0.30)	(0.41)	(0.49)	(0.15)	(0.16)	—
SRP120S	19.9	22.1	0.6	1.0	4.9	5.2	5.5	7.5	5.5	7.5	3.9	4.1	B16
	(0.78)	(0.87)	(0.02)	(0.04)	(0.19)	(0.20)	(0.22)	(0.30)	(0.22)	(0.30)	(0.15)	(0.16)	—
SRP175	20.9	23.1	0.6	1.0	4.9	5.2	4.1	5.5	4.1	5.5	3.9	4.1	B9
	(0.82)	(0.91)	(0.02)	(0.04)	(0.19)	(0.20)	(0.16)	(0.22)	(0.16)	(0.22)	(0.15)	(0.16)	—
SRP175L	29.9	32.1	0.6	1.0	4.9	5.2	5.5	7.5	10.5	12.5	3.9	4.1	B9
	(1.18)	(1.26)	(0.02)	(0.04)	(0.19)	(0.20)	(0.22)	(0.30)	(0.41)	(0.49)	(0.15)	(0.16)	—

Table B4. Dimensions for Strap Battery Devices in Millimeters (Inches) *continued*

	Dimension												
	A		B		C		D		E		F		
Part Number	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Figure**
SRP *continued*													
SRP175S	20.9 (0.82)	23.1 (0.91)	0.6 (0.02)	1.0 (0.04)	4.9 (0.19)	5.2 (0.20)	4.1 (0.16)	5.5 (0.22)	4.1 (0.16)	5.5 (0.22)	3.9 (0.15)	4.1 (0.16)	B16 —
SRP175SS	20.9 (0.82)	23.1 (0.91)	0.6 (0.02)	1.0 (0.04)	4.9 (0.19)	5.2 (0.20)	4.1 (0.16)	5.5 (0.22)	4.1 (0.16)	5.5 (0.22)	3.9 (0.15)	4.1 (0.16)	B17 —
SRP200	21.3 (0.84)	23.4 (0.92)	0.5 (0.02)	1.1 (0.04)	10.2 (0.40)	11.0 (0.43)	5.0 (0.20)	7.6 (0.30)	5.0 (0.20)	7.6 (0.30)	4.8 (0.19)	5.4 (0.21)	B9 —
SRP350	28.4 (1.12)	31.8 (1.25)	0.5 (0.02)	1.1 (0.04)	13.0 (0.53)	13.5 (0.51)	6.3 (0.25)	8.9 (0.35)	6.3 (0.25)	8.9 (0.35)	6.0 (0.24)	6.6 (0.26)	B9 —
SRP420	30.6 (1.20)	32.4 (1.28)	0.5 (0.02)	1.1 (0.04)	12.9 (0.51)	13.6 (0.54)	5.0 (0.20)	7.5 (0.30)	5.0 (0.20)	7.5 (0.30)	6.0 (0.24)	6.7 (0.26)	B9 —
TAC													
TAC170-09	16.5 (0.65)	17.5 (0.69)	— —	0.9 (0.036)	9.5 (0.37)	10.5 (0.42)	9.4 (0.37)	10.0 (0.40)	5.0 (0.19)	5.2 (0.21)	0.8 (0.03)	1.2 (0.05)	B12 —
TAC210	16.5 (0.65)	17.5 (0.69)	— —	0.9 (0.036)	9.5 (0.37)	10.5 (0.42)	9.4 (0.37)	10.0 (0.40)	5.0 (0.19)	5.2 (0.21)	0.8 (0.03)	1.2 (0.05)	B12 —

Figures B19–B25. Typical Time-to-trip Curves at 20°C for Strap Battery Devices

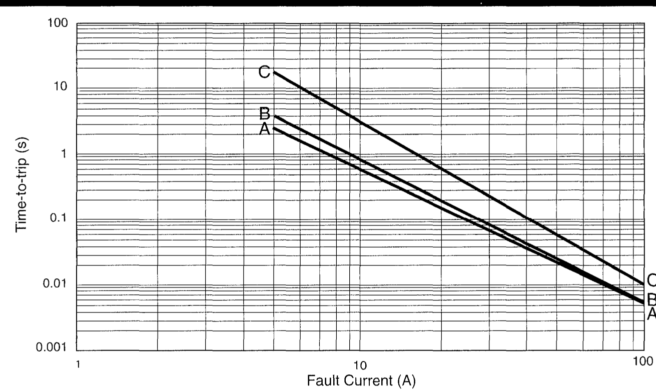
VLR (data at 25°C)

A = VLR170

B = VLR175

C = VLR230

Figure B19



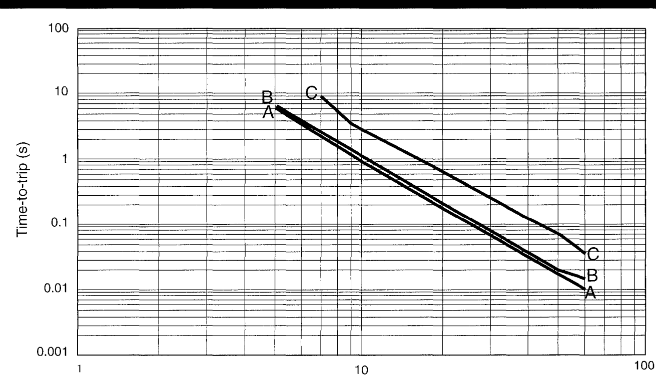
VLP (data at 25°C)

A = VLP210

B = VLP220

C = VLP270

Figure B20



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Figures B19–B25. Typical Time-to-trip Curves at 20°C for Strap Battery Devices *continued*

VTP (data at 25°C)

A = VTP170

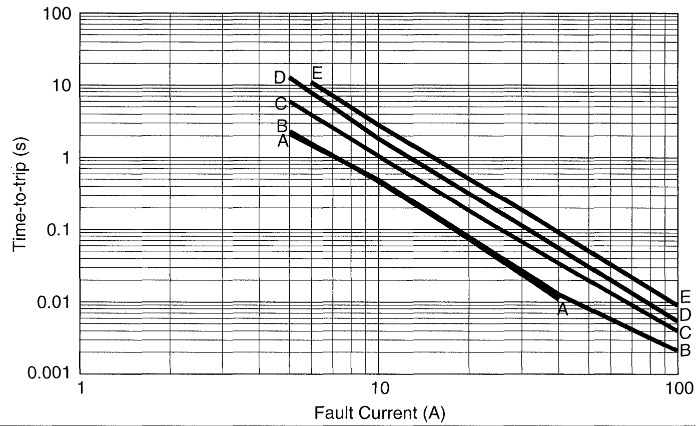
B = VTP175

C = VTP200

D = VTP210G

E = VTP240

Figure B21



LTP

A = LTP070

B = LTP100

C = LTP180

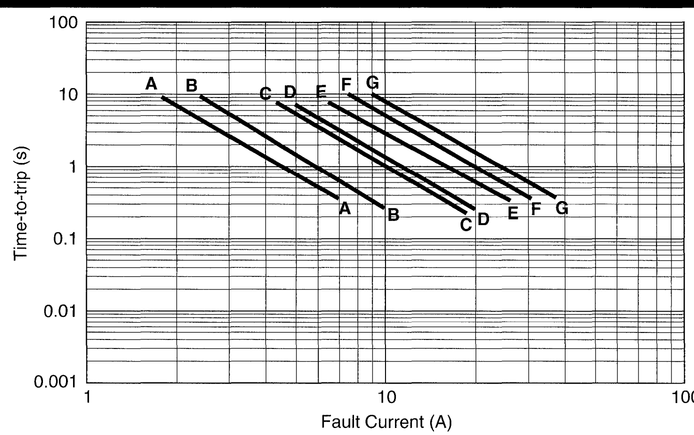
D = LTP190

E = LTP260

F = LTP300

G = LTP340

Figure B22



LR4

A = LR4-170U

B = LR4-190

C = LR4-260

D = LR4-380

E = LR4-450

F = LR4-550

G = LR4-600

H = LR4-730

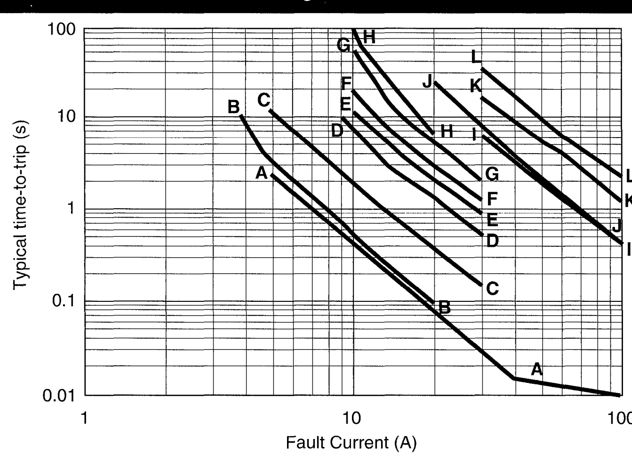
I = LR4-880

J = LR4-900

K = LR4-1300

L = LR4-1410

Figure B23



Figures B19–B25. Typical Time-to-trip Curves at 20°C for Strap Battery Devices *continued*

SRP

A = SRP120

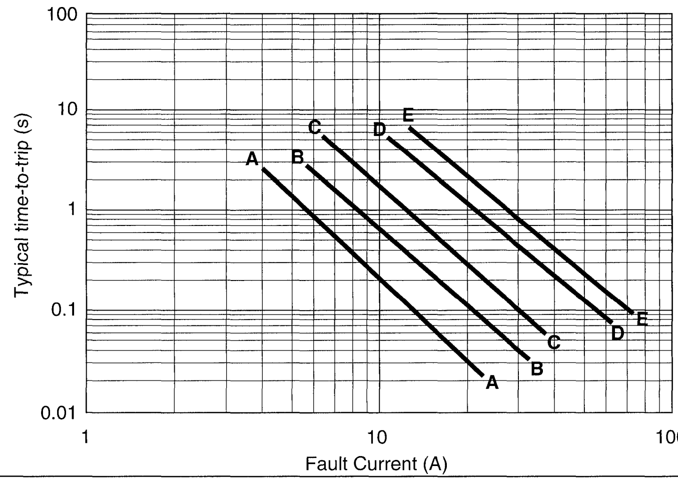
B = SRP175

C = SRP200

D = SRP350

E = SRP420

Figure B24



TAC & miniSMDE

A = TAC100-09

B = TAC170-09

C = TAC210

D = miniSMDE190

Figure B25

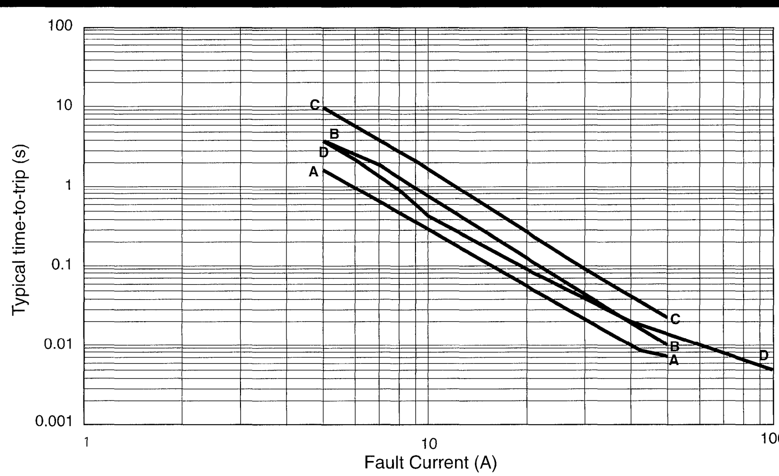


Table B5. Physical Characteristics and Environmental Specifications for Strap Battery Devices

VLR

Physical Characteristics

Lead material	0.125mm nominal thickness, quarter-hard nickel
Tape material	Polyester

Environmental Specifications

Test	Conditions	Resistance Change
Passive aging	-40°C, 1000 hours	±5%
	60°C, 1000 hours	±20%
Humidity aging	60°C/95% RH, 1000 hours	±30%
Thermal shock	85°C, -40°C (10 times)	±5%
Vibration	MIL-STD-883D, Method 2026	No change

VLP and VTP

Physical Characteristics

Lead material	0.125mm nominal thickness, quarter-hard nickel
Tape material	Polyester

Environmental Specifications

Test	Conditions	Resistance Change
Passive aging	-40°C, 1000 hours	±5%
	60°C, 1000 hours	±10%
Humidity aging	60°C/95% RH, 1000 hours	±10%
Thermal shock	85°C, -40°C (10 times)	±5%
Vibration	MIL-STD-883D, Method 2026	No change

4

LTP

Physical Characteristics

Lead material	0.125mm nominal thickness, quarter-hard nickel
Tape material	Polyester

Environmental Specifications

Test	Conditions	Resistance Change
Passive aging	70°C, 1000 hours	±10%
Humidity aging	85°C/85% RH, 7 days	±15%
Vibration	MIL-STD-883C, Test Condition A	No change

LR4

Physical Characteristics

Lead material	0.125mm nominal thickness, quarter-hard nickel
Tape material	Polyester

Environmental Specifications

Test	Conditions	Resistance Change
Passive aging	70°C, 1000 hours	±10%
Humidity aging	85°C/85% RH, 7 days	±5%
Vibration	MIL-STD-883D, Method 2026	No change

Table B5. Physical Characteristics and Environmental Specifications for Strap Battery Devices *continued*

SRP

Physical Characteristics

Lead material	0.125mm nominal thickness, quarter-hard nickel
Tape material	Polyester

Environmental Specifications

Test	Conditions	Resistance Change
Passive aging	70°C, 1000 hours	±10%
Humidity aging	85°C/85% RH, 7 days	±5%
Vibration	MIL-STD-883C, Test Condition A	No change

TAC

Physical Characteristics

Lead material	0.15mm nominal thickness, nickel-plated steel
Molding material	liquid crystal polymer

Environmental Specifications

Test	Conditions	Resistance Change
Passive aging	70°C, 1000 hours	±10%
Humidity aging	85°C/85% RH, 7 days	±15%
Vibration	MIL-STD-883D, Method 2026	No change

miniSMDE

Physical Characteristics

Termination pad materials	Solder-plated copper
Termination pad solderability	Meets EIA specification RS186-9E, ANSI/J-STD-002 Category 3

Environmental Specifications

Test	Conditions	Resistance Change
Passive aging	60°C, 1000 hours	±5% typical
	85°C, 1000 hours	±5% typical
Humidity aging	85°C/85% RH, 100 days	±15% typical
Thermal shock	85°C, -40°C (20 times)	-33% typical
	125°C, -55°C (10 times)	-33% typical
Vibration	MIL-STD-883D, Method 2026	No change
Reflow conditions	260°C for 10-20 seconds	Less than $R_{1\,MAX}$
Tape and reel specifications	Per EIA 481-1	N/A

Note: Storage conditions: 40°C max., 70% RH max.; devices should remain in original sealed bags prior to use. Devices may not meet specified values if these storage conditions are exceeded.

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Table B6. Packaging and Marking Information/Agency Recognition for Strap Battery Devices

Part Number	Bag Quantity	Tape & Reel Quantity	Standard Package	Part Marking	Agency Recognition
85°C Typical Activation—VLR					
VLR170	1,000	—	10,000	R17	UL, CSA,TÜV
VLR170L	1,000	—	10,000	R17	UL, CSA,TÜV
VLR170U	1,000	—	10,000	—	UL, CSA,TÜV
VLR170UF	1,000	—	10,000	—	UL, CSA,TÜV
VLR175	1,000	—	10,000	R1X	UL, CSA,TÜV
VLR175L	1,000	—	10,000	R1X	UL, CSA,TÜV
VLR175UF	1,000	—	10,000	—	UL, CSA,TÜV
VLR230	1,000	—	10,000	R23	UL, CSA,TÜV
VLR230-C36	1,000	—	10,000	R23	UL, CSA,TÜV
VLR230S	1,000	—	10,000	R23	UL, CSA,TÜV
VLR230SU	1,000	—	10,000	—	UL, CSA,TÜV
VLR230U	1,000	—	10,000	—	UL, CSA,TÜV
90°C Typical Activation—VLP					
VLP210	1,000	—	10,000	W21	UL, CSA, TÜV
VLP220	1,000	—	10,000	W22	UL, CSA, TÜV
VLP270	1,000	—	10,000	W27	UL, CSA, TÜV
90°C Typical Activation—VTP					
VTP110	1,000	—	10,000	—	UL, CSA, TÜV
VTP170	1,000	—	10,000	V17	UL, CSA, TÜV
VTP170SS	1,000	—	10,000	V17	UL, CSA, TÜV
VTP170X	1,000	—	10,000	V17	UL, CSA, TÜV
VTP170XS	1,000	—	10,000	V17	UL, CSA, TÜV
VTP175	1,000	—	10,000	V1X	UL, CSA, TÜV
VTP175U	1,000	—	10,000	—	UL, CSA, TÜV
VTP175L	1,000	—	10,000	V1X	UL, CSA, TÜV
VTP200G	1,000	—	10,000	V20	UL, CSA, TÜV
VTP200U	1,000	—	10,000	—	UL, CSA, TÜV
VTP210G	1,000	—	10,000	V21	UL, CSA, TÜV
VTP210GU	1,000	—	10,000	—	UL, CSA, TÜV
VTP210G-2	—	4,000	20,000	V21	UL, CSA, TÜV
VTP210L	1,000	—	10,000	V21	UL, CSA, TÜV
VTP210L-2	—	4,000	20,000	V21	UL, CSA, TÜV
VTP210S	1,000	—	10,000	V21	UL, CSA, TÜV
VTP210SF	1,000	—	10,000	V21	UL, CSA, TÜV
VTP210S-2	—	4,000	20,000	V21	UL, CSA, TÜV
VTP210SL	1,000	—	10,000	V21	UL, CSA, TÜV
VTP210SL-2	—	4,000	20,000	V21	UL, CSA, TÜV
VTP210SL-19.2/5.8	1,000	—	10,000	V21	UL, CSA, TÜV
VTP210SL-19.2/5.8-2	—	4,000	20,000	V21	UL, CSA, TÜV
VTP210SS	1,000	—	10,000	V21	UL, CSA, TÜV
VTP210ULD	1,000	—	10,000	—	UL, CSA, TÜV
VTP240	1,000	—	10,000	V24	UL, CSA, TÜV
110°C Typical Activation—LTP, TAC, miniSMDE					
LTP070	2,000	—	10,000	L07	UL, CSA, TÜV
LTP070S	2,000	—	10,000	L07	UL, CSA, TÜV
LTP100	2,000	—	10,000	L10	UL, CSA, TÜV
LTP100S	2,000	—	10,000	L10	UL, CSA, TÜV
LTP100S-2	—	4,000	20,000	L10	UL, CSA, TÜV
LTP100SL	2,000	—	40,000	L10	UL, CSA, TÜV
LTP100SL-2	—	4,000	20,000	L10	UL, CSA, TÜV
LTP100SS	2,000	—	10,000	L10	UL, CSA, TÜV

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Table B6. Packaging and Marking Information/Agency Recognition for Strap Battery Devices *continued*

Part Number	Bag Quantity	Tape & Reel Quantity	Standard Package	Part Marking	Agency Recognition
110°C Typical Activation—LTP, TAC, miniSMDE, *continued*					
LTP180	2,000	—	10,000	L18	UL, CSA, TÜV
LTP180L	500	—	10,000	L18	UL, CSA, TÜV
LTP180L-2	—	4,000	20,000	L18	UL, CSA, TÜV
LTP180S	2,000	—	10,000	L18	UL, CSA, TÜV
LTP180S-2	—	4,000	20,000	L18	UL, CSA, TÜV
LTP190	500	—	10,000	L19	UL, CSA, TÜV
LTP260	1,000	—	10,000	L26	UL, CSA, TÜV
LTP300	500	—	10,000	L30	UL, CSA, TÜV
LTP340	500	—	10,000	L34	UL, CSA, TÜV
miniSMDE190-2	—	5,000	5,000	19	UL, CSA, TÜV
TAC100-09	2,000	—	10,000	Black*	UL
125°C Typical Activation—LR4, SRP, TAC					
LR4-170U	2,000	—	10,000	NA	UL, CSA, TÜV
LR4-190	2,000	—	10,000	E19	UL, CSA, TÜV
LR4-190S	2,000	—	10,000	E19	UL, CSA, TÜV
LR4-190S-2	—	4,000	20,000	E19	UL, CSA, TÜV
LR4-260	1,000	—	10,000	E26	UL, CSA, TÜV
LR4-260S	1,000	—	10,000	E26	UL, CSA, TÜV
LR4-380	1,000	—	10,000	E38	UL, CSA, TÜV
LR4-380X	1,000	—	10,000	E3X	UL, CSA, TÜV
LR4-450	1,000	—	10,000	E45	UL, CSA, TÜV
LR4-550	1,000	—	10,000	E55	UL, CSA, TÜV
LR4-600	1,000	—	10,000	E60	UL, CSA, TÜV
LR4-600X	1,000	—	10,000	E60	UL, CSA, TÜV
LR4-730	1,000	—	10,000	E73	UL, CSA, TÜV
LR4-73X	500	—	10,000	E7X	UL, CSA, TÜV
LR4-880SS	250	—	8,000	E88	(UL, CSA, TÜV pending)
LR4-900	500	—	10,000	E90	UL, CSA, TÜV
LR4-1300SS	250	—	10,000	EX3	UL, CSA, TÜV
LR4-1410	250	—	10,000	E141	UL, CSA, TÜV
SRP120	2,000	—	10,000	120	UL, CSA, TÜV
SRP120L	1,000	—	10,000	120	UL, CSA, TÜV
SRP120S	2,000	—	10,000	120	UL, CSA, TÜV
SRP175	2,000	—	10,000	175	UL, CSA, TÜV
SRP175-2	—	4,000	20,000	175	UL, CSA, TÜV
SRP175L	1,000	—	10,000	175	UL, CSA, TÜV
SRP175S	2,000	—	10,000	175	UL, CSA, TÜV
SRP175SS	2,000	—	10,000	175	UL, CSA, TÜV
SRP200	500	—	10,000	200	UL, CSA, TÜV
SRP200-2	—	4,000	20,000	200	UL, CSA, TÜV
SRP350	500	—	10,000	350	UL, CSA, TÜV
SRP420	500	—	10,000	420	UL, CSA, TÜV
TAC170-09	2,000	—	10,000	Black*	UL, CSA
TAC210	2,000	—	10,000	White*	UL, CSA, TÜV
TAC210-2	—	4,000	20,000	White*	UL, CSA, TÜV

*Color indicated is mold ring material color.

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Agency Recognition for Strap Battery Devices

UL	File # E74889
CSA	File #78165C
TÜV	Certificate number available on request

Part Numbering System for Strap Battery Devices

LTP 190 SS -2

Blank = Bulk
2 = Tape and reel packaging

Modifier
F = Lead-free version
G = Global design (standard product)
L = Long lead or leads
S = Slit lead
SS = Both leads slit
X = Rotated chip
U = Untaped

Hold current indicator

Product series

VTP 210 SL 19.2/5.8 -2

Blank = Bulk
2 = Tape and reel packaging

19.2/5.8 = Maximum length of leads (mm)

Modifier
F = Lead-free version
G = Global design (standard product)
L = Long lead or leads
S = Slit lead
SS = Both leads slit
X = Rotated chip
U = Untaped

Hold current indicator

Product series

TAC 210 -09 -2

Blank = Bulk
2 = Tape and reel packaging

09 = Maximum thickness indicator

Hold current indicator

Product series

Table B7. Tape and Reel Specifications for TAC Series Devices (in Millimeters)

Description	Mark	Dimensions (mm)	Tolerance (mm)
Carrier tape width	A	24.0	±0.5
Sprocket hole pitch	F	4.0	±0.10
Embossed cavity pitch	D	12.0	±0.10
Ordinate to embossed cavity center	E	2.0	±0.2
Embossed cavity length (inside)	—	17.5	—
Embossed cavity width (inside)	—	10.4	—
Embossed cavity length (outside)	—	17.6	—
Sprocket hole diameter	G	1.55	±0.05
Abscissa to embossed cavity center	—	11.5	±0.15
Sprocket hole location	C	1.75	±0.15
Carrier tape thickness	—	0.3	±0.05
Cover tape thickness	—	0.055	—
Embossed cavity depth (inside)	—	1.35	±0.1
Leader min.	—	800	—
Trailer min.	—	800	—
Reel diameter	a	420	±2
Hub diameter	n	80	±1
Reel width measured at inside hub	W_1	24.4	+2, –0
Reel width measured at outside hub	W_2	30.4	+3, –1

Figure B26. Taped Component Dimensions for TAC Series

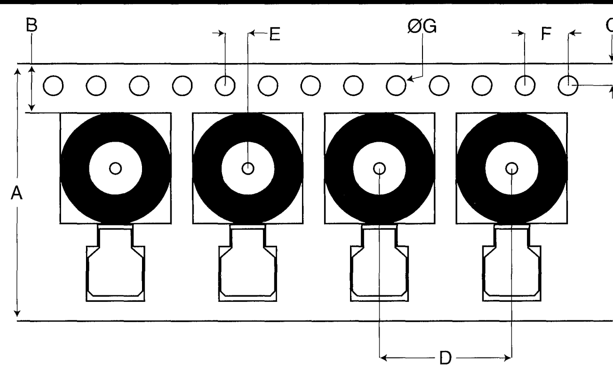


Figure B27. Reel Dimensions for TAC Series

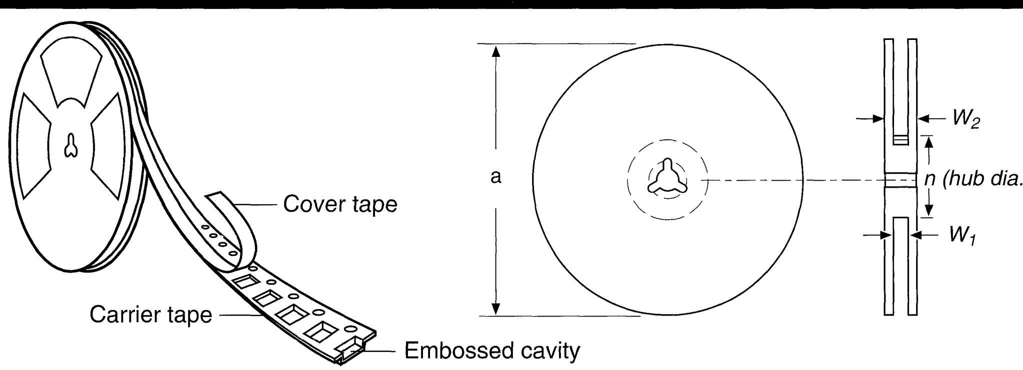
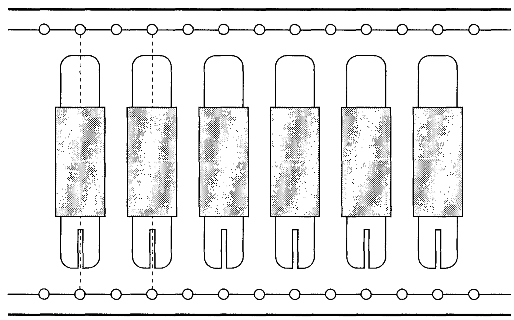


Figure B28. Typical Taped Component Layout for Strap Battery Products



Note: Contact your local Raychem Circuit Protection representative for dimensions and availabilty.

Installation Guidelines for the Strap Family

- Polymeric PTC devices operate by thermal expansion of the conductive polymer. If devices are placed under pressure or installed in spaces that would prevent thermal expansion, they may not properly protect against fault conditions. Designs must be selected in such a manner that adequate space is maintained over the life of the product.
- Twisting, bending, or placing the PPTC device in tension will decrease the ability of the device to protect against electrical faults. No residual force should remain on device after installation. Mechanical damage to PPTC chip may affect device performance and should be avoided.
- Chemical contamination of PPTC devices should be avoided. Certain greases, solvents, hydraulic fluids, fuels, industrial cleaning agents, volatile components of adhesives, silicones, and electrolytes can have an adverse effect on device performance.
- PPTC strap devices are designed to be resistance welded to battery cells or to pack interconnect straps, yet some precautions must be taken when doing so. In order for the PPTC device to exhibit its specified performance, weld placement should be a minimum of 2mm from the edge of the PPTC chip, weld splatter must not touch the PPTC chip, and welding conditions must not heat the PPTC device above its maximum operating temperature.
- PPTC strap devices are not designed for applications where reflow onto flex circuits or rigid circuit boards is required.
- The polyester tape on PolySwitch strap devices is intended for marking and indentification purposes only, not for electrical insulation.

Latest Information

- Please visit us at www.circuitprotection.com or contact your local representative for the latest information.
- The information in this Databook may contain some preliminary information. Raychem Circuit Protection, a divsion of Tyco Electronics, reserves the right to change any of the specifications without notice. In addition, Tyco Electronics reserves the right to make changes—without notification to Buyer—to materials or processing that do not affect compliance with any applicable specification.

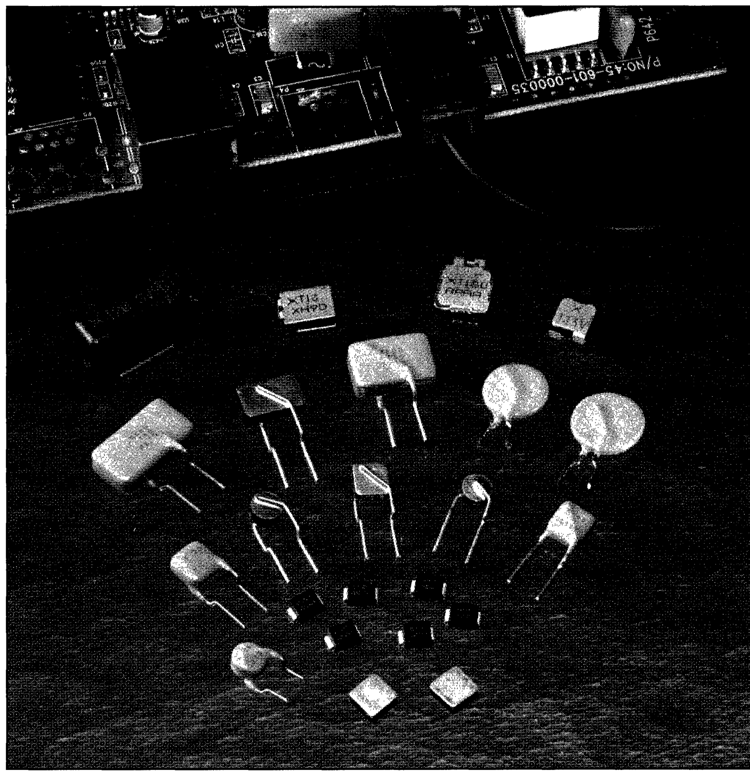
⚠ WARNING:

- Operation beyond the maximum ratings or improper use may result in device damage and possible electrical arcing and flame.
- The devices are intended for protection against occasional overcurrent or overtemperature fault conditions and should not be used when repeated fault conditions or prolonged trip events are anticipated.
- Contamination of the PPTC material with certain silicon based oils or some aggressive solvents can adversely impact the performance of the devices.
- Device performance can be impacted negatively if devices are handled in a manner inconsistent with recommendated electronic, thermal, and mechanical procedures for electronic components.
- Operation in circuit with a large inductance can generate a circuit voltage ($L\ ^{di}/_{dt}$) above the rated voltage of the PolySwitch resettable device.

4

PolySwitch Telecommunications and Networking
Resettable Devices

PolySwitch devices for telecommunication and networking applications were initially designed over ten years ago to meet the growing demand for resettable overcurrent protection. These product families help provide protection against power cross and power induction surge as defined in ITU, Telcordia, and UL. Available in chip, surface-mount, and radial-leaded configurations, PolySwitch devices help improve the reliability of customer premise and network equipment world wide.



Benefits:
- Many product choices give engineers more design flexibility
- Compatible with high volume electronics assembly
- Assist in meeting regulatory requirements
- Improved line balance
- Applicable for legacy POTS and modern digital communications equipment.

Features:
- Resettable overcurrent protection
- Surface-mount, radial-leaded, and chip form factors
- Fast time-to-trip
- Agency recognition: UL, CSA, TÜV
- Resistance sorted and matched devices available
- Low parasitic capacitance/flat impedance with frequency

Target Applications:
- Modems
- Phone sets
- Fax machines
- Phone wall outlets
- Alarm systems
- PBX systems
- MDF modules
- Analog and digital line cards
- T1/E1 equipment
- xDSL modems and splitters
- Powered ethernet systems
- VoIP (Voice over IP equipment)
- LAN, WAN equipment
- Customer premise equipment
- Access network hardware

Products in this section are grouped by:

Application/Specification, Product Series, Hold Current

Step 1. Review the Protection Application Guide on page 303 which is based on the agency specification required to qualify the final equipment.

Use the selection guide to narrow your product selection based on key device characteristics.

Step 2. Verify that the PolySwitch device hold current will accommodate the telecommunications circuit's maximum ambient temperature and normal operating current.

Look across the top of the thermal derating table T2 on page 306 to find the temperature that most closely matches the circuit's maximum operating temperature. Look down that column to find the value equal to or greater than the circuit's normal operating current. Now look to the far left of that row to find the part number for the PolySwitch telecommunications device that will best accommodate the circuit.

Note: The thermal derating curves in Figure T1 on page 307 are the normalized representations of the data in the thermal derating table.

4

Step 3. Verify that the time-to-trip characteristic of the chosen device meets the protection requirements of the telecommunications equipment circuit.

Time-to-trip is the amount of time it takes for a device to switch to a high resistance state once a fault current has been applied across the device. Identifying the PolySwitch device's time-to-trip is important in order to provide the desired protection capabilities. If the device you choose trips too fast, undesired or nuisance tripping will occur. If the device trips too slowly, the components being protected may be damaged before the device switches to a high resistance state.

Refer to typical time-to-trip curves (Figures T12-17) on pages 313-315 for each of the PolySwitch devices. If the PolySwitch device's time-to-trip is too fast or too slow for the circuit, go back to Step 2 and choose an alternate device.

Step 4. Verify ambient operating condition.

Ensure that your application's minimum and maximum ambient temperatures are within the operating temperature range of -40°C to 85°C.

Step 5. Independently evaluate and test the device.

PolySwitch devices assist your telecommunications equipment in meeting agency requirements. To confirm your selection, independently evaluate and test the device to the application requirements.

Protection Application Guide for Telecommunications and Networking Devices

To use this guide, follow the steps below:

1. Select your equipment type from the guide below.
2. Select the type of protection depending on the agency and regional specifications in the second column.
3. Use the Key Device Selection Criteria (size, resistance, time-to-trip) to determine best suitability for your application.
4. Use the Agency Specification/ PolySwitch Device Selection Guide on the next page to select a specific part number for each application based on the agency requirements.

Application	Region/ Specification	PolySwitch Resettable Devices Key Device Selection Citeria Small Footprint	Low Resistance	Fast Time-to-Trip	SiBar Thyristor Surge Protectors[1]
Customer premises equipment, IT equipment Analog modems, V.90 modems, ISDN modems, xDSL modems, ADSL splitters, phone sets, fax machines, answering machines, caller ID, internet appliances, PBX systems, POS terminals, wall plugs	**North America** TIA-968-A (formerly FCC Part 68), UL 60950	TSM600-250 TRF600-150 TS600-170 FT600-1250†	TSM600-250-RA TR600-150-RA TS600-200-RA FT600-1250	TSM600-250 TR600-150-RB TS600-170	TVBxxxSA or TVAxxxSA with TR/TS; TVBxxxSC with TR/TS or fuse
	Europe/Asia/ South America ITU K.21	TRF250-180 TR250-120 TR250-145 TS250-130 TSV250-130	TRF250-180 TS250-130-RA TSV250-130	TR250-120T-R2 TS250-130-RB	TVBxxxSA TVAxxxSA
Access network equipment (*) Remote terminals, line repeaters, multiplexers, cross-connects, WAN equipment	**North America** Telcordia GR-1089	TSM600-250 TR600-150-RA TS600-200-RA FT600-1250	TSM600-250-RA TR600-160-RA TS600-200-RA FT600-1250	TSM600-250 TR600-150-RB TS600-170	TVBxxxSC
	Europe/Asia/ South America ITU K.45	TRF250-180 TR250-120 TR250-145 TS250-130 TSV250-130	TRF250-180 TS250-130-RA TSV250-130	TR250-120T-R2 TS250-130-RB	TVBxxxSA TVAxxxSA
Central office switching equipment (*) Analog/POTS linecards, ISDN linecards, xDSL modems, ADSL/VDSL splitters, T1/E1 linecards, multiplexers, CSU/DSU, servers	**North America** Telcordia GR-1089	TSM600-250 TR600-150-RA TS600-200-RA FT600-1250	TSM600-250-RA TR600-160-RA TS600-200-RA FT600-1250	TSM600-250 TR600-150-RB TS600-170	TVBxxxSC
	Europe/Asia/ South America ITU K.20	TRF250-180 TR250-120 TR250-145 TS250-130 TSV250-130	TRF250-180 TS250-130-RA TSV250-130	TR250-120T-R2 TS250-130-RB	TVBxxxSA TVAxxxSA
Primary protection modules (*) MDF modules, Network Interface Devices (NID)	**North America** Telcordia GR-974	TRF250-180	TRF250-180	TRF250-180	N/A
	Europe/Asia/ South America ITU K.20	TCF250-120T TR240-120T TR250-120T TS250-130 TSV250-130	TC250-145T TGC250-145T TR250-145-RA TS250-130-RA TSV250-130	TCF250-120T TGC250-120T TR250-120T-R2 TS250-130-RB	N/A
Short-haul/intrabuilding communications equipment (*) LAN equipment, VoIP cards, cable telephony NIUs, wireless local loop handsets	**North America** Telcordia GR-1089 intrabuilding	TSL250-080 TR250-120 TS250-130	TR250-145 TRF250-180 TS250-130-RA TSV250-130	TR250-120T-R2 TSL250-080	TVBxxxSA TVAxxxSA
	Europe/Asia/ South America ITU K.21	TRF250-180 TR250-120 TR250-145 TS250-130 TSV250-130	TRF250-180 TS250-130-RA TSV250-130	TR250-120T-R2 TS250-130-RB	TVBxxxSA TVAxxxSA
LAN intrabuilding power cross protection LAN equipment, VoIP cards, IP phones		TSL250-080	TSL250-080	TSL250-080	TVBxxxSA TVAxxxSA
IEEE 802.3 Power over LAN protection Powered ethernet switches and terminals, IP phones, wireless LAN base stations, microcellular base stations, VoIP cards		SMD050-2018	SMD050-2018	SMD050-2018	N/A
Cable telephony powering systems Power passing taps		BBR550	BBR750	BBR550	N/A

Notes: This list is not exhaustive. Raychem Circuit Protection welcomes our customers' input for additional application ideas for PolySwitch resettable devices.
*For improved line balance in these applications, resistance-matched parts are recommended.
[1]For more information on Raychem Circuit Protection SiBar thyristor surge protectors, refer to the SiBar product section on page 339.
†FT600-1250 are surface mount Telecom fuse devices. FT600-0500 and FT600-2000 reference also available. See FT600 section.

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Agency Specification/PolySwitch Selection Guide for Telecommunications and Networking Devices

Use the guide below to select the PolySwitch devices which are typically used in your application. The following pages contain the specifications for the part numbers recommended below. PolySwitch devices assist telecommunication equipment in meeting the applicable protection requirements of these industry specifications. Refer to individual agency specifications for test procedures and circuit schematics. Users should independently evaluate the suitability of, and test each product for their application.

Family	Product *	Lightning	Power Cross
TGC250 **TC250** **TCF**	**TGC250-120T** **TC250-145T** **TC250-180** **TCF250-120T**	ITU K.20/21/45 – 1.5kV 10/700µs ITU K.20/21/45 – 4.0kV 10/700µs **	ITU K.20/21/45 – $230V_{AC}$, 10Ω ITU K.20/21/45 – $600V_{AC}$, 600Ω
TR250 **TRF250**	**TR250-080U**	ITU K.20 – 1.0kV 10/700µs	ITU K.20 – $230V_{AC}$, 10Ω ITU K.20 – $600V_{AC}$, 600Ω
	TR250-110U **TR250-120** **TR250-120T** **TR250-120U** **TR250-120UT** **TR250-145** **TR250-145U** **TRF250-180**	ITU K.20/21/45 – 1.5kV 10/700µs ITU K.20/21/45 – 4.0kV 10/700µs **	ITU K.20/21/45 – $230V_{AC}$, 10Ω ITU K.20/21/45 – $600V_{AC}$, 600Ω
TSV250 **TS250**	**TSV250-130** **TS250-130**	ITU K.20/21/45 – 1.5kV 10/700µs ITU K.20/21/45 – 4.0kV 10/700µs **	ITU K.20/21/45 – $230V_{AC}$, 10Ω ITU K.20/21/45 – $600V_{AC}$, 600Ω
TSL250	**TSL250-080**	Telcordia GR-1089 Intrabuilding – Surge 1 & 2	Telcordia GR-1089 Intrabuilding – $120V_{AC}$, 25A ITU K.20/21/45 – $230V_{AC}$, 10Ω
TR600	**TRF600-150** **TR600-160**	TIA-968-A (formerly FCC Part 68) Telcordia GR-1089 – Level 1 and 2 ***	UL60950, 3rd Ed. – $600V_{AC}$, 40A Telcordia GR-1089 – $600V_{AC}$, 60A
TS600	**TS600-170** **TS600-200-RA**	TIA-968-A (formerly FCC Part 68) Telcordia GR-1089 – Level 1 and 2 ***	UL60950, 3rd Ed. – $600V_{AC}$, 40A Telcordia GR-1089 – $600V_{AC}$, 60A
TSM600	**TSM600-250** **TSM600-250-RA**	TIA-968-A (formerly FCC Part 68) Telcordia GR-1089 – Level 1 and 2 ***	UL60950, 3rd Ed. – $600V_{AC}$, 40A Telcordia GR-1089 – $600V_{AC}$, 60A
FT600†	**FT600-0500**	TIA-968-A - Type A & B	UL60950, $600V_{AC}$, 40A
	FT600-1250 **FT600-2000**	TIA-968-A - Type A & B	UL60950, 3rd Ed. – $600V_{AC}$, 40A Telcordia GR-1089 – 600 V_{AC}, 60A

Notes:

*Applies to all products which share the same prefix.

**Tested with 230V gas discharge tube primary protector.

***May require 10 Ω series resistor to help telecommunication equipment pass Test 3 (1kV, 10/1000µs).

†See FT600 section.

Table T1. Product Series: Size, Current Rating, Voltage Rating, Typical Resistance for Telecommunications and Networking Devices

	TC250 TCF250 TGC250	TR250 TRF250	TS250	TSV250	TSL250	TS600 TSM600	TR600	BBR	RXE	SMD,midSMD miniSMDC
Voltage Rating (V)***	60/250	60/250	60/250	60/250	80/250	60/600	60/600	99	60	60
(Operating/Interrupt)									72*	
Specification	ITU	ITU	ITU	ITU	Telcordia GR-1089 Intrabuilding	UL60950 Telcordia GR-1089	UL60950 Telcordia GR-1089	Cable Taps		
Hold Current (A)										
0.080	—	17.0Ω	—	—	8.0Ω	—	—	—	—	—
0.100	—	—	—	—	—	—	—	—	3.5Ω	—
0.110	--	7.0Ω	—	—	—	—	—	—	—	—
0.120	10.5Ω	6.0-9.5Ω	—	—	—	—	—	—	—	—
0.130	—	—	8.0-10.5Ω	5.5Ω	—	—	—	—	—	—
0.140	—	—	—	—	—	—	—	—	—	4.0Ω
0.145	7.0Ω	4.3-5.0Ω	—	—	—	—	—	—	—	—
0.150	—	—	—	—	—	—	8.5-10.5Ω	—	—	—
0.160	—	—	—	—	—	—	5.5-7.0Ω**	—	—	—
0.170	—	—	—	—	—	11.0Ω	—	—	4.3Ω	—
0.180	1.4Ω	1.5Ω****	—	—	—	—	—	—	—	—
0.200	—	—	—	—	—	8.5Ω	—	—	2.3Ω*	—
0.250	—	—	—	—	—	3-3.5Ω**	—	—	1.6Ω*	—
0.300	—	—	—	—	—	—	—	—	1.1Ω*	1.4-3.0Ω
0.550	—	—	—	—	—	—	—	1.05Ω	—	—
0.750	—	—	—	—	—	—	—	0.58Ω	—	—

Notes:

*These devices have a maximum operating voltage of 72V
**These devices have a maximum operating voltage of 250V
***Voltage Rating for Telecommunications and Networking Devices is dependent upon the nature of the fault conditions. See below for details
****These devices have a maximum operating voltage of 100V

Voltage Ratings for Telecommunications and Networking Devices

For Raychem Circuit Protection telecommunications devices (TC, TGC, TRx, TSx series) there are two applicable voltage ratings. These are **V_{MAX} Operating** and **V_{MAX} Interrupt.** To help understand the nature of these two different voltage ratings the following definitions are provided:

V_{MAX} Operating: For telecommunications devices this is the voltage we have used to obtain component recognition under UL1434. Most Raychem Circuit Protection devices (TC, TGC, TRx, TRFx, TSx) are certified at 60V but can withstand higher V_{MAX}. TR600-160 and TSM600 product families are certified at 250V but can withstand higher V_{MAX}. Interrupt conditions as noted above.

V_{MAX} Interrupt: Under specified conditions this is the highest voltage that can be applied to the device at the maximum current. Devices have been designed to trip safely under higher power level cross conditions, as listed above, to assist equipment in meeting the appropriate industry conditions.

Table T2. Thermal Derating for Telecommunications and Networking Devices [Hold Current (A) at Ambient Temperature (°C)]

Part Number	Maximum Ambient Temperature -40°C	-20°C	0°C	20°C	40°C	50°C	60°C	70°C	85°C
Chip[1]—60/250V TC250/TGC250/TCF250									
TGC250-120T	0.186	0.165	0.143	0.120	0.099	0.088	0.077	0.066	0.050
TC250-145T	0.225	0.199	0.172	0.145	0.119	0.106	0.093	0.080	0.060
TGC250-145T	0.225	0.199	0.172	0.145	0.149	0.106	0.093	0.080	0.060
TC250-180*	0.269	0.240	0.211	0.180	0.153	0.138	0.123	0.109	0.087
Leaded[1]—60/250V TR250/TRF250									
TR250-080U	0.124	0.110	0.095	0.080	0.066	0.059	0.051	0.044	0.033
TR250-110U	0.171	0.151	0.131	0.110	0.091	0.081	0.071	0.061	0.046
TR250-120	0.186	0.165	0.143	0.120	0.099	0.088	0.077	0.066	0.050
TR250-145	0.225	0.199	0.172	0.145	0.119	0.106	0.093	0.080	0.060
TRF250-180*	0.279	0.247	0.213	0.180	0.147	0.131	0.115	0.99	0.74
Surface[2]—80/250V TLS250									
TSL250-080	0.124	0.110	0.095	0.080	0.066	0.059	0.051	0.044	0.033
Surface[1]—60/250V TS250/TSV250									
TS250-130	0.208	0.182	0.156	0.130	0.104	0.091	0.078	0.065	0.045
TSV250-130	0.208	0.182	0.156	0.130	0.104	0.091	0.078	0.065	0.045
Leaded[3]—60/600V TR600									
TRF600-150	0.233	0.206	0.178	0.150	0.143	0.124	0.11	0.096	0.083
TR600-160	0.249	0.219	0.190	0.160	0.132	0.117	0.103	0.088	0.066
Surface[3]—60/600V TS600									
TS600-170	0.264	0.230	0.200	0.170	0.140	0.125	0.109	0.094	0.070
TS600-200-RA	0.310	0.275	0.238	0.200	0.165	0.147	0.128	0.110	0.083
TSM600-250	0.400	0.350	0.300	0.250	0.198	0.170	0.141	0.117	0.083
Leaded—90V BBR									
BBR550*	0.850	0.750	0.650	0.550	0.450	0.400	0.350	0.300	0.220
BBR750*	1.150	1.000	0.900	0.750	0.610	0.550	0.480	0.410	0.300
Leaded—60/72V RXE									
RXE010*	0.160	0.140	0.110	0.100	0.080	0.072	0.067	0.050	0.040
RXE017*	0.260	0.230	0.210	0.170	0.140	0.120	0.110	0.090	0.070
RXE020*	0.310	0.270	0.240	0.200	0.160	0.140	0.130	0.110	0.080
RXE025*	0.390	0.340	0.300	0.250	0.200	0.180	0.160	0.140	0.100
RXE030*	0.470	0.410	0.360	0.300	0.240	0.220	0.200	0.160	0.120

Notes:

[1]60/250V products are designed to help equipment pass ITU specifications (K.20, K.21, etc) and Telcordia GR-1089 Intrabuilding power cross.

[2]80/250V product designed to help equipment pass Telcordia GR-1089 Intrabuilding power cross ($120V_{AC}$/25A).

[3]60/600V products are designed to help equipment pass UL60950, TIA-968-A (formerly FCC Part 68) and GR1089 specifications.

*Product is not currently available in a resistance matched or sorted option.

Table T2. Thermal Derating for Telecommunications and Networking Devices [Hold Current (A) at Ambient Temperature (°C)] *continued*

	Maximum Ambient Temperature								
Part Number	-40°C	-20°C	0°C	20°C	40°C	50°C	60°C	70°C	85°C
Surface—60 V SMD, midSMD									
SMD030*	0.44	0.39	0.32	0.30	0.26	0.23	0.19	0.18	0.15
SMD030-2018*	0.48	0.42	0.35	0.30	0.24	0.21	0.17	0.15	0.10
SMD050-2018*	0.86	0.77	0.70	0.55	0.48	0.43	0.38	0.36	0.26
Surface—60 V miniSMD									
miniSMDC014*	0.23	0.20	0.17	0.14	0.11	0.10	0.09	0.07	0.05
miniSMDC014F*	0.23	0.20	0.17	0.14	0.11	0.10	0.09	0.07	0.05

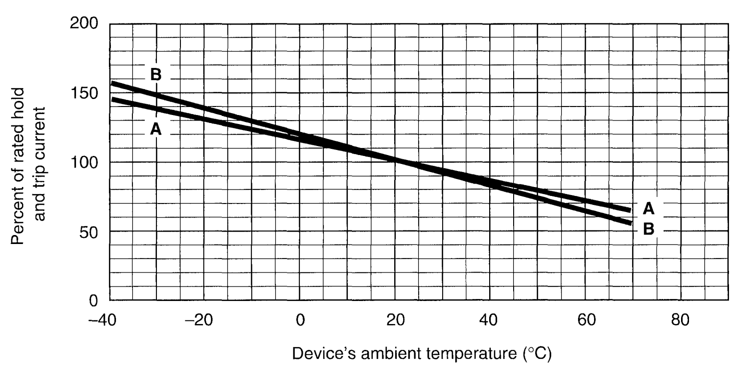
Notes:
*Product is not currently available in a resistance matched or sorted option.

Figure T1. Thermal Derating [Hold Current (A) at Ambient Temperature (°C)]

A = TC250-180

B = All other TC, TGC, TCF, TRx TRFx, TSx, TSMx series devices

Figure T1. Thermal Derating Curve (Normalized)



For thermal derating of BBR and RXE series devices, see radial-leaded product section on pages 217-252. For SMD, midSMD, miniSMDC series, see surface-mount product section on page 187 of this Raychem Circuit Protection Databook.

Table T3. Electrical Characteristics for Telecommunications and Networking Devices

Part Number	I_H (A)	I_T (A)	$V_{MAX\ Operating}$ (V_{DC})	$V_{MAX\ Interrupt}$ (V_{RMS})	I_{MAX} (A)	Pd_{TYP} (W)	Time-to-Trip (nom/max*) (A)	Time-to-Trip (nom/max*) (s)	R_{MIN} (Ω)	R_{MAX} (Ω)	$R_{1\ Max}$ (Ω)	Figure for Dimensions
Chip[1]—60/250V TC250/TCF250/TGC250												
TGC250-120T	0.120	0.240	60	250	3.0	1.0	1.0	1.20*	8.0	13.0	18.0	T4
TC250-145T	0.145	0.290	60	250	3.0	1.0	1.0	1.50	5.0	9.0	14.0	T4
TGC250-145T	0.145	0.290	60	250	3.0	1.0	1.0	1.00	6.0	10.0	14.0	T4
TC250-180	0.180	0.500	60	250	3.0	1.0	1.0	15.00	0.8	2.0	4.0	T4
Leaded[1]—60/250V (TRF for Pb-free version of product) TR250/TRF250												
TR250-080T	0.080	0.160	60	250	3.0	1.0	0.35	3.00*	15.0	22.0	33.0	T2
TR250-080U	0.080	0.160	60	250	3.0	1.0	0.35	3.00*	14.0	20.0	33.0	T2
TR250-110U	0.110	0.220	60	250	3.0	1.0	1.0	0.75	5.0	9.0	16.0	T2
TR250-120	0.120	0.240	60	250	3.0	1.0	1.0	1.50	4.0	8.0	16.0	T3
TR250-120T	0.120	0.240	60	250	3.0	1.0	1.0	0.70	7.0	12.0	16.0	T3
TR250-120T-RA	0.120	0.240	60	250	3.0	1.0	1.0	0.70	7.0	9.0	16.0	T3
TR250-120T-RC	0.130	0.260	60	250	3.0	1.0	1.0	0.85	5.4	7.5	14.0	T3
TR250-120T-RF	0.120	0.240	60	250	3.0	1.0	1.0	0.70	6.0	10.5	16.0	T3
TR250-120T-R1	0.120	0.240	60	250	3.0	1.0	1.0	0.75	6.0	9.0	16.0	T3
TR250-120T-R2	0.120	0.240	60	250	3.0	1.0	1.0	0.70	8.0	10.5	16.0	T3
TR250-120U	0.120	0.240	60	250	3.0	1.0	1.0	1.00	6.0	10.0	16.0	T3
TR250-120UT	0.120	0.240	60	250	3.0	1.0	1.0	0.90	7.0	12.0	16.0	T3
TR250-145	0.145	0.290	60	250	3.0	1.0	1.0	2.50	3.0	6.0	14.0	T3
TR250-145-RA	0.145	0.290	60	250	3.0	1.0	1.0	2.50	3.0	5.5	12.0	T3
TR250-145-RB	0.145	0.290	60	250	3.0	1.0	1.0	2.00	4.5	6.0	14.0	T3
TR250-145T	0.145	0.290	60	250	3.0	1.0	1.0	1.00	5.4	7.5	14.0	T3
New TR250-145U	0.145	0.290	60	250	3.0	1.0	1.0	2.00	3.5	6.5	12.0	T3
TRF250-180	0.180	0.650	100	250	10.0	1.5	3.0	0.5	0.8	2.2	4.0	T2
Surface[2]—/80/250V TSL250												
TSL250-080	0.080	0.160	80	250	3.0	1.2	1.0	0.80	5.0	11.0	20.0[6]	T9
Surface[1]—60/250V TS250/TSV250												
TS250-130	0.130	0.260	60	250	3.0	1.1	1.0	0.9	6.5	12.0	20.0	T6
	—	—	60	650	1.1	—	—	—	—	—	—	—
TS250-130-RA	0.130	0.260	60	250	3.0	1.1	1.0	1.4	6.5	9.0	15.0	T6
	—	—	60	650	1.1	—	—	—	—	—	—	—
TS250-130-RB	0.130	0.260	60	250	3.0	1.1	1.0	0.7	9.0	12.0	20.0	T6
	—	—	60	650	1.1	—	—	—	—	—	—	—
TS250-130-RC	0.130	0.260	60	250	3.0	1.1	1.0	1.1	7.0	10.0	17.0	T6
	—	—	60	650	1.1	—	—	—	—	—	—	—
TSV250-130	0.130	0.260	60	250	3.0	1.5	1.0	2.0	4.0	7.0	12.0[6]	T7

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Table T3. Electrical Characteristics for Telecommunications and Networking Devices *continued*

	Part Number	I_H (A)	I_T (A)	V_{MAX} Operating (V_{DC})	V_{MAX} Interrupt (V_{RMS})	I_{MAX} (A)	Pd_{TYP} (W)	Time-to-Trip (nom/max*) (A)	(s)	R_{MIN} (Ω)	R_{MAX} (R_{TYP}*) (Ω)	$R_{1\,MAX}$ (Ω)	Figure for Dimensions
	Leaded[3] **TR600**												
New	TRF600-150	0.150	0.300	60	600	3.0	1.0	1.0	1.4	6.0	10.0	17.0	T6
	TR600-150-RA	0.150	0.300	60	600	3.0	1.0	1.0	5.0	7.0	10.0	20.0	T3
	TR600-150-RB	0.150	0.300	60	600	3.0	1.0	1.0	4.5	9.0	12.0	22.0	T3
	TR600-160	0.160	0.320	250	600	3.0	1.0	1.0	7.5	4.0	10.0	18.0	T3
	TR600-160-RA	0.160	0.320	250	600	3.0	1.0	1.0	9.5	4.0	7.0	16.0	T3
	TR600-160-R1	0.160	0.320	250	600	3.0	1.0	1.0	9.0	4.0	8.0	17.0	T3
	Surface[3]—60/600V **TS600**												
	TS600-170	0.170	0.400	60	600	3.0	2.5	1.0	10.0	4.0	9.0	18.0	T10
	TS600-200-RA	0.200	0.400	60	600	3.0	2.5	1.0	12.0	4.0	7.5	13.5	T10
New	TSM600-250	0.250	0.860	250	600	3.0	2.0	3.0	0.8	1.0	3.5*	7.0	T11
New	TSM600-250-RA	0.250	0.860	250	600	3.0	2.0	3.0	1.0	1.0	3.0*	5.0	T11
	Leaded—99V **BBR**												
New	BBR550[4]	0.550	1.1	—	99	20.0	1.5	1.6	60*	0.8	1.3	1.95	T2
New	BBR750[4]	0.750	1.5	—	99	20.0	1.7	2.0	60*	0.40	0.75	1.2	T2
	Leaded—60,72V **RXE**												
	RXE010[4]	0.100	0.200	—	60[5]	40.0	0.38	0.50	4.0*	2.50	4.50	7.50	T2
	RXE017[4]	0.170	0.340	—	60[5]	40.0	0.48	0.85	3.0*	3.30	5.21	8.00	T2
	RXE020[4]	0.200	0.400	—	72[5]	40.0	0.41	1.00	2.2*	1.83	2.75	4.40	T2
	RXE025[4]	0.250	0.500	—	72[5]	40.0	0.45	1.25	2.5*	1.25	1.95	3.00	T2
	RXE030[4]	0.300	0.600	—	72[5]	40.0	0.49	1.50	3.0*	0.88	1.33	2.10	T2
	Surface—60V **SMD, midSMD**												
	SMD030[4]	0.300	0.600	—	60[5]	10.0	1.5	1.5	3.0*	1.20	3.00*	4.8	T9
	SMD030-2018[4]	0.300	0.800	—	60[5]	20.0	0.7	1.5	1.5*	0.50	1.40*	2.3	T8
	SMD050-2018[4]	0.550	1.200	—	57	10.0	1.0	2.5	5.0*	0.20	—	1.0	T8
	Surface—60V **miniSMD**												
	miniSMDC014[4]	0.140	0.340	—	60[5]	10.0	0.6	1.5	0.15*	1.5	4.0*	6.0	T5
	miniSMDC014F[4]	0.140	0.340	—	60[5]	10.0	0.6	1.5	0.15*	1.5	4.0*	6.0	T5

Notes:

[1]60/250V products are designed to help equipment pass ITU specifications (K.20, K.21, etc) and Telcordia GR-1089 Intrabuilding power cross.

[2]80/250V product designed to help equipment pass Telcordia GR-1089 Intrabuilding power cross ($120V_{AC}$/25A).

[3]60/600V products are designed to help equipment pass UL 60950, TIA-968-A (formerly FCC part 68), and Telcordia GR-1089 specifications.

[4]Product is not currently available in a resistance-matched or resistance sorted option.

[5]Voltage rating for these products is Vmax operating (V_{DC})

[6]R_{1MAX} measured 1 hour post-trip, or 24 hours post-reflow at 20°C.

I_H = Hold current: maximum current device will pass without interruption in 20°C still air.

I_T = Trip current: minimum current that will switch the device from low resistance to high resistance in 20°C still air.

V_{MAX} Interrupt = Maximum voltage that can be safely placed across a device in its tripped state under specified fault conditions.

I_{MAX} = Maximum fault current device can withstand without damage at rated voltage.

P_d = Power dissipated from device when in the tripped state in 20°C still air.

R_{1MAX} is measured one hour post-trip or post-reflow at 20°C.

R_{MAX} = Maximum resistance of device as supplied at 20°C unless otherwise specified.

Figures T2–T11. Physical Description for Dimensions for Telecommunications and Networking Devices

Figure T2

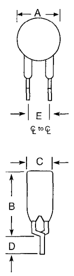

Figure T3

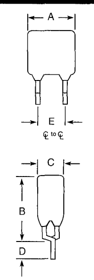

Figure T4

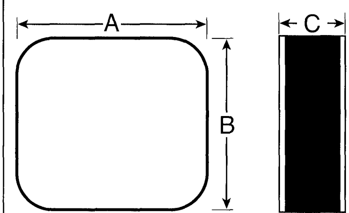

Figure T5

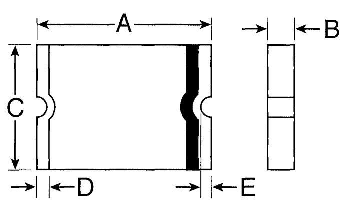

Figure T6

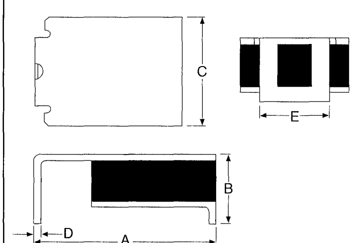

Figure T7

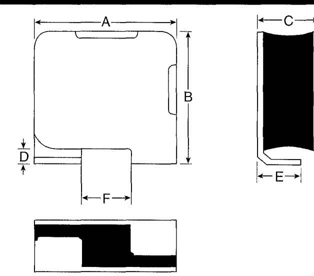

Figure T8

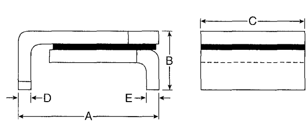

Figure T9

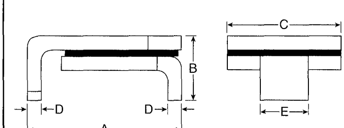

Figure T10

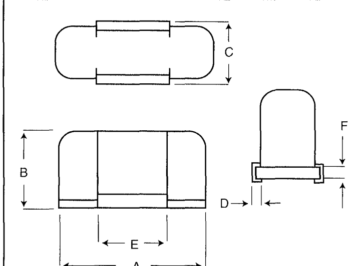

Figure T11

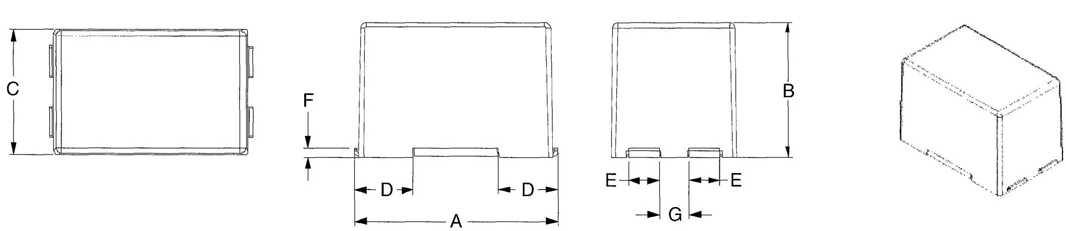

Table T4. Dimensions for Telecommunications and Networking Devices in Millimeters (Inches)

	Dimension														
	A		B		C		D		E		F		G		
Part Number	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Figure
TC/TCF/TGC—60/250V[1]															
TCF250-120T	5.4 (0.213)	5.6 (0.221)	5.4 (0.213)	5.6 (0.221)	2.0 (0.079)	2.3 (0.091)	—	—	—	—	—	—	—	—	T4
TC250-145T	5.4 (0.213)	5.6 (0.221)	5.4 (0.213)	5.6 (0.221)	2.0 (0.080)	2.5 (0.100)	—	—	—	—	—	—	—	—	T4
TGC250-145T	5.7 (0.226)	5.9 (0.234)	5.7 (0.226)	5.9 (0.234)	2.0 (0.079)	2.3 (0.091)	—	—	—	—	—	—	—	—	T4
TC250-180	9.8 (0.386)	10.4 (0.410)	6.1 (0.242)	6.6 (0.260)	2.0 (0.080)	2.5 (0.100)	—	—	—	—	—	—	—	—	T4
TR250/TRF250—60/250V[1]															
TR250-080T	—	5.8 (0.228)	—	9.9 (0.390)	—	4.6 (0.181)	4.7 (0.185)	— —	5.0* (0.197)	—	—	—	—	—	T2
TR250-080U	—	4.8 (0.189)	—	9.3 (0.366)	—	3.8 (0.150)	4.7 (0.185)	—	5.0* (0.197)	—	—	—	—	—	T2
TR250-110U	—	5.3 (0.210)	—	9.4 (0.370)	—	3.8 (0.150)	4.7 (0.185)	—	5.0* (0.197)	—	—	—	—	—	T2
TR250-120	—	6.5 (0.256)	—	11.0 (0.433)	—	4.6 (0.181)	4.7 (0.185)	—	5.0* (0.197)	—	—	—	—	—	T3
TR250-120U	—	6.0 (0.236)	—	10.0 (0.394)	—	3.8 (0.150)	4.7 (0.185)	—	5.0* (0.197)	—	—	—	—	—	T3
TR250-145	—	6.5 (0.256)	—	11.0 (0.433)	—	4.6 (0.181)	4.7 (0.185)	—	5.0* (0.197)	—	—	—	—	—	T3
TR250-145U	—	6.0 (0.236)	—	10.0 (0.394)	—	3.8 (0.150)	4.7 (0.185)	—	5.0* (0.197)	—	—	—	—	—	T3
TRF250-180	—	9.0 (0.354)	—	12.0 (0.412)	—	3.8 (0.150)	4.7 (0.185)	—	5.0* (0.197)	—	—	—	—	—	T2
TSL250—80/250V[2]															
TSL250-080	6.7 (0.265)	7.9 (0.310)	2.7 (0.110)	3.7 (0.145)	4.8 (0.190)	5.3 (0.210)	0.2 (0.008)	0.4 (0.015)	2.5 (0.100)	3.1 (0.120)	—	—	—	—	T9
TS250/TSV250—60/250V[1]															
TS250-130	8.5 (0.335)	9.4 (0.370)	—	3.4 (0.135)	—	7.4 (0.290)	0.3* (0.011)	—	3.8* (0.150)	—	—	—	—	—	T6
TSV250-130	—	6.1 (0.240)	—	6.9 (0.270)	—	3.2 (0.126)	0.56 (0.022)	—	—	1.9 (0.075)	1.6 (0.065)	2.3 (0.091)	—	—	T7
TR600—60/600V[3]															
TRF600-150	— —	9.0 (0.354)	— —	12.5 (0.492)	— —	4.6 (0.180)	4.7 (0.185)	— —	5.0 (0.197)	— —	— —	9.0 (0.354)	— —	— —	T6
TR600-160	—	16.0 (0.630)	—	12.6 (0.496)	—	6.0 (0.236)	4.7 (0.185)	—	5.0* (0.197)	—	—	—	—	—	T3
TS600 60/600V[3]															
TS600-170	18.2 (0.720)	19.4 (0.765)	11.5 (0.455)	12.3 (0.485)	7.2 (0.285)	8.3 (0.325)	1.6 (0.065)	2.4 (0.095)	9.9 (0.390)	10.4 (0.410)	1.5 (0.060)	2.3 (0.090)	—	—	T10
TS600-200-RA	18.2 (0.720)	19.4 (0.765)	11.5 (0.455)	12.3 (0.485)	7.2 (0.285)	8.3 (0.325)	1.6 (0.065)	2.4 (0.095)	9.9 (0.390)	10.4 (0.410)	1.5 (0.060)	2.3 (0.090)	—	—	T10
TSM600-250 TSM600-250-RA	—	17.6 (0.69)	—	11.7 (0.46)	—	11.2 (0.44)	—	5.2 (0.20)	—	2.8 (0.11)	0.6 (0.02)	—	2.0 (0.080)	—	T11

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Table T4. Dimensions for Telecommunications and Networking Devices in Millimeters (Inches) *continued*

	Dimension														
	A		B		C		D		E		F		G		
Part Number	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Figure**
BBR—90V															
BBR-550	—	10.9 (0.43)	—	14.0 (0.55)	—	3.6 (0.14)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	—	T2
BBR-750	—	11.9 (0.47)	—	15.5 (0.61)	—	3.6 (0.14)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	—	T2
RXE—60,72V															
RXE010	—	7.4 (0.29)	—	11.6 (0.46)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	—	T2
RXE017	—	7.4 (0.29)	—	12.7 (0.50)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	—	T2
RXE020	—	7.4 (0.29)	—	11.7 (0.46)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	—	T2
RXE025	—	7.4 (0.29)	—	12.7 (0.50)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	—	T2
RXE030	—	7.4 (0.29)	—	12.7 (0.50)	—	3.0 (0.12)	7.6 (0.30)	—	4.3 (0.17)	5.8 (0.23)	—	—	—	—	T2
mid**SMD—60V**															
SMD030	6.73 (0.265)	7.98 (0.314)	—	3.18 (0.125)	4.8 (0.19)	5.44 (0.214)	0.56 (0.022)	0.71 (0.028)	0.56 (0.022)	0.71 (0.028)	2.16 (0.085)	2.41 (0.095)	—	—	T9
SMD030-2018	4.72 (0.186)	5.44 (0.214)	—	1.78 (0.070)	4.22 (0.166)	4.93 (0.194)	0.25 (0.010)	0.36 (0.014)	0.25 (0.010)	0.36 (0.14)	0.30 (0.012)	0.46 (0.018)	—	—	T8
SMD050-2018	4.72 (0.186)	5.44 (0.214)	—	1.78 (0.070)	4.22 (0.166)	4.93 (0.194)	0.25 (0.010)	0.36 (0.014)	0.25 (0.010)	0.36 (0.14)	0.30 (0.012)	0.46 (0.018)	—	—	T8
miniSMD—60V															
miniSMDC014	4.37 (0.172)	4.73 (0.186)	0.635 (0.025)	0.89 (0.035)	3.07 (0.121)	3.41 (0.134)	0.30 (0.012)	—	0.25 (0.010)	0.50 (0.020)	—	—	—	—	T5
miniSMDC014F	4.37 (0.172)	4.73 (0.186)	0.635 (0.025)	0.89 (0.035)	3.07 (0.121)	3.41 (0.134)	0.30 (0.012)	—	0.25 (0.010)	0.50 (0.020)	—	—	—	—	T5

Notes:

*Indicates dimension is typical, not minimum.

[1]60/250V products are designed to help equipment pass ITU specifications (K.20, K.21, etc) and Telcordia GR-1089 Intrabuilding power cross.

[2]80/250V product designed to help equipment pass Telcordia GR-1089 Intrabuilding power cross ($120V_{AC}$/25A).

[3]60/600V products are designed to help equipment pass UL 60950,TIA-968-A (formerly FCC Part 68), and Telcordia GR-1089 specification.

Figures T12–T17. Typical Time-to-trip Curves at 20°C for Telecommunications and Networking Devices

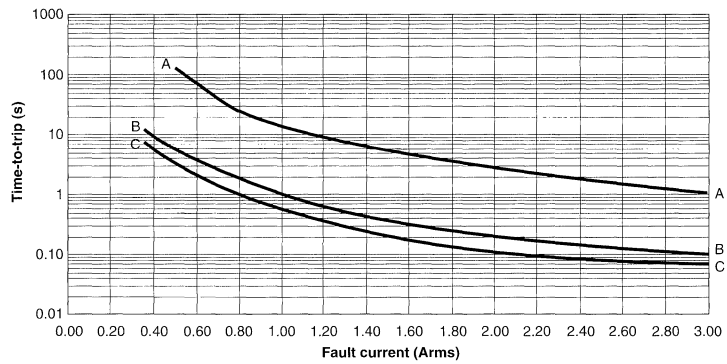
TC250/TGC250

A = TC250-180

B = TC250-145T

C = TCF250-120T

Figure T12



TR/TRF250

A = TRF250-180

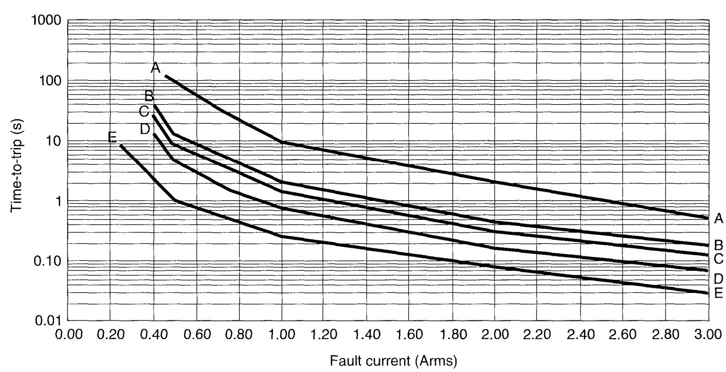
B = TR250-145/145U

C = TR250-120/120U

D = TR250-110U/120UT/120T

E = TR250-080T/080U

Figure T13



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Figures T12–T17. Typical Time-to-trip Curves at 20°C for Telecommunications and Networking Devices *continued*

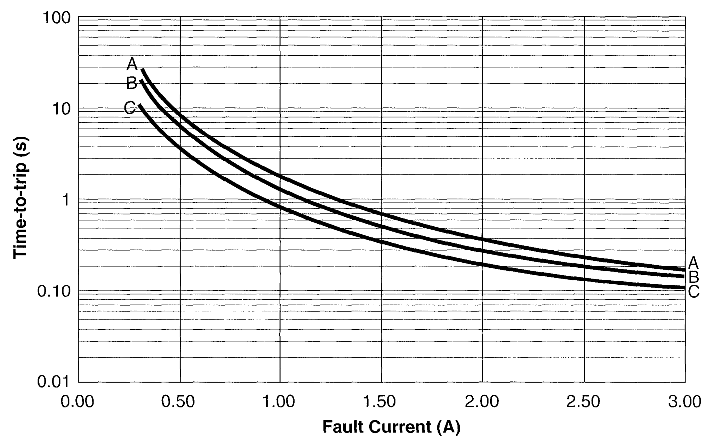
TS250/TSV250/TSL250

A = TSV250-130

B = TS250-130

C = TSL250-080

Figure T14



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TR600/TRF600/TS600/TSM600

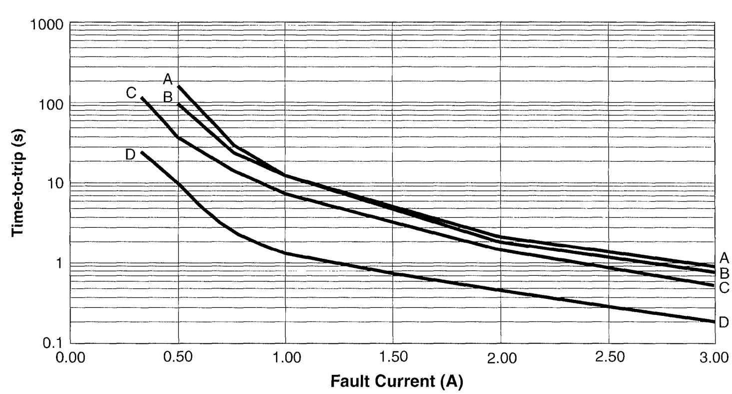
A = TSM600-250

B = TS600-170/200

C = TR600-160

D = TRF600-150

Figure T15



Figures T12–T17. Typical Time-to-trip Curves at 20°C for Telecommunications and Networking Devices *continued*

RXE

A = RXE010

B = RXE017

C = RXE020

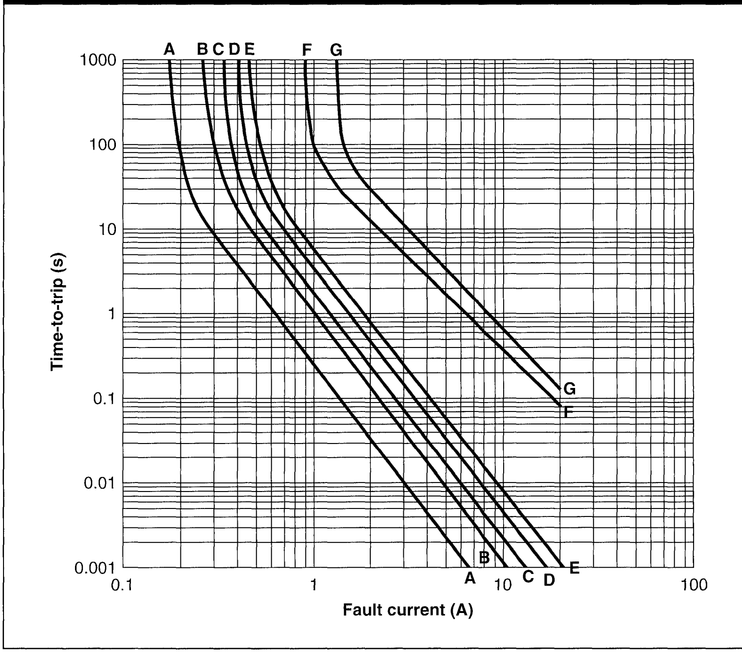
D = RXE025

E = RXE030

F = BBR550

G = BBR750

Figure T16



SMD/miniSMDC/midSMD

A = miniSMDC014 &
miniSMDC014F

B = SMD030-2018

C = SMD030

D = SMD050-2018

Figure T17

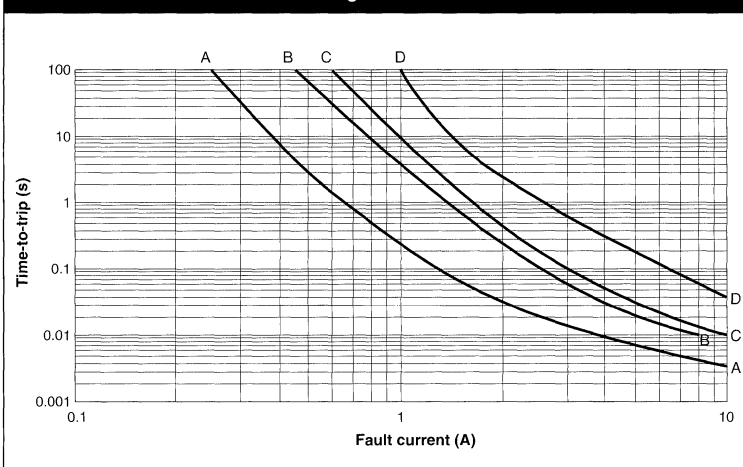


Table T5. Physical Characteristics and Environmental Specifications for Telecommunications and Networking Devices*

(Operating temperature range for all listed products is -40°C to 85°C)

TC250[1]/TGC250[1]/TCF250[1]

Physical Characteristics

Terminal material	Nickel foil or tin/lead plated nickel foil

Environmental Specifications

Test	Conditions
Passive aging	60°C, 1000 hours 85°C, 1000 hours
Humidity aging	85°C, 85% RH, 1000 hours
Thermal shock	125°C, -55°C (10 times)
Solvent resistance	MIL-STD-202, Method 215F

Note: Storage conditions: 40°C max., 70% RH max., devices should remain in original sealed bag prior to use. Devices may not meet specified values if these storage conditions are exceeded.

TR250[1]/TRF250

Physical Characteristics

Lead material	Tin/lead plated copper (except TRF250: tin plated copper)
Insulating material	Cured epoxy polymer
Flammability	per IEC 695-2-2 Needle Flame Test for 20s
Soldering characteristics	ANSI/J-STD-002, Category 3
Solder heat withstand	IEC-STD 68-2-20, Test Tb, Section 5 Method 1A

Note: Devices are not designed to be placed through a reflow process.

Environmental Specifications

Test	Conditions
Passive aging	60°C, 1000 hours 85°C, 1000 hours
Humidity aging	85°C, 85% RH, 1000 hours
Thermal shock	125°C, -55°C (10 times)
Solvent resistance	MIL-STD-202, Method 215F

Note: Storage conditions: 40°C max., 70% RH max., devices should remain in original sealed bag prior to use. Devices may not meet specified values if these storage conditions are exceeded.

TS250[1]/TSV250[1]/TSL250[2]

Physical Characteristics

Terminal material	Tin plated brass
Soldering characteristics	IEA 6008-2-5 Method 7

Environmental Specifications

Test	Conditions
Passive aging	60°C, 1000 hours 85°C, 1000 hours
Humidity aging	85°C, 85% RH, 500 hours
Thermal shock	125°C, -55°C (10 times)
Solvent resistance	MIL-STD-202, Method 215F

Note: Storage conditions: 40°C max., 70% RH max., devices should remain in original sealed bag prior to use. Devices may not meet specified values if these storage conditions are exceeded.

TR600[3]/TRF600

Physical Characteristics

Lead material	Tin/lead plated copper
Insulating material	Cured epoxy polymer
Flammability	per IEC 695-2-2 Needle flame test for 20s
Soldering characteristics	ANSI/J-STD-002, Category 3
Solder heat withstand	IEC-STD 68-2-20, Test Tb, Section 5 Method 1A

Note: Devices are not designed to be placed through a reflow process. Contact your Raychem Circuit Protection representative for TR600 series devices that are compatible with this process.

Table T5. Physical Characteristics and Environmental Specifications for Telecommunications and Networking Devices* *continued*

(Operating temperature range for all listed products is -40°C to 85°C)

Environmental Specifications

Test	Conditions
Passive aging	60°C, 1000 hours 85°C, 1000 hours
Humidity aging	85°C, 85% RH, 1000 hours
Thermal shock	125°C, -55°C (10 times)
Solvent resistance	MIL-STD-202, Method 215F

Note: Storage conditions: 40°C max., 70% RH max., devices should remain in original sealed bag prior to use. Devices may not meet specified values if these storage conditions are exceeded.

TS600[3]

Physical Characteristics

Terminal material	Tin-plated brass
Insulating material	Nylon resin (UL94V-0), 1000V dielectric rating
Flammability	IEC 695-2-2 Needle Flame Test for 20s
Soldering characteristics	ANSI/J-STD-002, Category 3
Solder heat withstand	IEC-STD 68-2-20, Test Tb, Section 5 Method 1A

Environmental Specifications

Test	Conditions
Passive aging	60°C, 1000 hours 85°C, 1000 hours
Humidity aging	85°C, 85% RH, 1000 hours
Thermal shock	125°C, -55°C (10 times)
Solvent resistance	MIL-STD-202, Method 215F

Note: Storage conditions: 40°C max., 70% RH max., devices should remain in original sealed bag prior to use. Devices may not meet specified values if these storage conditions are exceeded.

TSM600

Environmental Specifications

Lead material	Tin-plated brass
Case material	Nylon resin (UL94 V-0), 1000 V dielectric rating
Lead solderability	EIC60068-2-58, Method 7
Solder heat withstand	IEC-STD 68-2-20, Test Tb, Section 5, Method 1A
Solvent resistance	MIL-STD-202, Method 215J
Flammability rating	IEC 695-2-2 Needle Flame Test for 20 s
Storage humidity	Per IPC/JEDEC J-STD-020A Level 2a

Note: Storage conditions: 40°C max., 70% RH max., devices should remain in original sealed bag prior to use. Devices may not meet specified values if these storage conditions are exceeded.

BBR

Physical Characteristics

Lead material	Tin/lead-plated copper, 0.52mm² (20AWG), ø 0.81mm (0.032 in.)
Soldering characteristics	Solderability per ANSI/J-STD-002 Category 3
Solder heat withstand	per IEC-STD 68-2-20, Test Tb, Method 1a, condition b; can withstand 10 seconds at 260°C ± 5°C
Insulating material	Cured, flame-retardant epoxy polymer; meets UL 94V-0

Note: *Devices are not designed to be placed through a reflow process.

Environmental Specifications

Test	Conditions	Resistance Change
Passive aging	70°C, 1000 hours 85°C, 1000 hours	±5% ±5%
Humidity aging	85°C, 85% RH, 1000 hours	±5%
Thermal shock	85°C, -40°C (10 times)	±5%
Solvent resistance	MIL-STD-202, Method 215F	No change

Notes: [1]60/250V products are designed to help equipment pass ITU specifications (K.20, K.21, etc) and Telcordia GR-1089 Intrabuilding power cross.
[2]80/250V product designed to help equipment pass Telcordia GR-1089 Intrabuilding power cross (120V_{AC}/25A).
[3]60/600V products are designed to help equipment pass UL 60950,TIA-968-A (formerly FCC Part 68) and Telcordia GR-1089 specifications.
*For physical and environmental characteristics of RXE, see the radial-leaded product section. For SMD, midSMD, and miniSMDC series, see surface-mount product section.

Table T6. Packaging and Marking Information for Telecommunications and Networking Devices

Part Number	Bag Quantity	Tape & Reel Quantity	Standard Package	Part Marking	Agency Recognition
Chip[1]—60/250 TC250/TCF250					
TCF250-120T	2,500	—	10,000	—	—
TC250-145T	2,500	—	10,000	—	UL
TC250-180[4]	2,500	—	10,000	—	UL
Radial-leaded[1]—60/250V TR250/TRF250					
TR250-080U	500	—	10,000	—	UL, CSA, TÜV
TR250-080U-2	—	1,500	7,500	—	UL, CSA, TÜV
TR250-080T	500	—	10,000	08	UL, CSA, TÜV
TR250-110U	500	—	10,000	—	UL, CSA, TÜV
TR250-110U-2	—	1,500	7,500	—	UL, CSA, TÜV
TR250-120	500	—	10,000	20	UL, CSA, TÜV
TR250-120-2	—	1,500	7,500	20	UL, CSA, TÜV
TR250-120T	500	—	10,000	20	UL, CSA, TÜV
TR250-120T-2	—	1,500	7,500	20	UL, CSA, TÜV
TR250-120U	500	—	10,000	20	UL, CSA, TÜV
TR250-120U-2	—	1,500	7,500	20	UL, CSA, TÜV
TR250-120UT	500	—	10,000	20	UL, CSA, TÜV
TR250-145	500	—	10,000	45	UL, CSA, TÜV
TR250-145-2	—	1,500	7,500	45	UL, CSA, TÜV
TR250-145-RA	500	—	10,000	45	UL, CSA, TÜV
TR250-145U	500	—	10,000	45	UL, CSA, TÜV
TR250-145U-2	—	1,500	7,500	45	UL, CSA, TÜV
TRF250-180[4]	500	—	10,000	80	UL, CSA, TÜV
TRF250-180-2[4]	—	1,500	7,500	80	UL, CSA, TÜV
Surface[2]—80/250V TSL250					
TSL250-080-2	—	1,500	7,500	T08	UL,CSA,TÜV
Surface[1]—60/250V TS250/TSV250					
TS250-130-2	—	1,500	7,500	T13	UL, CSA, TÜV
TSV250-130-2	—	1,200	6,000	T13V	UL, CSA, TÜV
Radial-leaded[3]—60/600V TR600/TRF600					
TRF600-150	500	—	10,000	150	UL, CSA
TRF600-150-2	—	1,500	7,500	150	UL, CSA
TR600-160	500	—	10,000	160	UL, CSA
TR600-160-2	—	600	3,000	160	UL, CSA

Table T6. Packaging and Marking Information for Telecommunications and Networking Devices *continued*

Part Number	Bag Quantity	Tape & Reel Quantity	Standard Package	Part Marking	Agency Recognition
Surface[3]—60/600V TS600/TSM600					
TS600-170-2	—	300	900	T20	UL, CSA
TS600-200-RA-2	—	300	900	T20	UL, CSA
TSM600-250-2	—	200	1,000	TSM600	UL, CSA
TSM600-250-RA-2	—	200	1,000	TSM600	UL, CSA
Radial[4]—90V BBR					
BBR550	500	—	10,000	B550	UL, CSA
BBR550-2	—	1,500	7,500	B550	UL, CSA
BBR750	500	—	10,000	B750	UL, CSA
BBR750-2	—	1,500	7,500	B750	UL, CSA
Radial[4]—60,72V RXE					
RXE010	500	—	10,000	X010	UL, CSA, TÜV
RXE010-2	—	3,000	15,000	X010	UL, CSA, TÜV
RXE017	500	—	10,000	X017	UL, CSA, TÜV
RXE017-2	—	2,500	12,500	X017	UL, CSA, TÜV
RXE020	500	—	10,000	X020	UL, CSA, TÜV
RXE020-2	—	3,000	15,000	X020	UL, CSA, TÜV
RXE025	500	—	10,000	X025	UL, CSA, TÜV
RXE025-2	—	3,000	15,000	X025	UL, CSA, TÜV
RXE030	500	—	10,000	X030	UL, CSA, TÜV
RXE030-2	—	3,000	15,000	X030	UL, CSA, TÜV
Surface[4]—60V SMD, midSMD					
SMD030-2		2,000	10,000	030	UL, CSA, TÜV
SMD030-2018-2		4,000	20,000	A03	UL, CSA, TÜV
SMD050-2018-2		4,000	20,000	A05	UL, CSA
Surface[4]—60V miniSMD					
miniSMDC014-2		2,000	10,000	14	UL, CSA, TÜV
miniSMDC014F-2		2,000	10,000	14	UL, CSA, TÜV

Notes:

[1]60/250V products are designed to help equipment pass ITU specifications (K.20, K.21, etc) and Telcordia GR-1089 Intrabuilding power cross.

[2]80/250V product designed to help equipment pass Telcordia GR-1089 Intrabuilding power cross ($120V_{AC}$/25A).

[3]60/600V products are designed to help equipment pass UL 60950,TIA-968-A (formerly FCC Part 68) and Telcordia GR-1089 specifications.

[4]Product is not currently available in a resistance-matched or resistance sorted option.

Agency Recognition for Telecommunications and Networking Devices*

UL	File # E74889	
CSA	File #78165C	
TÜV	Per IEC60730-1	Certificate # for individual products available upon request.

Note: *For agency recognition information on BBR and RXE series, see radial-leaded product section. For SMD, midSMD and miniSMDC series, see surface-mount product section.

Table T7. Recommended Pad Layouts for Surface-mount Telecommunications and Networking Devices in millimeters (inches) Nominal

Device	A	B	C	D	E	F	G	Figures for Dimensions
TS250 (All)	4.6 (0.18)	1.8 (0.07)	6.1 (0.24)	— —	— —	— —	— —	T18
TSV250-130	2.29 (0.09)	2.41 (0.095)	6.35 (0.25)	3.43 (0.135)	— —	— —	— —	T19
TSL250-080	3.6 (0.14)	1.8 (0.07)	5.5 (0.22)	— —	— —	— —	— —	T18
TS600 (All)	10.42 (0.410)	3.30 (0.130)	3.35 (0.132)	— —	— —	— —	— —	T18
TSM600	5.20 (0.205)	17.80 (0.701)	5.54 (0.218)	6.75 (0.266)	2.08 (0.082)	3.12 (0.123)	8.39 (0.331)	T20
SMD030-2018	4.6 (0.18)	1.5 (0.06)	3.4 (0.13)	— —	— —	— —	— —	T18
SMD030	3.1 (0.12)	2.3 (0.09)	5.1 (0.20)	— —	— —	— —	— —	T18
SMD050-2018	4.6 (0.18)	1.5 (0.06)	3.4 (0.13)	— —	— —	— —	— —	T18
miniSMDC014	3.15 (0.124)	1.78 (0.07)	3.45* (0.136*)	— —	— —	— —	— —	T18
miniSMDC014F	3.15 (0.124)	1.78 (0.07)	3.45* (0.136*)	— —	— —	— —	— —	T18

Note: *Indicates minimum dimension.

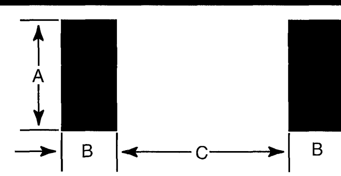


Figure T18

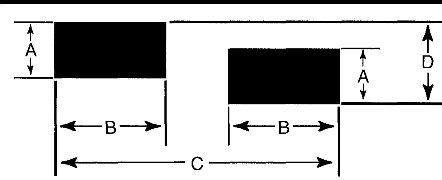


Figure T19

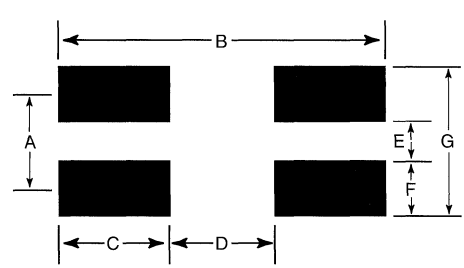


Figure T20

Part Numbering System for Telecommunications and Networking Devices

TR250 -120 T -RA -B-0.5 -2

- -2: (blank) = Bulk; 2 = Tape and reel packaging
- -B-0.5: B-x.x = Resistance matched in bins of x.xΩ (optional)
- -RA: Rx = Resistance range (optional)
- T: Modifier (optional) U - Uncoated chip S - Straight lead T - Fast Trip device
- -120: Hold Current (mA)
- TR250: Product series (TC, TCF, TGC, TRx, TRFx*, TSx, TSMx)

*F = lead free

SMD 030 /30 -2

- -2: 2 = Tape and reel packaging
- /30: Alternative Voltage rating (if applicable)
- 030: Hold Current Indicator
- SMD: Product series

Resistance-sorted and Resistance-matched Devices

Most TC, TCF, TGC, TR and TS devices are available in resistance-sorted and/or resistance-matched versions.

Resistance-sorted Devices
Resistance sorted devices (part number suffix "Rx", where x = 1, 2, A, B, C, F etc.) are supplied with resistance values that are within specified segments of the device's full range of resistance.

Feature
- Narrow resistance range.

Benefits
- Greater flexibility for design engineers.
- Lower resistance devices can allow for increased loop length on line card designs.
- Higher resistance devices may provide greater protection by offering faster time-to-trip.

Resistance-matched Devices
Resistance-matched devices are supplied such that all parts in one particular package (or reel) are within 0.5Ω of each other (1.0Ω for TR250-080T devices). Individual matched packages are supplied from the full resistance range of the specified device.

Feature
- Tighter resistance balance between any two parts in a package.

Benefit
- Resistance-matched devices may reduce the tip-ring resistance differential, reducing the possibility of line imbalance.

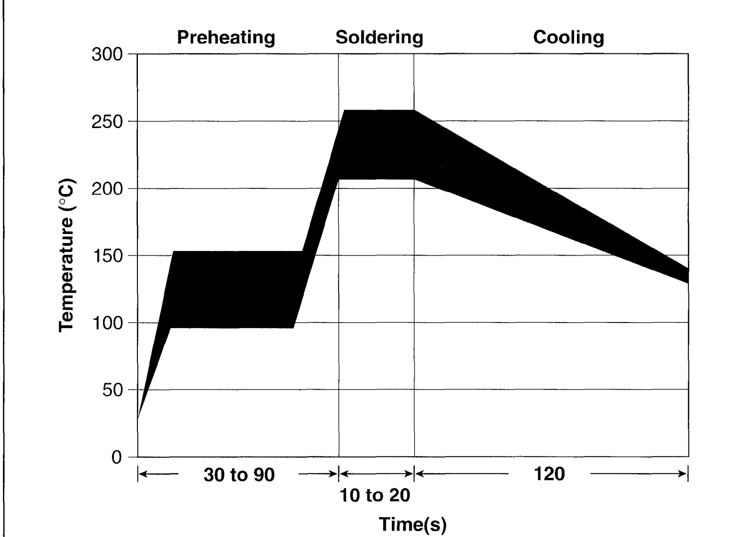
Solder Reflow

- Recommended reflow methods: IR, vapor phase oven, hot air oven.
- Surface-mount devices are not designed to be wave soldered to the bottom side of the board (with the exception of miniSMDC014).
- Recommended maximum paste thickness of 0.25mm (0.010 in).
- Devices can be cleaned using standard industry methods and solvents.

Rework

- If a device is removed from the board, it should be discarded and replaced with a new device.

Figure T21



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⚠ CAUTION:

- If reflow temperatures exceed recommended profile, devices may not meet the performance requirements.
- Leaded devices are not designed to be compatible with reflow manufacturing operations.
- Recommended solder/temperature exposure for leaded devices is designated in the environmental/ physical tables for the product family. Exposure to temperatures or duration at temperature in excess of these values may lead to device not meeting performance requirements.

Table T8. TR250/TR600 Tape and Reel Specifications for Telecommunications and Networking Devices

TR250/TR600 devices are available in tape and reel packaging per EIA 468-B standard. See Figures T20 and T21 for details.

Dimension Description	EIA Mark	IEC Mark	Dimensions (mm)	Tolerance
Carrier tape width	W	W	18	-0.5/+1.0
Hold down tape width	W_4	W_0	5	Minimum
Top distance between tape edges	W_6	W_2	3	Maximum
Sprocket hole position	W_5	W_1	9	-0.5/+0.75
Sprocket hole diameter	D_0	D_0	4	±0.2
Abcissa to plane (straight lead)	H	H	18.5	±3.0
Abcissa to plane (kinked lead)*	H_0	H_0	16	-0.5/+0.6
Abcissa to top	H_1	H_1	32.2	Maximum
Overall width w/lead protrusion	—	C_1	43.2	Maximum
Overall width w/o lead protrusion	—	C_2	42.5	Maximum
Lead protrusion	L_1	l_1	1.0	Maximum
Protrusion of cut-out	L	L	11	Maximum
Protrusion beyond hold down tape	l_2	l_2	Not specified	—
Sprocket hole pitch	P0	P0	12.7	±0.3
Device pitch: TR250	—	—	12.7	—
Device pitch: TR600	—	—	25.4	—
Pitch tolerance	—	—	20 consecutive	±1
Tape thickness	t	t	0.9	Maximum
Tape thickness with splice*	t_1	—	2.0	Maximum
Splice sprocket hole alignment	—	—	0	±0.3
Body lateral deviation	Δh	Δh	0	±1.0
Body tape plane deviation	Δp	Δp	0	±1.3
Lead spacing plane deviation	ΔP_1	P_1	0	±0.7
Lead spacing*	F	F	5.08	±0.6
Reel width	w_2	w	56	Maximum
Reel diameter	a	d	370	Maximum
Space between flanges less device	w_1	—	4.75	±3.25
Arbor hole diameter	c	f	26	±12.0
Core diameter	n	h	80	Maximum
Box	—	—	56/372/372	Maximum
Consecutive missing pieces*	—	—	3 maximum	—
Empty places per reel*	—	—	Not specified	—

Note: *Differs from EIA specification.

Figure T22. EIA Referenced Taped Component Dimensions for TR Devices

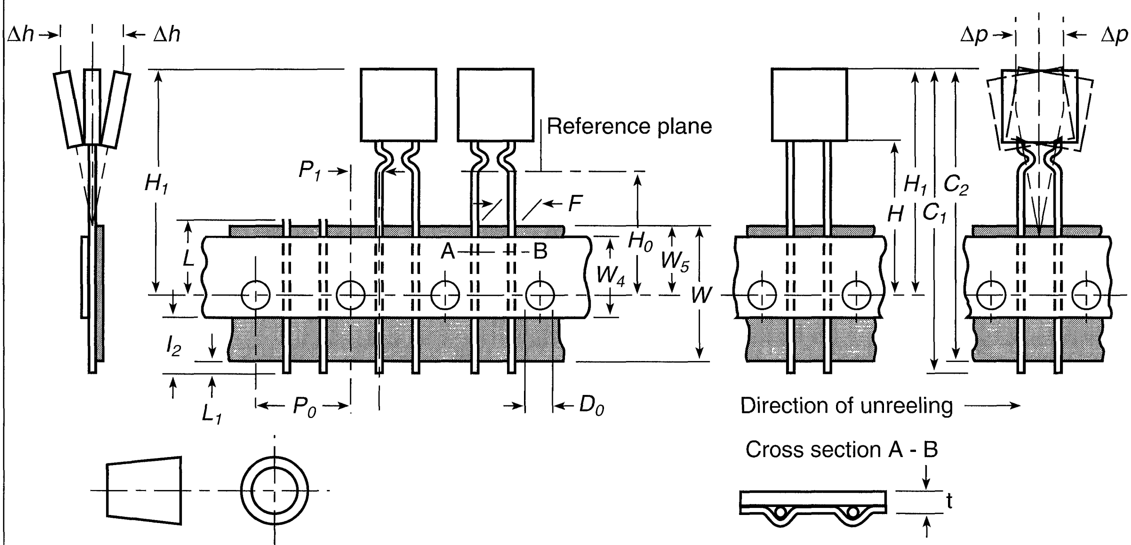

Figure T23. Reel Dimensions for TR Devices

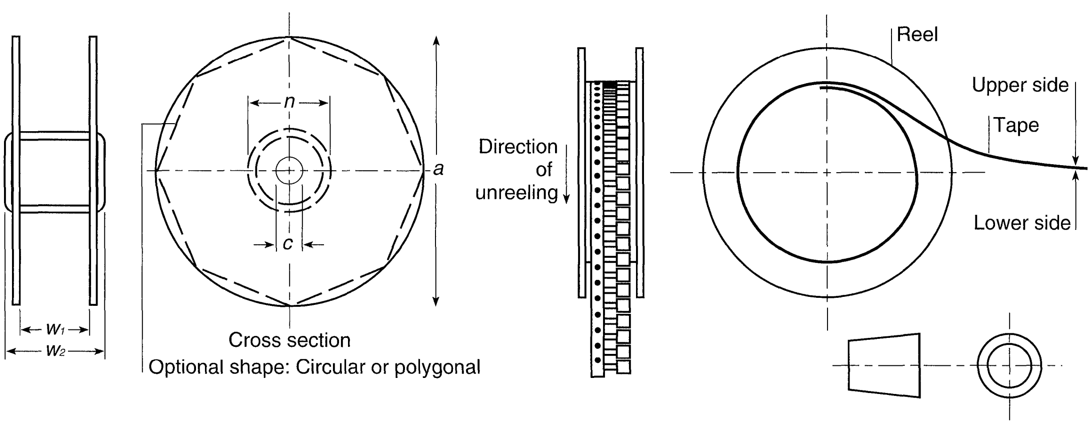

Table T9. TS Tape and Reel Specifications for Telecommunications and Networking Devices

TS devices are packaged per EIA 481 and EIA 481-2 standards. See Figures T22 and T23 for details.

TS250/TSL250/TSV250

Dimension Description	EIA Mark	TS250 Dimension (mm)	TS250 Tolerance (mm)	TSV250 Dimension (mm)	TSV250 Tolerance (mm)	TSL250 Dimension (mm)	TSL250 Tolerance (mm)
Carrier tape width	W	16	±0.3	16	±0.3	16	±0.3
Sprocket hole pitch	P_0	4.0	±0.10	4.0	±0.1	4.0	±0.10
	P_1	12.0	±0.10	8.0	±0.1	8.0	±0.10
	P_2	2.0	±0.10	2.0	±0.1	2.0	±0.10
	A_0	6.9	±0.23	5.5	±0.1	5.5	±0.10
	B_0	9.6	±0.15	6.2	±0.1	7.9	±0.10
	$B_{1\,MAX.}$	12.1	—	8.0	—	9.2	—
Sprocket hole diameter	D_0	1.5	-0/+0.1	1.55	±0.05	1.55	±0.05
	F	7.5	±0.10	7.5	±0.10	7.5	±0.10
	E_1	1.75	±0.10	1.75	±0.10	1.75	±0.10
	$E_{2\,MIN.}$	14.25	—	—	—	—	—
Tape thickness	$T_{MAX.}$	0.4	—	0.45	—	0.35	—
Tape thickness with splice cover tape thickness	$T_{1\,MAX.}$	0.1	—	0.1	—	0.1	—
	K_0	3.4	±0.15	7.00	±0.1	3.70	±0.10
	Leader min.	300	—	390	—	390	—
	Trailer min.	300	—	160	—	160	—
Reel dimensions							
Reel diameter	A max.	340	—	340	—	340	—
Core diameter	N min.	50	—	50	—	50	—
Space between flanges less device	W_1	16.4	-0/+2.0	16.4	-0/+2.0	16.4	-0/+2.0
Reel width	$W_{2\,MAX}$	22.4	—	22.4	—	22.4	—

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Table T9. TS Tape and Reel Specifications for Telecommunications and Networking Devices *continued*

TS600

Dimension Description	EIA Mark	Dimension (mm)	Tolerance (mm)
Carrier tape width	W	32	±0.3
Sprocket hole pitch	P_0	4.0	±0.1
	P_1	16	±0.1
	P_2	2.0	±0.1
	A_0	10	±0.1
	B_0	19.2	±0.1
	B_1 max.	21.6	
Sprocket hole diameter	D_0	1.5	-0/+0.1
	F	14.2	±0.1
	E1	1.75	±0.1
	E_2 min.	28.4	±0.1
Tape thickness	T max.	0.50	±0.5
Tape thickness with splice	T_1 max.	0.1	
	K_0	13.2	±0.1
	Leader min.	390	
	Trailer min.	160	

Reel Dimensions			
Reel diameter	A max.	360	
Core diameter	N min.	50	
Space between flanges less device	W_1	32.4	-0/+2.0
Reel width	W_2 max.	40	

TSM600

Dimension Description	EIA Mark	Dimension (mm)	Tolerance (mm)
Carrier tape width	W	32	±0.3
Sprocket hole pitch	P_0	4.0	±0.1
	P_1	24	±0.1
	P_2	2.0	±0.1
	A_0	11.2	±0.1
	B_0	17.8	±0.1
	B_1 max.	23.45	
Sprocket hole diameter	D_0	1.5	-0/+0.1
	F	14.2	±0.1
	E_1	1.74	±0.1
	E_2 min.	28.4	±0.1
Tape thickness	T max.	0.5	±0.5
Tape thickness with splice	T_1 max.	0.1	
	K_0	11.9	±0.1
	Leader min.	390	
	Trailer min.	160	

Reel Dimensions			
Reel diameter	A max.	360	
Core diameter	N min.	50	
Space between flanges less device	W_1	32.4	-0/+2.0
Reel width	W_2 max.	40	

Note: For tape and reel specifications for BBR and RXE devices, see radial-leaded section, page 247. For SMD, midSMD, miniSMDC see surface-mount section, page 215.

Figure T24. EIA Referenced Taped Component Dimensions for TS Devices

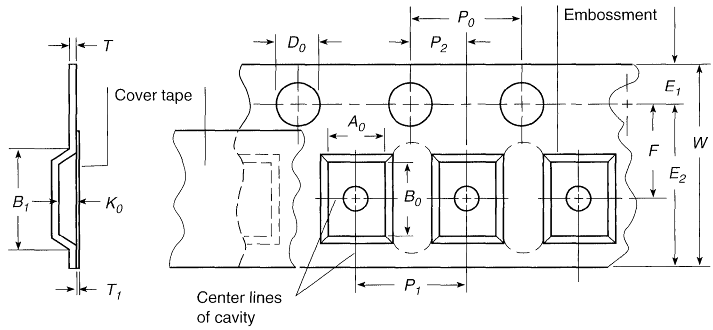
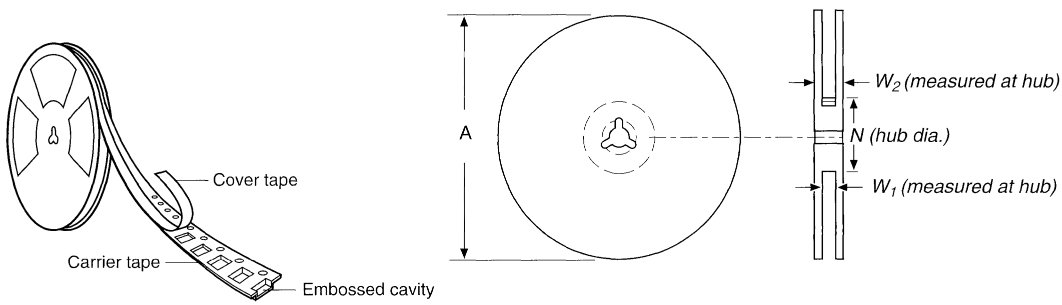


Figure T25. EIA Referenced Reel Dimensions for TS Devices



Latest Information

- Please visit us at www.circuitprotection.com or contact your local representative for the latest information.
- Databook may contain some preliminary information. Raychem Circuit Protection, a division of Tyco Electronics, reserves the right to change any of the specifications without notice. In addition, Tyco Electronics reserves the right to make changes—without notification to Buyer—to materials or processing that do not affect compliance with any applicable specification.

WARNING:

- Operation beyond the maximum ratings or improper use may result in device damage and possible electrical arcing and flame.
- The devices are intended for protection against occasional overcurrent or overtemperature fault conditions and should not be used when repeated fault conditions or prolonged trip events are anticipated.
- Contamination of the PPTC material with certain silicon based oils or some aggressive solvents can adversely impact the performance of the devices.
- Device performance can be impacted negatively if devices are handled in a manner inconsistent with recommended electronic, thermal, and mechanical procedures for electronic components.
- Operation in circuit with a large inductance can generate a circuit voltage ($L\,{}^{di}/_{dt}$) above the rated voltage of the PolySwitch resettable device.

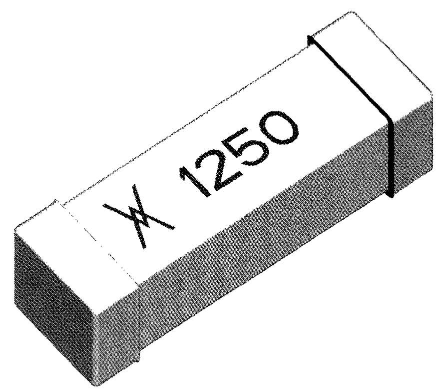
New Surface-mount Telecom Fuse for Overcurrent Protection of Telecommunications Equipment

Non-resettable Fuse Devices

The new FT600 fuse series is designed to assist telecommunications equipment manufacturers in complying with North American overcurrent protection requirements, including Telcordia GR-1089, TIA-968-A (formerly FCC Part 68), and UL60950 3rd edition.

The low profile and small footprint of the FT600 fuse provide a reliable, non-resettable overcurrent protection solution. The device offers low temperature-rise performance under sneak current fault events to prevent damage to circuit traces or multilayer boards. When used in conjunction with SiBar™ thyristor devices, it provides designers with a complete overcurrent/overvoltage protection solution to help them comply with regulatory standards.

This new fuse offering complements the telecom resettable PolySwitch device series for use in applications where intervention is desired after an overcurrent fault.



Benefits:
- High density placement in multiport system designs
- Improved temperature rise performance over other similar SMT fuse devices under sneak-current testing
- In conjunction with a SiBar overvoltage protection device, assists the FT600 designers in meeting regulatory standards with no additional series components

Features:
- Low profile and small footprint
- The lightning robust surface-mount fuse offers overcurrent protection in case of power fault events
- Enables the design of equipment complying with applicable telecom specifications including UL60950, TIA-968-A (formerly FCC Part 68), and Telcordia GR-1089
- Low resistance

Target Applications:
- ADSL, ADSL2, ADSL2plus, SHDSL, VDSL linecards and modems
- T1/E1 systems
- Twisted-pair telecom ports requiring Telcordia GR-1089, UL60950 and FCC Part TIA-968-A (formerly FCC Part 68) compliance

Products in this section are grouped by:

Telecom Standards and Nominal Current

Selection Table for Telecom Surface-mount Fuses

Step 1. Review the Protection Application Guide on page 331 which is based on the agency specification required to qualify the final equipment.

Use the selection guide to narrow your product selection based on key device characteristics.

Step 2. Define your selection criteria and choose the appropriate nominal current device.

Step 3. Independently evaluate and test the device.

Telecom surface-mount fuses assist your telecommunications equipment in meeting agency requirements. To confirm your selection, independently evaluate and test the device to the application requirements.

Protection Application Guide for Telecommunications and Networking Devices

To use this guide, follow the steps below:

1. Select your equipment type from the guide below.
2. Use the Key Device Selection Criteria (time-to-open, surface temperature) to determine best suitability for your application.
3. Use Agency Specification / Selection Guide on the next page to select a specific part number for each application based on the agency requirements.

Application	Specification	Key Device Selection Citeria: Faster Time-To-Open	Key Device Selection Citeria: Cooler Surface Temperature	SiBar Thyristor Surge Protectors[1]
Customer premises equipment, IT equipment Analog modems, V.90 modems, ISDN modems, xDSL modems, ADSL splitters, phone sets, fax machines, answering machines, caller ID, internet appliances, PBX systems, POS terminals, wall plugs	UL 60950 TIA-968-A	FT600-0500 FT600-1250	FT600-2000	TVBxxxSC
Access network equipment Remote terminals, line repeaters, multiplexers, cross-connects, WAN equipment	Telcordia GR-1089 TIA-968-A	FT600-1250	FT600-2000	TVBxxxSC
Central office switching equipment Analog/POTS linecards, ISDN linecards, xDSL modems, ADSL/VDSL splitters, T1/E1 linecards, multiplexers, CSU/DSU, servers	Telcordia GR-1089 TIA-968-A	FT600-1250	FT600-2000	TVBxxxSC

Notes: This list is not exhaustive. Raychem Circuit Protection welcomes our customers' input for additional application ideas for overcurrent protection of Telecom applications.
[1]For more information on Raychem Circuit Protection SiBar thyristor surge protectors, refer to the SiBar product section on page 339.

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Agency Specification/Selection Guide for FT600 Devices

Use the guide below to select FT600 devices appropriate for use in your application. The following pages contain specifications for part numbers recommended below. FT600 devices enable telecommunication equipment in meeting the applicable protection requirements of these industry specifications. Refer to individual agency specifications for test procedures and circuit schematics. Users should independently evaluate the suitability of, and test each product for their application.

Family	Product	Lightning	Power Cross
FT600	**FT600-050**	TIA-968-A (formerly FCC Part 68) - Type A & B	UL60950, 3rd Ed. – 600VAC, 40A
	FT600-1250 **FT600-2000**	Telcordia GR-1089 – Level 1 and 2 TIA-968-A	Telcordia GR-1089 – 600 VAC, 40A UL60950

Notes:

Note: FT600-1250 and FT600-2000 are designed to assist equipment in complying with Telcordia GR-1089 specifications. In-circuit testing is strongly recommended.

The FT600-0500, FT600-1250 and FT600-2000 are designed to meet the UL60950 Power Cross and FCC TIA-968-A 68 lightning surge requirements. Note that Type A tests allow for an overcurrent protection component to fuse open during the surge.

Interrupt Voltage and Current Ratings

Part Number	Ampere Rating (A)	Voltage Rating (V)	Typical Resistance (Ω)	Typical I2t (A^2s)*
FT600-0500	0.50	250	0.5	1
FT600-1250	1.25	250	0.1	16
FT600-2000	2.00	250	0.05	18

The FT600-xxxx devices are designed to carry 100% of rated current for 4 hours minimum and 250% of rated current for 1 second minimum, 120 seconds maximum. Resistance measured at 10% of rated current.

*I^2t is calculated at 10 ms or less.

Figure 1. Thermal Derating

Figure 1. Thermal Derating Curve (Normalized)

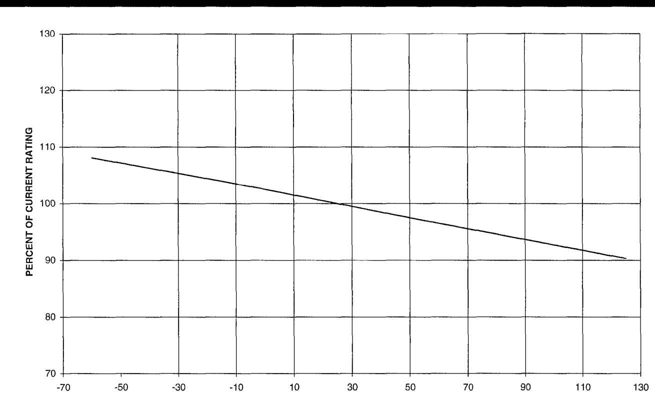


Figure 2. Physical Description for Dimensions for Telecommunications and Networking Devices

Figure F2. Product Dimensions

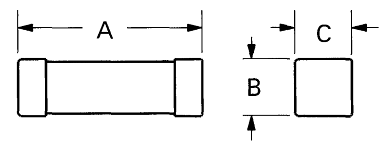


Table 1. Dimensions for FT600 Devices in Millimeters (Inches)

	Dimension						
	A		B		C		
Part Number	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Figure**
FT600							
FT600-050		10.5 (0.413)		3.4 (0.133)		3.4 (0.133)	F2
FT600-1250		10.5 (0.413)		3.4 (0.133)		3.4 (0.133)	F2
FT600-2000		10.5 (0.413)		3.4 (0.133)		3.4 (0.133)	F2

Figures 3. Typical Time-to-open Characteristics (at 20°C) for FT600 Devices

FT600

A = FT600-0500

B = FT600-1250

C = FT600-2000

Figure F3

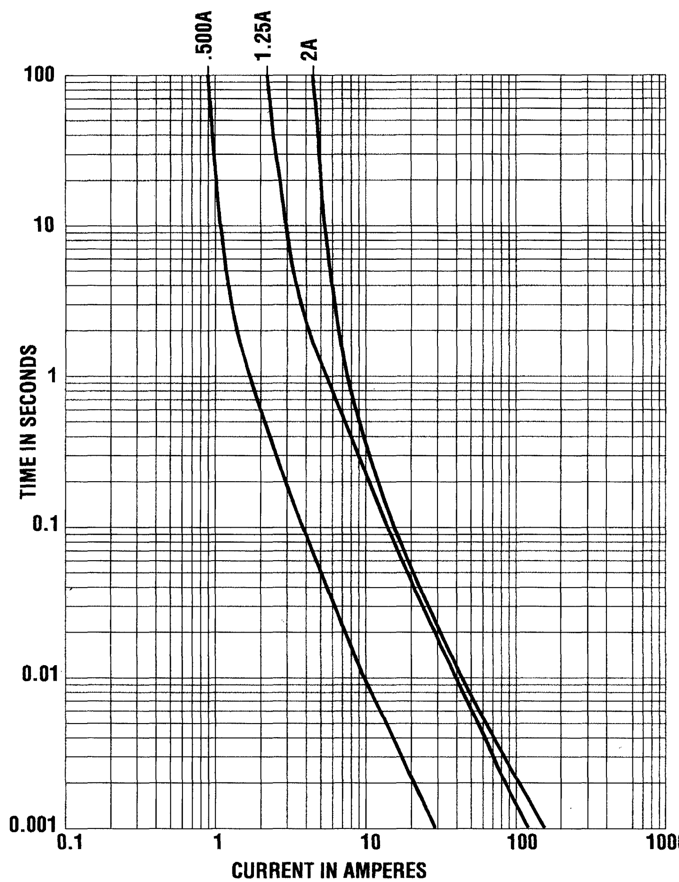


Table 2. Physical Characteristics and Environmental Specifications for FT600 Devices*

FT600
Physical Characteristics

Terminal material	Silver-plated brass*
Body material	Ceramic
Termination solderability	Per IEC-60127-4

*FT600 devices use high Pb content solder for internal construction. They are RoHs compliant.

Environmental Specifications

Test	Conditions
Solder heat withstand	Per MIL-STD-202, Method 210, Test Condition J
Solvent resistance	Per MIL-STD-202F, Method 215J
Storage temperature	-40/+85°C
Storage humidity	Per MIL-STD-202F, Method 106F

Table 3. Packaging and Marking Information for FT600 Devices

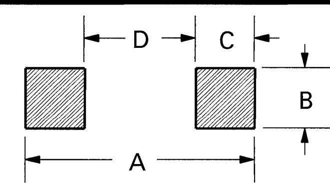
Part Number	Bag Quantity	Tape & Reel Quantity	Standard Package	Part Marking	Agency Recognition
Chip—60/250 TC250/TCF250					
FT600-0500-2	—	2,500	10,000	500	UL, CSA
FT600-1250-2	—	2,500	10,000	1250	UL, CSA
FT600-2000-2	—	2,500	10,000	2000	UL, CSA

Notes: The -2 designates tape and reel, the package style for this product.

Table 4. Recommended Pad Layouts for FT600 Devices in millimeters (inches) Nominal

Device	A	B	C	D	Figures for Dimensions
FT600-050	12.6 (0.496)	4.0 (0.157)	3.7 (0.145)	5.2 0.204	4
FT600-1250	12.6 (0.496)	4.0 (0.157)	3.7 (0.145)	5.2 0.204	4
FT600-2000	12.6 (0.496)	4.0 (0.157)	3.7 (0.145)	5.2 0.204	4

Figure 4



Solder Reflow and Rework Recommendations for FT600 Devices

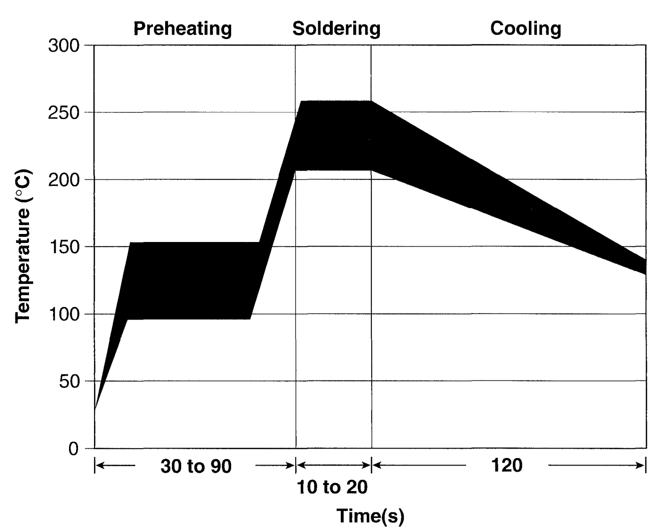
Solder Reflow:

- Recommended reflow methods: IR, vapor phase oven, hot air oven
- Devices can be cleaned using standard industry methods and solvents

Rework:

- If a device is removed from the board, it should be discarded and replaced by a new device

Figure 5



⚠ CAUTION:

- If reflow temperatures exceed recommended profile, devices may not meet the performance requirements.

Table 5. Tape and Reel Specifications for FT600 Devices

Dimension Description	EIA Mark	Dimension (mm)	Tolerance
Carrier tape width	W	24	±0.3
Sprocket hole pitch	P0	4	±0.1
	P_1	8	±0.1
	P_2	2	±0.1
	A0	3.3	±0.1
	B0	10.44	±0.1
	B_1 max.	11.24	
Sprocket hole diameter	D0	1.5	±0.1 – 0.0
	F	11.5	±0.1
	E_1	1.75	±0.1
	E_2 min.	22.25	
Tape thickness	T max.	0.35	
Tape thickness with splice	T_1 max.	0.1	
	K0	3.25	±1.0
	Leader min.	400	
	Trailer min.	160	
Reel Dimensions			
Reel diameter	A max.	330	
Core diameter	N min.	95	
Space between flanges less devices	W_1	24.4	±2.0 – 0.0
Reel width	W_2 max.	30.4	

Figure 6. EIA Referenced Taped Component Dimensions for FT Devices

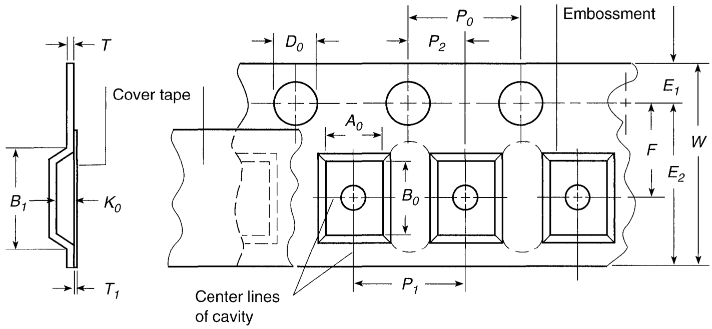
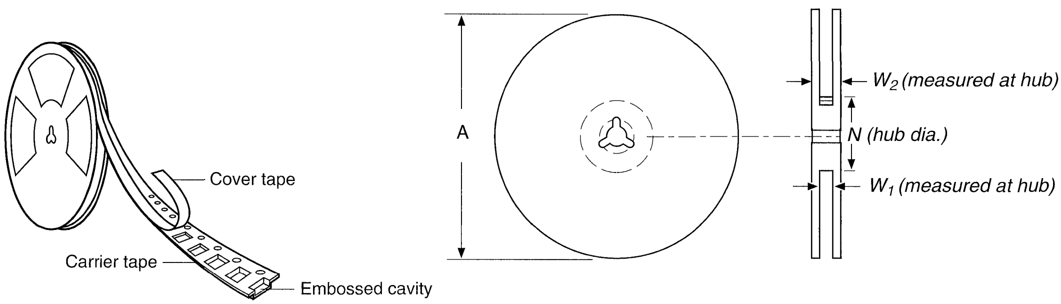


Figure 7. EIA Referenced Reel Dimensions for FT Devices



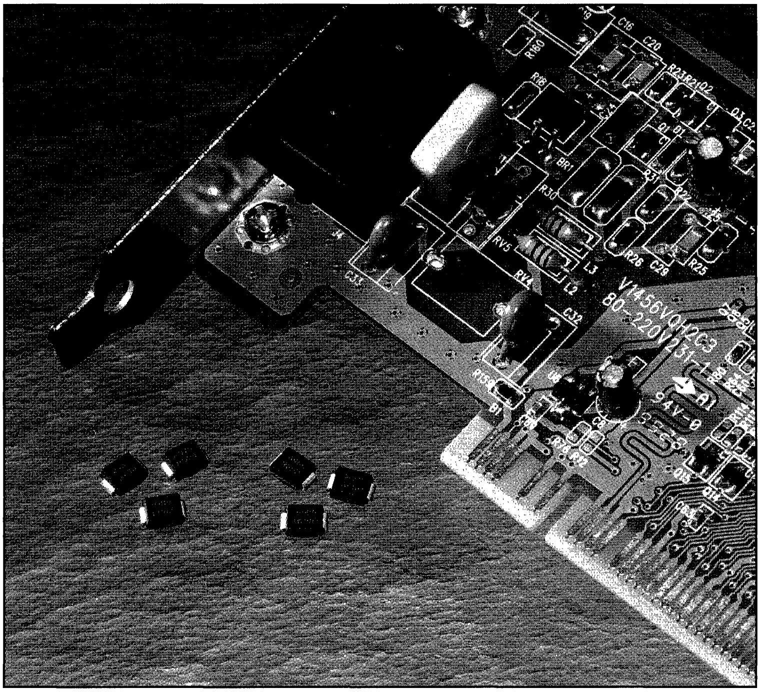
Latest Information

- Please visit us at www.circuitprotection.com or contact your local representative for the latest information.
- Databook may contain some preliminary information. Raychem Circuit Protection, a division of Tyco Electronics, reserves the right to change any of the specifications without notice. In addition, Tyco Electronics reserves the right to make changes—without notification to Buyer—to materials or processing that do not affect compliance with any applicable specification.

SiBar Thyristor Surge Protectors

Raychem Circuit Protection's SiBar thyristor surge protectors are designed to help protect sensitive telecommunication equipment from the hazards caused by lightning, power contact, and power induction. These devices have a high electrical surge capability to help protect against transient faults and a high off-state impedance, rendering them virtually transparent during normal system operation.

SiBar thyristor surge protectors are designed to assist telecommunication and computer telephony equipment meet the applicable requirements and industry specifications.



Benefits:

- Helps provide protection for sensitive telecom electronic equipment
- Low leakage current
- Low power dissipation
- Fast, reliable operation
- No wear-out mechanisms
- Helps designers meet world-wide telecom standards
- Helps reduce warranty and service costs
- Easy installation
- Helps improve power efficiency of equipment

Features:

- Bidirectional transient voltage protection
- High off-state impedance
- Low on-state voltage
- High surge capability
- Short-circuit failure mode
- Surface-mount technology
- Lead-free leads available on all parts

Applications:

- Modems
- Fax machines
- PBX systems
- Phones
- POS systems
- Analog and digital linecards
- Other customer premise and network equipment requiring protection

Devices in this section are grouped by:

Surge Capability, Maximum Off-State Voltage, Package Size

Step 1. Determine the circuit's operating parameters.

Fill in the following information about the circuit:

Maximum ambient operating temperature ____________________

Maximum DC supply voltage (V_{DC} Max.) ____________________

Maximum ringing (AC) voltage (V_{AC} Max.) ____________________

System voltage damage threshold ____________________

Maximum fault current and duration ____________________

Maximum system operating current ____________________

Applicable industry requirements ____________________

Step 2. Calculate the maximum operating voltage of your system.

Maximum operating voltage = V_{DC} Max. + (1.414 x V_{AC} Max.)

Refer to Table V1 to select a SiBar thyristor device with a maximum off-state voltage (V_{DM}) rating that is close to, but greater than, the maximum operating voltage of your system.

4

Step 3. Verify that the system voltage damage threshold is greater than the rated maximum breakover voltage (V_{BO}).

Refer to Table V1 to confirm that the maximum breakover voltage of the device you selected in Step 2 is less than the system voltage damage threshold.

Selection Guide for SiBar Thyristor Surge Protectors continued

Step 4. Verify that the maximum fault current of the system and its duration or the fault current defined in the industry specification(s) are less than the surge current rating of the device selected. For help in determining which industry specifications may apply, refer to the Protection Application Guide on the next page.

Refer to Table V2 for SiBar thyristor surge current ratings applicable to TIA 968-A (FCC Part 68), Telcordia GR-1089, ITU K.20, K.21, K.45 industry specifications.

Step 5. Verify that the maximum system operating current is less than the minimum hold current rating (I_H) in Table V1 for the device selected.

Using Figure V4, verify that I_H is greater than the maximum system operating current over the entire ambient operating temperature range. (As with I_H, V_{DM} and V_{BO} also vary with ambient temperature, to a lesser degree. Figures V2 and V3 can be used to determine that the device selected continues to meet your requirements over the ambient operating temperature range.)

4

Step 6. Verify that the dimensions in Table V4 for the SiBar thyristor device are compatible witht the application's space requirements.

Protection Application Guide for SiBar Thyristor Surge Protectors

To use this guide, follow the steps below:

1. Select your equipment type from the guide below.
2. Select the type of protection depending on the agency and regional specifications in the second column.

Application	Region/ Specification	SiBar Thyristor Surge Protectors[1]	PolySwitch Resettable Devices Key Device Selection Citeria Small Footprint	 Low Resistance	 Fast Time-to-Trip
Customer premises equipment, IT equipment Analog modems, V.90 modems, ISDN modems, xDSL modems, ADSL splitters, phone sets, fax machines, answering machines, caller ID, internet appliances, PBX systems, POS terminals, wall plugs	**North America** TIA-968-A (FCC Part 68), UL 1950, UL 1459	TVBxxxSA(-L) or TVAxxxSA(-L) with TR/TS; TVBxxxSC(-L) with TS/TR or fuse	TR600-150 TS600-170	TR600-150-RA TS600-200-RA	TR600-150-RB TS600-170
	Europe/Asia/ South America ITU K.21	TVBxxxSA(-L) TVAxxxSA(-L)	TR250-120 TR250-145 TS250-130 TSV250-130	TR250-180U TS250-130-RA TSV250-130	TR250-120T-R2 TS250-130-RB
Access network equipment (*) Remote terminals, line repeaters, multiplexers, cross-connects, WAN equipment	**North America** Telcordia GR-1089	TVBxxxSC(-L)	TR600-150-RA TS600-200-RA	TR600-160-RA TS600-200-RA	TR600-150-RB TS600-170
	Europe/Asia/ South America ITU K.45	TVBxxxSA(-L) TVAxxxSA(-L)	TR250-120 TR250-145 TS250-130 TSV250-130	TR250-180U TS250-130-RA TSV250-130	TR250-120T-R2 TS250-130-RB
Central office switching equipment (*) Analog/POTS linecards, ISDN linecards, xDSL modems, ADSL/VDSL splitters, T1/E1 linecards, multiplexers, CSU/DSU, servers	**North America** Telcordia GR-1089	TVBxxxSC(-L)	TR600-150-RA TS600-200-RA	TR600-160-RA TS600-200-RA	TR600-150-RB TS600-170
	Europe/Asia/ South America ITU K.20	TVBxxxSA(-L) TVAxxxSA(-L)	TR250-120 TR250-145 TS250-130 TSV250-130	TR250-180U TS250-130-RA TSV250-130	TR250-120T-R2 TS250-130-RB
Primary protection modules (*) MDF modules, Network Interface Devices (NID)	**North America** Telcordia GR-974	N/A	TR250-180U	TR250-180U	TR250-180U
	Europe/Asia/ South America ITU K.20	N/A	TGC250-120T TR250-120T TS250-130 TSV250-130	TC250-145T TR250-145-RA TS250-130-RA TSV250-130	TGC250-120T TR250-120T-R2 TS250-130-RB
Short-haul/intrabuilding communications equipment (*) LAN equipment, VoIP cards, cable telephony NIU's, wireless local loop handsets	**North America** Telcordia GR-1089 intrabuilding	TVBxxxSA(-L) TVAxxxSA(-L)	TSL250-080 TR250-120 TS250-130 TSV250-130	TR250-145 TR250-180U TS250-130-RA	TSV250-130 TR250-120T-R2 TSL250-080
	Europe/Asia/ South America ITU K.21	TVBxxxSA(-L) TVAxxxSA(-L)	TR250-120 TR250-145 TS250-130 TSV250-130	TR250-180U TS250-130-RA TSV250-130	TR250-120T-R2 TS250-130-RB
LAN intrabuilding power cross protection LAN equipment, VoIP cards, IP phones		TVBxxxSA(-L) TVAxxxSA(-L)	TSL250-080	TSL250-080	TSL250-080 TVAxxxSA
IEEE 802.3 Power over LAN protection Powered ethernet switches and terminals, IP phones, wireless LAN base stations, microcellular base stations, VoIP cards		N/A	miniSMDC014 SMD030	SMD030-2018	SMD030-2018
Cable telephony powering systems Power passing taps		N/A	BBR550	BBR750	BBR550

Notes: This list is not exhaustive. Raychem Circuit Protection welcomes our customers' input for additional application ideas.

[1]For more information on Raychem Circuit Protection PolySwitch resettable devices, refer to telecommunication and networking devices on page 301.

*For improved line balance in these applications, resistance-matched parts are recommended. See Telecom and Networking section, page 301 for details.

(-L) Lead-free leaded devices are also applicable for these applications.

Table V1. Product Electrical Characteristics for SiBar Thyristor Surge Protectors

	Part Number	V_{DM} Max. (V)	V_{BO} Max. (V)	I_H Min. (mA)	V_T Max. (V)	C_1 Typ. (pF)
	TVA270SA-L	270	365	150	3.0	22
NEW	TVB058SA-L	58	78	150	4.0	43
	TVB170SA	170	265	150	4.0	20
	TVB170SA-L	170	265	150	4.0	20
	TVB200SA	200	320	150	4.0	20
	TVB200SA-L	200	320	150	4.0	20
	TVB270SA	270	365	150	4.0	20
	TVB270SA-L	270	365	150	4.0	20
NEW	TVB300SA-L	300	400	150	4.0	20
NEW	TVB200SB-L	200	320	150	4.0	25
NEW	TVB270SB-L	270	365	150	4.0	25
NEW	TVB300SB-L	300	400	150	4.0	25
	TVB170SC	170	265	150	4.0	50
	TVB170SC-L	170	265	150	4.0	50
	TVB200SC	200	320	150	4.0	50
	TVB200SC-L	200	320	150	4.0	50
	TVB270SC	270	365	150	4.0	50
	TVB270SC-L	270	365	150	4.0	50
NEW	TVB300SC-L	300	400	150	4.0	50

Notes: All electrical characteristics are measured at 25°C.
V_{DM} measured per UL497B pulse requirements: at max. off-state leakage current (I_{DM}) = 5 µA.
V_{BO} Measured at 100V/µs.
C_1 measured at 1 MHz with a 50 V_{DC} bias.
(-L) Lead-free leaded devices

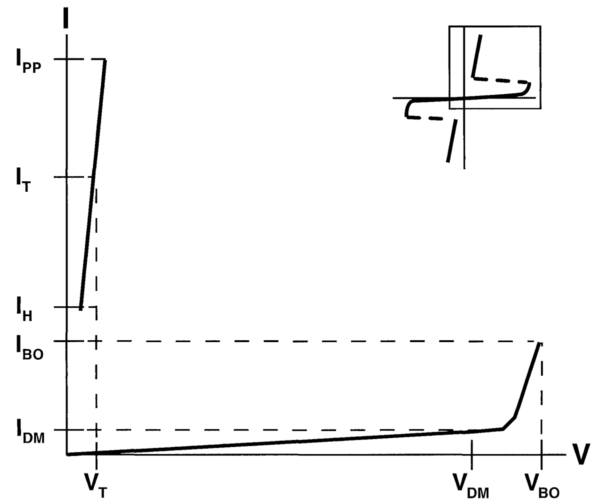
Table V2. Surge Current Rating for SiBar Thyristor Surge Protectors

	Part Description	Telcordia GR-1089* I_{pp}(A) 10 x 1000 µs	I_{pp}(A) 2 x 10 µs	8 x 20 µs	I_{TSM} Min. (A)	di/dt (A/µs)	dV/dt (V/µs)
	TVA270SA-L	50	150	150	22	500	2000
NEW	TVB058SA-L	50	150	150	22	500	2000
	TVB170SA-L	50	150	150	22	500	2000
	TVB170SA-L	50	150	150	22	500	2000
	TVB200SA	50	150	150	22	500	2000
	TVB200SA-L	50	150	150	22	500	2000
	TVB270SA	50	150	150	22	500	2000
	TVB270SA-L	50	150	150	22	500	2000
NEW	TVB300SA-L	50	150	150	22	500	2000
NEW	TVB200SB-L	80	250	250	30	500	2000
NEW	TVB270SB-L	80	250	250	30	500	2000
NEW	TVB300SB-L	80	250	250	30	500	2000
	TVB170SC	100	500	400	60	500	2000
	TVB170SC-L	100	500	400	60	500	2000
	TVB200SC	100	500	400	60	500	2000
	TVB200SC-L	100	500	400	60	500	2000
	TVB270SC	100	500	400	60	500	2000
	TVB270SC-L	100	500	400	60	500	2000
NEW	TVB300SC-L	100	500	400	60	500	2000

Notes: *Lightning current wave forms for applicable industry specification.
I_{TSM}, peak on-state surge current is measured at 60 Hz, one cycle.
di/dt: critical rate-of-rise of on-state current (max. 2 x 10 µs wave form, I_{SC} = 120A).
dV/dt: critical rate-of-rise of off-stage voltage (linear wave form, V_D = rated V_{BO}, Tj = 25°C).

4

Figure V1. Voltage-Current Characteristics



Note: The voltage current (V-I) is useful in depicting the electrical characteristics of the SiBar thyristor surge protectors in relation to each other.

4

Table V3. Parameter Definitions for SiBar Thyristor Surge Protectors

Symbol	Parameter	Definition
V_{BO}	Breakover voltage	Maximum voltage across the device at breakdown measured under a specified voltage and current rate of rise.
I_{BO}	Breakover current	Instantaneous current flowing at the breakover voltage (V_{BO}).
I_H	Hold current	Minimum current required to maintain the device in the on-state.
I_T	On-state current	Current through the device in the on-state condition.
V_T	On-state voltage	Voltage across the device in the on-state condition at a specified current (I_T).
V_{DM}	Maximum off-state voltage	Maximum DC voltage that can be applied to the device while maintaining it in the off-state condition.
I_{DM}	Off-state current	Maximum DC value of current that results from the application of the maximum off-state voltage.
I_{pp}	Peak pulse current	Rated peak pulse current of specified amplitude and waveshape that may be applied without damage.
di/dt, dv/dt	Critical rate of rise of on-state current and voltage	Maximum current and voltage rate of rise the device can withstand without damage.

Figures V2–V5. Typical Electrical Characteristics vs. Temperature

Figure V2. Off-state Voltage vs. Temperature

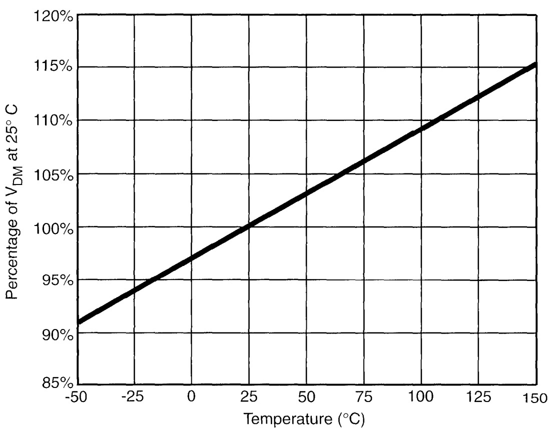


Figure V3. Breakover Voltage vs. Temperature

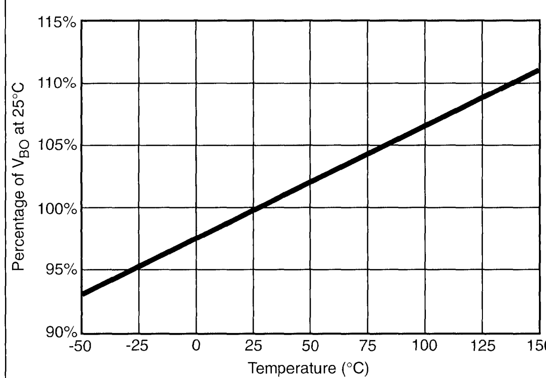


Figure V4. Hold Current vs. Temperature

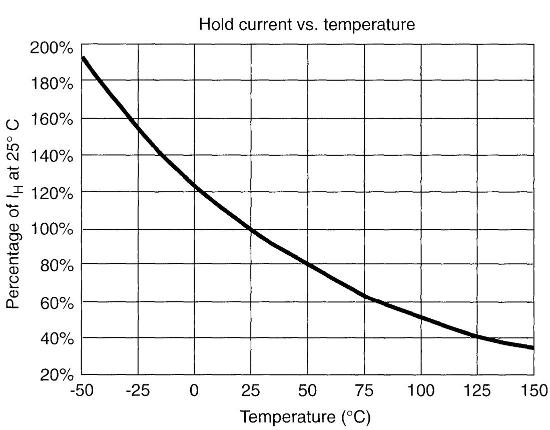
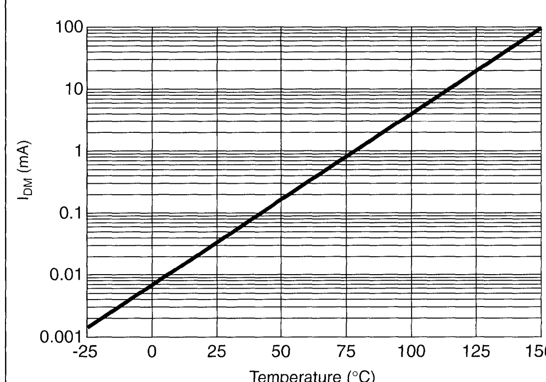


Figure V5. Off-state Current vs. Temperature



Physical Description for Dimensions for SiBar Thyristor Surge Protectors

Figure V6. Physical Description for Dimensions

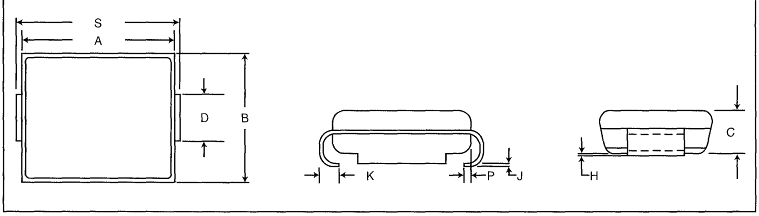


Table V4. Product Dimensions for SiBar Thyristor Surge Protectors in Millimeters (Inches)

Dimension	A Min.	A Max.	B Min.	B Max.	C Min.	C Max.	D* Min.	D* Max.	H Min.	H Max.	J Min.	J Max.	K Min.	K Max.	P Ref.	S Min.	S Max.
TVBxxxSA, TVBxxxSA-L, TVBxxxSB, TVBxxxSB-L, TVBxxxSC, TVBxxxSC-L	4.06 (0.160)	4.57 (0.180)	3.30 (0.130)	3.94 (0.155)	1.90 (0.075)	2.44 (0.096)	1.95 (0.077)	2.20 (0.086)	0.05 (0.002)	0.20 (0.008)	0.15 (0.006)	0.31 (0.012)	0.76 (0.030)	1.52 (0.060)	0.51 (0.020)	5.21 (0.205)	5.59 (0.220)
TVAxxxSA	4.06 (0.160)	4.57 (0.180)	2.29 (0.090)	2.92 (0.115)	1.91 (0.075)	2.41 (0.095)	1.27 (0.050)	1.63 (0.064)	0.010 (0.004)	0.152 (0.006)	0.15 (0.006)	0.41 (0.016)	0.76 (0.030)	1.52 (0.060)	— —	4.83 (0.190)	5.59 (0.220)

Notes: *D dimension is measured within dimension P.
TVA series devices use industry standard SMA package type.
TVB series devices use industry standard SMB package type.

All devices are bidirectional and may be oriented in either direction for installation.

Table V5. Physical Characteristics and Environmental Specifications for SiBar Thyristor Surge Protectors

Lead material	Tin/lead finish or matte tin finish(-L devices)
Encapsulating material	Epoxy, meets UL94V-0 requirements
Solderability	per MIL-STD-750, Method 2026
Solder heat withstand	per MIL-STD-750, Method 2031
Solvent resistance	per MIL-STD-750, Method 1022
Mechanical shock	per MIL-STD-750, Method 2016
Vibration	per MIL-STD-750, Method 2056
Storage temperature (°C)	−55 to 150
Operating temperature (°C)	−40 to 125
Junction temperature (°C)	175

Table V6. Reliability Tests for SiBar Thyristor Surge Protectors

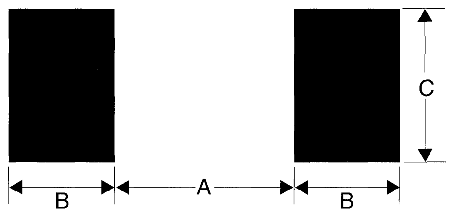
Test	Conditions	Duration
High temperature, reverse bias	+100˚C, 50 V_{DC} bias	1000 hours
High humidity, high temperature, reverse bias	85% RH, +85˚C, 50 V_{DC} bias	1000 hours
High temperature storage life	+150˚C	1000 hours
Temperature cycling	-65˚C to +150˚C, 15 minute dwell	1000 cycles
Autoclave	100% RH, +121˚C, 15 PSI	96 hours

Table V7. Packaging and Marking Information for SiBar Thyristor Surge Protectors

					Recommended Pad Layout (mil/inch)			
	Part Description	Tape and Reel Quantity	Standard Package	Part Marking	Dimension A (Nom.)	Dimension B (Nom.)	Dimension C (Nom.)	Agency Recognition
	TVA270SA-L	5,000	20,000	REAB	2.0 (0.079)	2.0 (0.079)	2.0 (0.079)	UL
NEW	TVB058SA-L	2,500	10,000	058SA	2.261 (0.089)	2.159 (0.085)	2.743 (0.108)	UL
	TVB170SA	2,500	10,000	RCBB	2.261 (0.089)	2.159 (0.085)	2.743 (0.108)	UL
	TVB170SA-L	2,500	10,000	170A	2.261 (0.089)	2.159 (0.085)	2.743 (0.108)	UL
	TVB200SA	2,500	10,000	RDBB	2.261 (0.089)	2.159 (0.085)	2.743 (0.108)	UL
	TVB200SA-L	2,500	10,000	200A	2.261 (0.089)	2.159 (0.085)	2.743 (0.108)	UL
	TVB270SA	2,500	10,000	REBB	2.261 (0.089)	2.159 (0.085)	2.743 (0.108)	UL
	TVB270SA-L	2,500	10,000	270A	2.261 (0.089)	2.159 (0.085)	2.743 (0.108)	UL
NEW	TVB300SA-L	2,500	10,000	300A	2.261 (0.089)	2.159 (0.085)	2.743 (0.108)	UL
NEW	TVB200SB-L	2,500	10,000	200B	2.0 (0.079)	2.0 (0.079)	2.0 (0.079)	UL
NEW	TVB270SB-L	2,500	10,000	270B	2.0 (0.079)	2.0 (0.079)	2.0 (0.079)	UL
NEW	TVB300SB-L	2,500	10,000	300B	2.0 (0.079)	2.0 (0.079)	2.0 (0.079)	UL
	TVB170SC	2,500	10,000	RCBD	2.261 (0.089)	2.159 (0.085)	2.743 (0.108)	UL
	TVB170SC-L	2,500	10,000	170C	2.261 (0.089)	2.159 (0.085)	2.743 (0.108)	UL
	TVB200SC	2,500	10,000	RDBD	2.261 (0.089)	2.159 (0.085)	2.743 (0.108)	UL
	TVB200SC-L	2,500	10,000	200C	2.261 (0.089)	2.159 (0.085)	2.743 (0.108)	UL
	TVB270SC	2,500	10,000	REBD	2.261 (0.089)	2.159 (0.085)	2.743 (0.108)	UL
	TVB270SC-L	2,500	10,000	270C	2.261 (0.089)	2.159 (0.085)	2.743 (0.108)	UL
NEW	TVB300SC-L	2,500	10,000	300C	2.261 (0.089)	2.159 (0.085)	2.743 (0.108)	UL

Recommended Pad Layout for SiBar Thyristor Surge Protectors

Figure V7. Recommended Pad Layout



Agency Recognition for SiBar Thyristor Surge Protectors

UL	File # E179610

Part Numbering System for SiBar Thyristor Surge Protectors

TV B 270 S A -L

- -L: Lead-free leads (matte tin finish)
- A: Surge current rating
  A, B, C, refer to Table V2
- 270: V_{DM} (max. off-state voltage indicator)
- B: Package type:
  A: SMA package
  B: SMB package
- TV: Product Family

Solder Reflow and Rework Recommendations for SiBar Thyristor Surge Protectors

SiBar thyristor devices are compatible with standard reflow and wave soldering techniques.

Solder Reflow

- Recommended reflow methods: IR, vapor phase oven, hot air oven.
- Always preheat the device to prevent excessive thermal shock and stress.
- Recommended maximum paste thickness of 0.25mm (0.010 in.).
- Devices may be cleaned using standard industry methods and solvents.

Solder Rework

- Use standard industry practices for the SiBar Thyristor Surge Protectors.

Figure V8

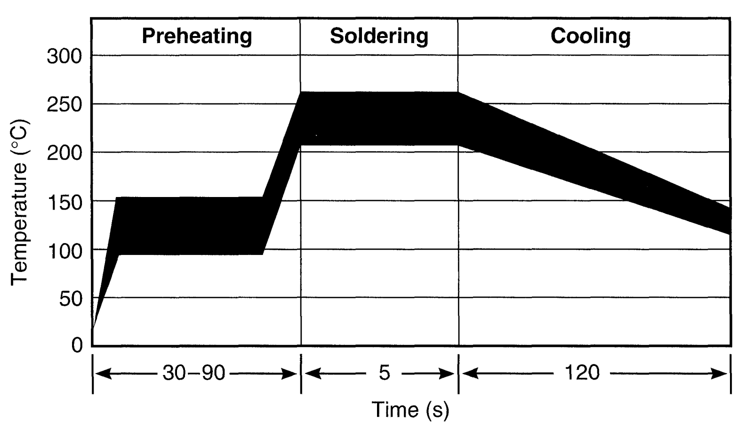
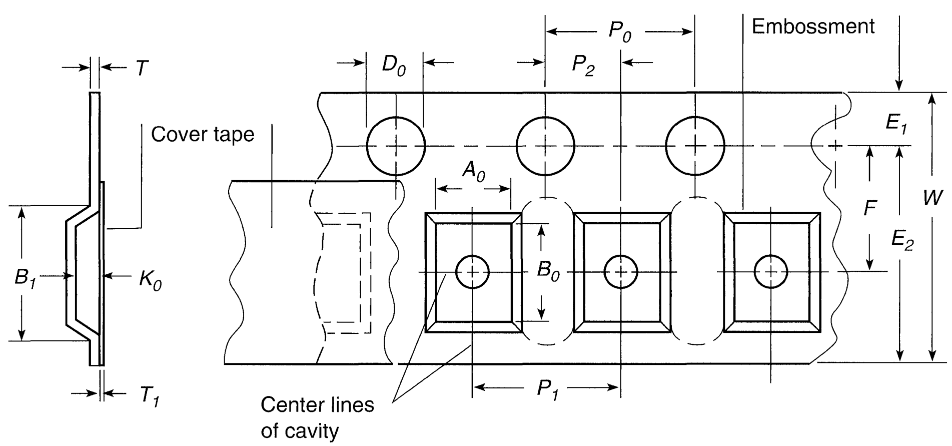


Table V8. Tape and Reel Specifications for SiBar Thyristor Surge Protectors

SiBar thyristor devices are supplied on tape and reel per EIA481-1 standard. (See Figures V9 and V10 for details.)

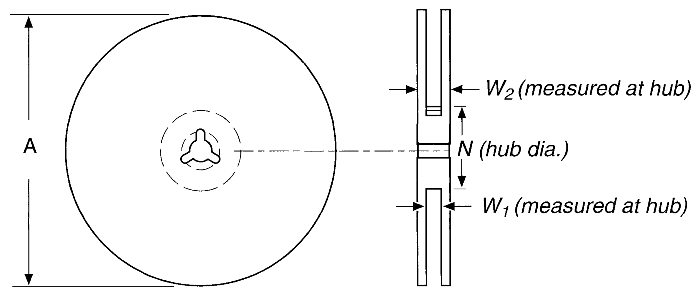
	TVB Series		TVA Series	
Description	**Dimensions (mm)**	**Tolerance (mm)**	**Dimensions (mm)**	**Tolerance (mm)**
W	12	+/- 0.30	12	+/- 0.3
P_0	4.0	+/- 0.10	4.0	+/- 0.10
P_1	8.0	+/- 0.10	8.0	+/- 0.10
P_2	2.0	+/- 0.10	2.0	+/- 0.10
A_0	4.3	—	2.9	+/- 0.10
B_0	6.2	—	5.59	+/- 0.10
B_1 max.	8.2	—	8.2	—
D0	1.5	+ 0.1, -0.0	1.5	+ 0.1, -0
F	5.5	+/- 0.05	5.5	+/- 0.05
E_1	1.75	+/- 0.10	1.75	+/- 0.10
E_2 min.	9.85	—	9.85	—
T max.	0.6	—	0.6	—
T_1 max.	0.1	—	0.1	—
K_0 max.	2.59	+/- 0.10	2.36	+/- 0.10
Leader min.	390	—	390	—
Trailer min.	160	—	160	—

Figure V9. EIA Referenced Taped Component Dimensions for SiBar Thyristor Surge Protectors



Reel Dimension	
A max.	330
N min.	50
W1	12.4 + 2.0, -0
W2 max.	18.4

Figure V10. EIA Referenced Reel Dimensions for SiBar Thyristor Protectors



⚠ WARNING:

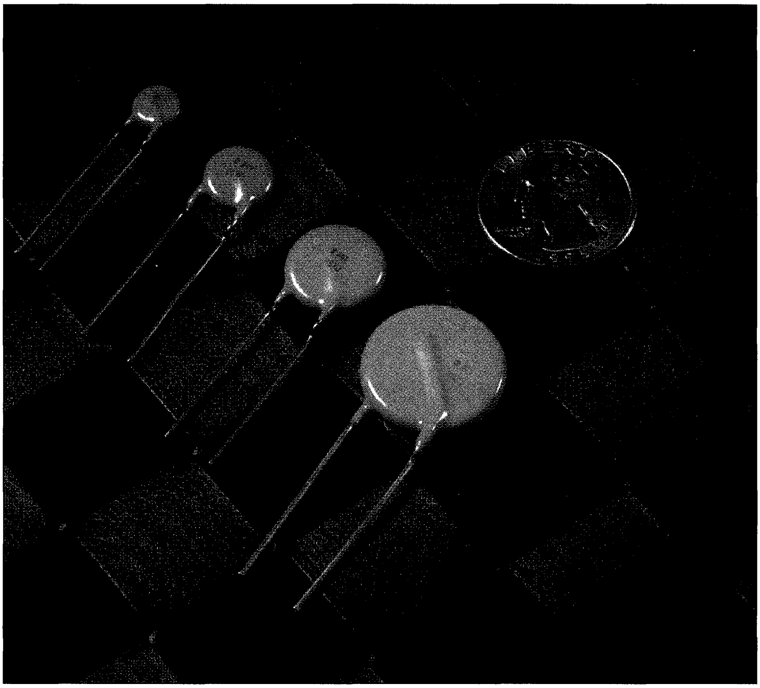
- Operation beyond the maximum ratings or improper use may result in device damage and possible electrical arcing and flame.
- The devices are intended for protection against occasional overvoltage fault conditions and should not be used when repeated fault conditions or prolonged trip events are anticipated.
- Device performance can be impacted negatively if devices are handled in a manner inconsistent with recommended electronic, thermal, and mechanical procedures for electronic components.

4

Radial-leaded Metal Oxide Varistor
Resettable Devices

Raychem Circuit Protection's ROV (Radial-leaded Metal Oxide Varistor) products help to provide protection against overvoltage faults such as lightning, power contact, and power induction, for a wide variety of power systems. Suitable for a broad range of applications including, but not limited to, security systems, power supplies, surge strips, motors, and telecommunications equipment, ROV devices help to protect valuable equipment from potential power surge damage by clamping high-energy, short-duration impulses. The ROV devices have high current handling and energy absorption capability and fast response times to help protect against transient faults.

The ROV overvoltage protection devices expand Raychem Circuit Protection's portfolio, which can now offer the circuit board designer a complete overcurrent/overvoltage solution. For example, pairing an ROV device with Raychem Circuit Protection's PolySwitch™ LVR overcurrent protection devices can help provide a completely resettable circuit protection solution for power supplies, surge strips and control board transformers. In addition, ROV devices can be combined with PolySwitch devices to help provide protection for electric motors.



Benefits:
- Helps provide overvoltage fault protection for a wide variety of power systems
- Helps designers meet UL, CSA, and VDE standards
- Helps reduce warranty and service costs
- Low cost ($/Joule)

Features:
- Various diameter sizes: 5mm, 7mm, 10mm, 14mm, 20mm
- Broad varistor voltage range: 18V - 1800V
- Various surge capabilities: standard, high surge, extra high surge
- High current handling and energy absorption capability
- Fast response time
- Low leakage current
- Various lead types: straight, kinked, other special lead types
- Various packaging options: bulk, tape and reel, ammo pack

Applications:
- Power systems
- Surge strips
- Security systems
- Motor protection
- Telecommunications equipment
- Automotive electrical systems
- Household appliances

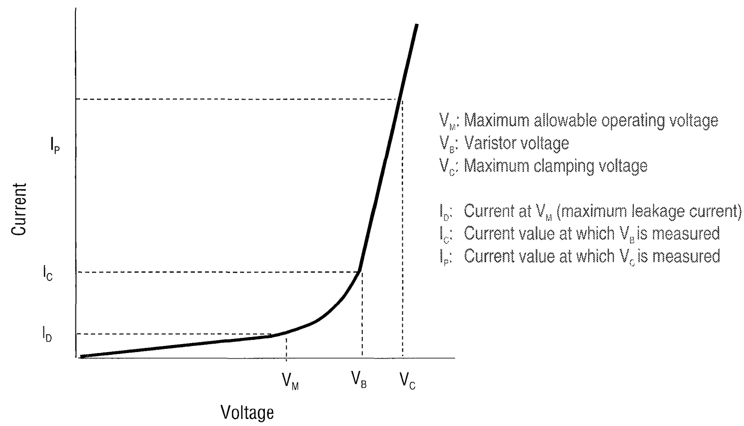
Devices in this section are grouped by:

Diameter, Varistor Voltage, Surge Capability

4

General Characteristics and Parameter Definitions

Figure 1. Parameter Definitions Reference V-I Curve



General characteristics

- Maximum response time: 25ns
- Storage temperature: -40°C~+125°C
- Maximum operating temperature: -40°C~+85°C
- Maximum working surface temperature: +115°C
- Temperature coefficient of voltage: +0.05% / °C maximum
- Insulation resistance of coating (at 500 V_{DC}): Over 1000MΩ

Varistor Voltage (V_B)

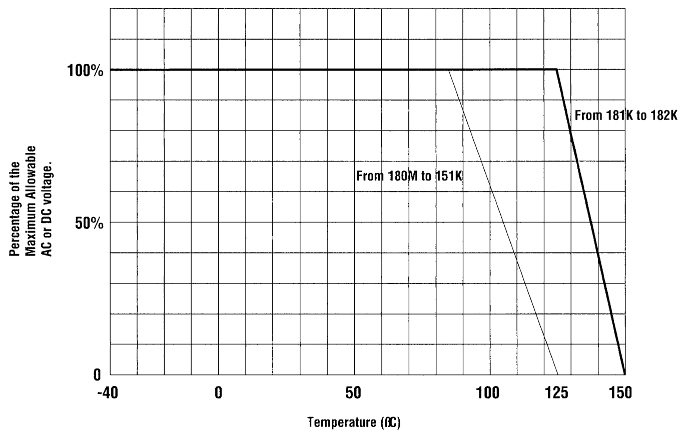
The Varistor Voltage, V_B, is the peak DC voltage measured across a varistor when a specified current, I_C, is applied. For 5mm devices, I_C = 0.1mA; for 7, 10, 14, 20mm devices, I_C = 1.0mA. Each ROV device varistor voltage has a corresponding tolerance value, which represents the maximum variation (± X%) of the device's varistor voltage value, measured at 25°C. The ROV device rating and characteristics tables list the varistor voltage and tolerance for each device. Additionally, an ROV device's varistor voltage rating and tolerance specification are used in the device's part numbering scheme.

Maximum Allowable Operating Voltage (V_M)

The ROV device rating and characteristics tables list maximum allowable AC (V_{RMS}) and DC (V_M) voltage values for each varistor device. The maximum allowable AC voltage is the maximum allowable sinusoidal voltage (V_{RMS}) at 50-60Hz across the varistor in its off state. The maximum allowable DC voltage is the maximum allowable steady state voltage (V_{DC}) of the varistor in its off state. As shown in Figure 2, the maximum allowable AC (V_{RMS}) or DC voltage decreases linearly as ambient temperature exceeds 125°C (for ROV*DDS*181K to ROV*DDS*182K) or 85°C (for ROV*DDS*180M to ROV*DDS*151K).

General Characteristics and Parameter Definitions *continued*

Figure 2. Maximum Allowable Operating AC or DC Voltage as a Function of Temperature



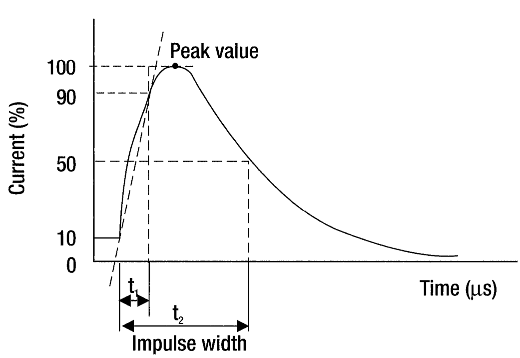
Maximum Clamping Voltage (V_C)

The maximum clamping voltage, V_C, is the maximum voltage measured across a varistor device when a standard impulse, having an 8x20µs current waveform, is applied to the device. The ROV device rating and characteristics tables list the maximum clamping voltage corresponding to specified peak currents, I_P, of an 8x20µs waveform. For example, 5mm series devices from ROV05-180M to ROV05-680K are tested with an I_P value of 1A; 5mm series devices from ROV05-820K to ROV05-751K are tested with an I_P value of 5A. Additionally, the ROV devices' V-I characteristic curves depict the clamping voltage values over a range of current values.

Maximum Surge Current (I_{MAX})

The maximum surge current is the maximum peak current for the ROV device when the specified standard impulse current (8x20µs waveform) is applied one time, with a maximum permissible variation of 10% in the varistor voltage value after the test. Figure 3 depicts the characteristics of a typical current impulse waveform. The rating and characteristics tables display the maximum surge current allowed for 1 and 2 impulses. The pulse lifetime ratings curves display the maximum surge currents over a range of pulse repetitions and pulse durations.

Figure 3. Waveform of a Typical Current Impulse



$t_1 = 8\mu s$	$t_2 = 20\mu s$	for 8 x 20µs
$t_1 = 10\mu s$	$t_2 = 1000\mu s$	for 10 x 1000µs

4

General Characteristics and Parameter Definitions *continued*

Rated Wattage

The rated wattage is the maximum steady state power that can be applied to an ROV device, within the ambient temperature range specified on page 352.

Energy (E)

The ROV device rating and characteristics tables list the maximum energy absorption capability, E, for an ROV device when one surge of a 10x1000μs waveform is applied to the device and the change in varistor voltage is ≦±10%. The following equation is used to determine the energy absorption capability, E:

E (Joules) = K x V_{me} x I_{me} x T

Where:

K : Constant = 1.4

V_{me} : Maximum clamping voltage value at I_{me}

I_{me} : Maximum allowable single surge current value of a 10x1000μs waveform (where the change in varistor voltage value is ≦±10%).

T : Duration of surge current (1000μs for the 10x1000μs waveform)

Capacitance

The ROV device rating and characteristics tables list the reference capacitance value of an ROV device. The reference capacitance value is the typical capacitance measured across an ROV device's terminals at 1kHz and 0V DC bias. The reference capacitance value of an ROV device typically increases as the device's diameter increases and typically decreases with increasing ROV device varistor voltage.

4

Certifications

The ROV device rating and characteristics tables list the certifications that have been obtained for each device. An ROV device may have certifications for the following standards:

UL1414	: "Across-the-Line Capacitors, Antenna-Coupling and Line-bypass Components"
UL1449 (2nd Edition)	: "Transient Voltage Surge Suppressors"
CSA	: "Accessories and Parts for Electronic Equipment"
VDE	: "Varistors for Use in Electronic Equipment"

Pulse Lifetime Ratings Curves

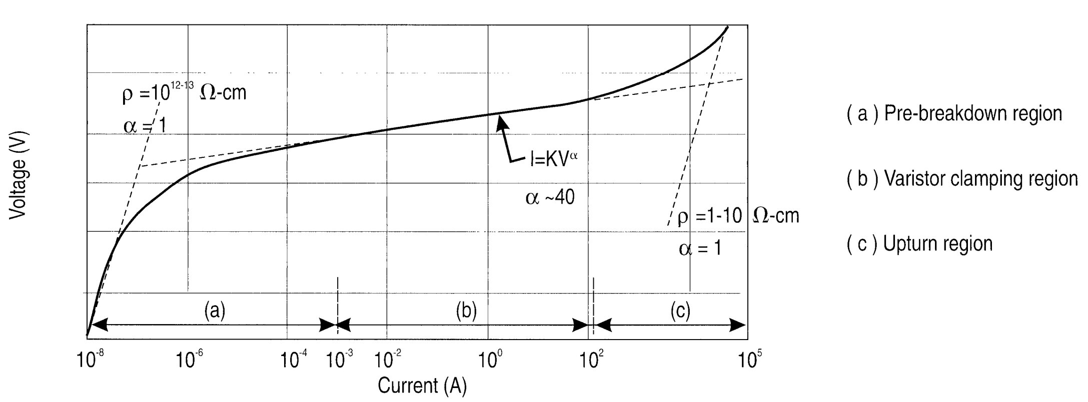
The ROV device pulse lifetime ratings curves display the maximum allowable surge currents over a range of current pulse repetitions and pulse waveforms applied at 30 second intervals. The number of current pulse repetitions ranges from 1 to 10^6 pulses; the pulse waveform durations range from 20–2000μs.

General Characteristics and Parameter Definitions *continued*

V-I (Voltage-Current) Characteristic Curves

The ROV device V-I characteristic curves depict the voltage values of a device, over a range of current values. Figure 4 depicts a typical ROV device V-I characteristic curve.

Figure 4. Typical V-I Characteristic Curve



The curve is separated into three regions that depict an ROV device's V-I relationship at various stages:

Pre-breakdown region (a): This region of the curve represents the V-I characteristics of an ROV device during normal operating conditions (i.e., in the absence of a transient overvoltage condition). In this region the ROV device essentially acts as an open circuit: the resistance of the device, ρ, (measured at DC voltage) is extremely high; the leakage current in this region is much less than 1mA.

Varistor clamping region (b): This region of the curve represents the V-I characteristics of an ROV device during an overvoltage transient. In this region the ROV device's resistance decreases, the device conducts current and clamps the voltage across the protected device. The V-I values follow the $I = KV^{\alpha}$ relationship as described on page 354. In this region, the V-I curves depict the maximum clamping voltage of a device over a range of 8x20µs waveform impulse currents.

Upturn region (c): This region of the curve represents the V-I characteristics of an ROV device when the maximum surge current rating of the device is exceeded. In this region the voltage across the device and across the protected device increases exponentially. Region (c) of the curve is useful to understand the worst case operating scenarios of the device and the conditions which should be avoided to prevent damage to the varistor.

Step 1. Determine the circuit's operating parameters (complete as much of the following information as possible).

Complete the following information about the circuit, if known:

1-a. Source and path of the transient ________ Source ________ Path

1-b. Normal operating voltage of protected equipment or device ________ (V_{RMS} AC) or ________ (V_{DC})

1-c. Tolerance of normal operating voltage (1-b) ________ (V) or ________ Unkown

1-d. Maximum allowable voltage of protected equipment or device ________ (V_{RMS} AC) or ________ (V_{DC})

1-e. Maximum expected surge current* and number of hits ________ (A) ________ (# of hits)
**Specify 8x20µs waveform equivalent of surge current*

1-f. Maximum energy applied to device in surge event ________ (Joules) E = V x I x T

1-g. Maximum power applied to device in surge event ________ (W) (P = VI)

1-h. Maximum allowable varistor capacitance* (@1kHz; $0V_{DC}$ bias) ________ (pF)
**This is the maximum capacitance of the varistor device that will not impair the functionality of the circuit*

1-i. Required safety standards ________ Name of standard(s) required (UL, CSA, VDE)

4

Step 2. Calculate the required varistor voltage value.

2-a. The required varistor voltage value should be equal to: (the operating voltage of the protected equipment or device*) + (the tolerance of the operating voltage). If the tolerance is not known, multiply the operating voltage of protected equipment or device by 1.10 to 1.25 (i.e. 10–25% above operating voltage value).
**If the operating voltage is in AC (V_{RMS}), convert to V_{DC}.*

_____Operating voltage AC (V_{RMS}) X 1.414 = _____Operating voltage (V_{DC})

_____Operating voltage of equipment or device (V_{DC}) + _____Tolerance (V) = _____Required varistor voltage (V)

or

_____Operating voltage of equipment or device (V_{DC}) X _____(1.10 to 1.25) = _____Required varistor voltage (V)

Selection Guide for ROV Devices *continued*

Step 3. Select a varistor that meets the following requirements.

If the response to one of the requirements below is "False", refer to the appropriate corrective action notes (A-F) at bottom of list:

3-a. Varistor voltage value - Tolerance of varistor ≥ Required varistor voltage value (2-a)
______True ______False (A)

3-b. Varistor maximum clamping voltage value ≦ Maximum allowable voltage of protected equipment or device (1-d)*
**Max. current should be less than the current at which maximum clamping voltage is measure at.*
______True ______False (B)

3-c. Varistor maximum peak current value ≥ Maximum expected surge current (1-e)*
**If surge current waveform is not 8 x 20μs, use Pulse Lifetime Ratings curves.* ______True ______False (C)

3-d. Varistor maximum energy rating ≥ Maximum energy applied to system (1-f) ______True ______False (D)

3-e. Varistor maximum rated power ≥ Maximum power applied to system (1-g) ______True ______False (E)

3-f. Varistor capacitance ≦ Maximum allowable system capacitance (1-h) ______True ______False (F)

Corrective action notes:

A. Select next varistor on the list (i.e. next varistor with increasing varistor voltage value) and then re-verify 3-a.
B. Select previous varistor on the list (i.e. previous varistor with decreasing varistor voltage value) and then re-verify 3-b.
C. Select next varistor diameter level and then re-verify 3-c*.
D. Select next varistor diameter level and then re-verify 3-d*.
E. Select next varistor diameter level and then re-verify 3-e*.
F. Select lower varistor diameter level and then re-verify 3-c, 3-d, 3-e and 3-f*.

** If varistor voltage is below 82V, selecting an 82V ROV may be preferable over a higher diameter part.*

Step 4. Verify the following system conditions.

4-a. Leakage current of the selected varistor is appropriate for the circuit ______True ______False

4-b. Verify the performance of the varistor under fault conditions* ______Verified

**This selection guide is intended to assist the user in selecting a Raychem Circuit Protection ROV device. However, users should independently evaluate the suitability of, and test each ROV device in their application.*

4

Table 1. ROV Quick Selection Guide

Standard Series ROV Devices

Varistor Voltage	V_{RMS} AC	Maximum Surge Current (8x20µs)	Rated Wattage	Energy (10x1000µs)	Possible Varistor Reference
18-68V	11-40V	≦100A	≦0.01W	0.6–2.1J	5mm series: 180M - 680K
		≦250A	≦0.02W	1.2–4.3J	7mm series: 180M - 680K
		≦500A	≦0.05W	2.4–8.5J	10mm series: 180M - 680K
		≦1000A	≦0.10W	4.7–17.0J	14mm series: 180M - 680K
		≦2000A	≦0.20W	7.0–24.0J	20mm series: 180M - 680L
82-750V	50-460V	≦400A	≦0.10W	2.8–22.5J	5mm series : 820K - 751K
82-820V	50-510V	≦1200A	≦0.25W	5.5–47.0J	7mm series: 820K - 821K
82-1800V	50-1000V	≦2500A	≦0.40W	11.0–174.0J	10mm series: 820K - 182K
		≦4500A	≦0.60W	22.0–348.0J	14mm series: 820K - 182K
		≦6500A	≦1.00W	44.0–695.0J	20mm series: 820K - 182K

High Surge Series (H Series) ROV Devices

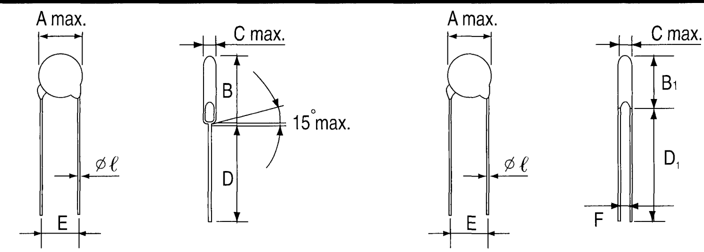
Varistor Voltage	V_{RMS} AC	Maximum Surge Current (8x20µs)	Rated Wattage	Energy (10x1000µs)	Possible Varistor Reference
18-68V	11-40V	≦250A	≦0.01W	0.7–2.6J	5mm series: H180M - H680K
		≦500A	≦0.02W	1.5–5.4J	7mm series: H180M - H680K
		≦1000A	≦0.05W	2.6–9.8J	10mm series: H180M - H680K
		≦2000A	≦0.10W	5.2–20.0J	14mm series: H180M - H680K
		≦3000A	≦0.20W	13.0–49.0J	20mm series: H180M - H680L
82-750V	50-460V	≦800A	≦0.10W	3.5–29.0J	5mm series : H820K - H751K
82-820V	50-510V	≦1750A	≦0.25W	7.0–60.0J	7mm series: H820K - H821K
82-1100V	50-680V	≦3500A	≦0.40W	14.0–155.0J	10mm series: H820K - H112K
		≦6000A	≦0.60W	28.0–310.0J	14mm series: H820K - H112K
		≦10000A	≦1.00W	56.0–620.0J	20mm series: H820K - H112K

4

Extra High Surge Series (E Series) ROV Devices

Varistor Voltage	V_{RMS} AC	Maximum Surge Current (8x20µs)	Rated Wattage	Energy (10x1000µs)	Possible Varistor Reference
200-360V	130-230V	≦6500A	≦0.60W	84.0–151.0J	14mm series: E201K - E361K
		≦12500A	≦1.00W	168.0–302.0J	20mm series: E201K - E361K

Figure 5. Dimensions



Kinked lead (Standard)

Straight lead (-S)

Table 2. Dimensions in Millimeters

Diameter	5mm	7mm	10mm	14mm	20mm
A max.	7.5	9.0	12.5	16.5	23.0
ℓ ± 0.05	0.6	0.6	0.8	0.8	1.0
E ± 1.0	5.0	5.0	7.5	7.5	10.0
B max.	11.0	13.0	18.0	22.0	28.0
D_1 min.	25.0	25.0	25.0	25.0	25.0
D min.	24.0	24.0	24.0	24.0	24.0

C Max. F & B_1 Max.

Diameter	5mm			7mm			10mm			14mm			20mm		
Type No.	C max.	F±0.8	B_1 max.	C max.	F±0.8	B_1 max.	C max.	F±0.8	B_1 max.	C max.	F±0.8	B_1 max.	C max.	F±0.8	B_1 max.
180M	4.5	0.8	10.5	4.5	0.8	12.0	4.9	0.8	15.5	5.0	0.9	19.5	5.2	0.9	26.5
220L	4.5	0.9	10.5	4.5	0.9	12.0	4.9	0.9	15.5	5.0	1.0	19.5	5.3	1.0	26.5
270K	4.7	0.9	10.5	4.7	0.9	12.0	5.1	0.9	15.5	5.2	1.1	19.5	5.4	1.1	26.5
330K	4.7	1.0	10.5	4.7	1.0	12.0	5.1	1.0	15.5	5.2	1.2	19.5	5.4	1.2	26.5
390K	4.7	1.2	10.5	4.7	1.2	12.0	5.1	1.2	15.5	5.2	1.4	19.5	5.4	1.4	26.5
470K	5.0	1.2	10.5	5.0	1.2	12.0	5.5	1.2	15.5	5.6	1.4	19.5	5.6	1.4	26.5
560K	5.0	1.4	10.5	5.0	1.4	12.0	5.5	1.4	15.5	5.6	1.6	19.5	5.6	1.6	26.5
680K	5.5	1.7	10.5	5.5	1.7	12.0	6.0	1.7	15.5	6.1	1.9	19.5	6.1	1.9	26.5
820K	3.8	0.8	10.5	3.8	0.8	12.0	4.3	0.8	15.5	4.4	1.0	19.5	4.9	1.2	26.5
101K	3.9	0.8	10.5	3.9	0.8	12.0	4.4	0.8	15.5	4.5	1.0	19.5	5.1	1.2	26.5
121K	4.1	0.9	10.5	4.1	0.9	12.0	4.5	0.9	15.5	4.6	1.1	19.5	5.3	1.3	26.5
151K	4.5	1.2	10.5	4.5	1.2	12.0	4.9	1.2	15.5	5.1	1.4	19.5	5.6	1.6	26.5
181K	4.1	1.0	10.5	4.1	1.0	12.0	4.5	1.0	15.5	4.7	1.2	19.5	5.2	1.4	26.5
201K	4.2	1.0	10.5	4.2	1.0	12.0	4.6	1.0	15.5	4.8	1.2	19.5	5.3	1.4	26.5
221K	4.3	1.1	10.5	4.3	1.1	12.0	4.7	1.1	15.5	4.9	1.3	19.5	5.4	1.5	26.5
241K	4.4	1.1	10.5	4.4	1.3	12.0	4.8	1.3	15.5	5.0	1.5	19.5	5.5	1.7	26.5
271K	4.6	1.3	10.5	4.6	1.4	12.0	5.0	1.4	15.5	5.2	1.5	19.5	5.7	1.9	26.5
301K	4.8	1.3	10.5	4.8	1.5	12.0	5.2	1.6	15.5	5.4	1.7	19.5	5.9	2.1	26.5
331K	4.9	1.3	10.5	4.9	1.5	12.0	5.3	1.6	15.5	5.5	1.7	19.5	6.0	2.1	26.5
361K	5.1	1.8	10.5	5.1	1.9	12.0	5.5	1.9	15.5	5.7	2.1	19.5	6.2	2.3	26.5
391K	5.3	2.0	11.0	5.3	2.0	12.5	5.7	2.2	16.0	5.9	2.2	20.0	6.4	2.4	26.5
431K	6.1	2.1	11.0	6.1	2.0	12.5	6.5	2.5	16.0	6.7	2.5	20.0	7.2	2.7	26.5
471K	6.4	2.2	11.0	6.4	2.3	12.5	6.8	2.6	16.0	7.0	2.7	20.0	7.5	2.9	27.0
511K	6.6	2.5	11.5	6.6	2.5	13.0	7.0	3.1	16.5	7.2	3.1	20.5	7.7	3.3	27.0
561K	6.9	2.8	11.5	6.9	2.8	13.0	7.3	3.4	16.5	7.5	3.4	20.5	8.0	3.6	27.0
621K	7.2	3.1	11.5	7.2	3.1	13.0	7.6	4.0	16.5	7.8	3.8	20.5	8.3	4.1	27.0
681K	7.5	3.4	11.5	7.5	3.4	13.0	8.0	4.4	16.5	8.2	4.1	20.5	8.7	4.4	27.0
751K	7.9	3.7	11.5	7.9	3.7	13.0	8.4	4.4	16.5	8.6	4.3	20.5	9.1	4.5	27.0
781K	—	—	—	8.1	3.9	13.0	8.6	4.6	16.5	8.8	4.6	20.5	9.3	4.8	27.0
821K	—	—	—	8.3	4.1	13.0	8.8	4.6	16.5	9.0	4.6	20.5	9.5	4.8	27.0
911K	—	—	—	—	—	—	9.4	5.4	16.5	9.6	5.4	20.5	10.1	5.7	27.0
102K	—	—	—	—	—	—	9.9	5.4	16.5	10.1	5.6	20.5	10.7	5.8	27.0
112K	—	—	—	—	—	—	10.5	5.7	16.5	10.7	6.1	20.5	11.2	6.3	27.0
182K	—	—	—	—	—	—	12.6	9.8	18.5	12.8	10.2	22.5	13.5	10.4	29.0

4

Figure 6. Special Lead Configurations

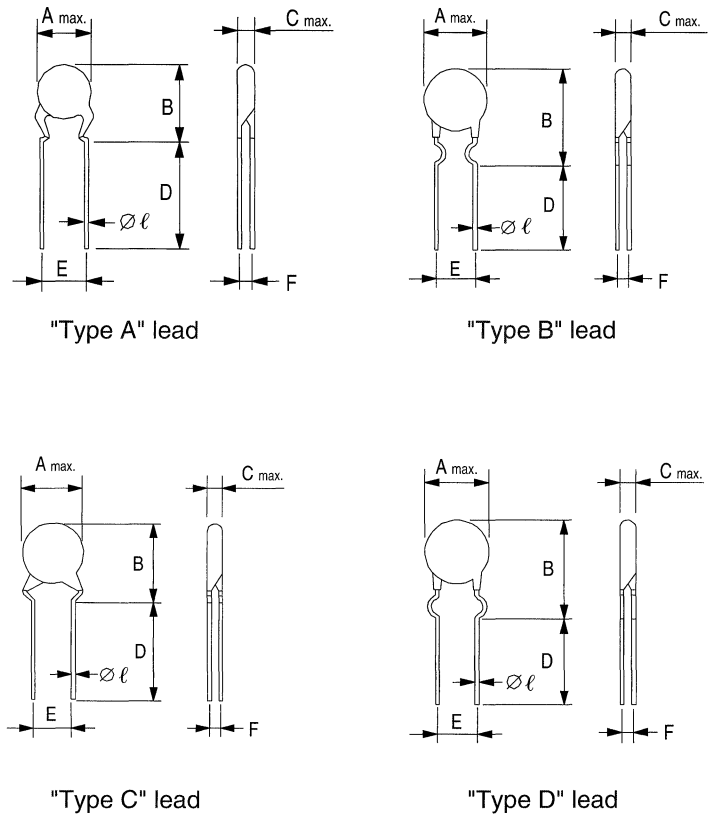


Table 3. Dimensions in Millimeters*

Lead Type	Diameter	5mm	7mm	10mm	14mm	20mm
A, C	B max.	10.0	12.0	15.0	19.0	26.0
B, D	B max.	12.0	14.0	17.0	21.0	28.0

* All other dimensions are the same as those of the (standard) kinked leads, shown on page 359.

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Standard Series Specifications—5mm Devices

Table 4. Rating and Characteristics

	Varistor Voltage V@0.1mA		Maximum Allowable Voltage		Maximum Clamping Voltage	Maximum Surge Current (8x20µs)		Rated Wattage	Energy (10x1000µs)	Capacitance (Typical)	Certification*
Number	DC (V)	Tolerance	AC (V_{RMS})	DC (V)	V@5A (V)	1 Time (A)	2 Times (A)	(W)	(J)	(pF)	
ROV05-180M	18	±20%	11	14	40[1]	100	50	0.01	0.6	1121	●
ROV05-220L	22	±15%	14	18	48[1]	100	50	0.01	0.7	1233	●
ROV05-270K	27	±10%	17	22	60[1]	100	50	0.01	0.9	1073	●
ROV05-330K	33	±10%	20	26	73[1]	100	50	0.01	1.1	834	●
ROV05-390K	39	±10%	25	31	86[1]	100	50	0.01	1.2	877	●
ROV05-470K	47	±10%	30	38	104[1]	100	50	0.01	1.5	715	●
ROV05-560K	56	±10%	35	45	123[1]	100	50	0.01	1.8	643	●
ROV05-680K	68	±10%	40	56	150[1]	100	50	0.01	2.1	501	●
ROV05-820K	82	±10%	50	65	145	400	200	0.10	2.8	269	● ■
ROV05-101K	100	±10%	60	85	175	400	200	0.10	3.5	263	● ■
ROV05-121K	120	±10%	75	100	210	400	200	0.10	4.0	180	● ■
ROV05-151K	150	±10%	95	125	260	400	200	0.10	5.5	180	● ■
ROV05-181K	180	±10%	115	150	320	400	200	0.10	6.5	95	● ■
ROV05-201K	200	±10%	130	170	355	400	200	0.10	7.1	85	◆●▲■
ROV05-221K	220	±10%	140	180	380	400	200	0.10	7.8	80	◆●▲■
ROV05-241K	240	±10%	150	200	415	400	200	0.10	8.4	74	◆●▲■
ROV05-271K	270	±10%	175	225	475	400	200	0.10	9.9	69	◆●▲■
ROV05-301K	300	±10%	195	250	525	400	200	0.10	10.5	65	◆●▲■
ROV05-331K	330	±10%	210	275	575	400	200	0.10	11.5	60	◆●▲■
ROV05-361K	360	±10%	230	300	620	400	200	0.10	13.0	69	◆●▲■
ROV05-391K	390	±10%	250	320	675	400	200	0.10	15.0	56	◆●▲■
ROV05-431K	430	±10%	275	350	745	400	200	0.10	16.5	47	◆●▲■
ROV05-471K	470	±10%	300	385	810	400	200	0.10	17.5	50	◆●▲■
ROV05-511K	510	±10%	320	418	880	400	200	0.10	18.5	50	◆●▲
ROV05-561K	560	±10%	350	460	940	400	200	0.10	19.5	50	◆●▲
ROV05-621K	620	±10%	385	505	1050	400	200	0.10	20.5	50	◆●▲
ROV05-681K	680	±10%	420	560	1150	400	200	0.10	21.5	43	◆●▲
ROV05-751K	750	±10%	460	615	1290	400	200	0.10	22.5	45	◆●▲

[1] The clamping voltages from 180M to 680K are tested at 1A current.

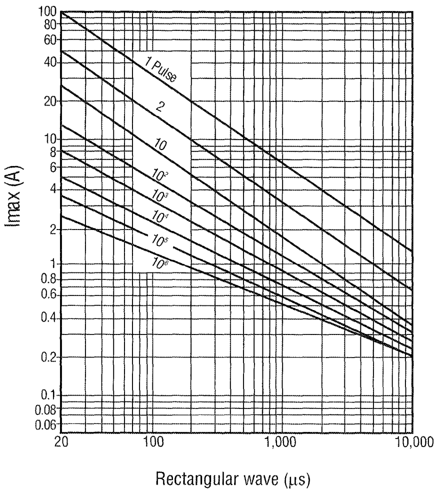
*Certification

Standard	UL1414**	UL1449 (2nd Edition)**	CSA	VDE
Title	Across-the-Line Components	Transient Voltage Surge Suppressors	Accessories and Parts for Electronic Equipment	Varistors for Use in Electronic Equipment
Symbols	◆	●	▲	■
File Number	E223034	E223033	220978	40006997

**For UL1449 (2nd Edition), the maximum clamping voltage is measured at 500A.

Figure 7. ROV05-180M~ROV05-680K

Pulse Lifetime Ratings



V-I Characteristic Curve

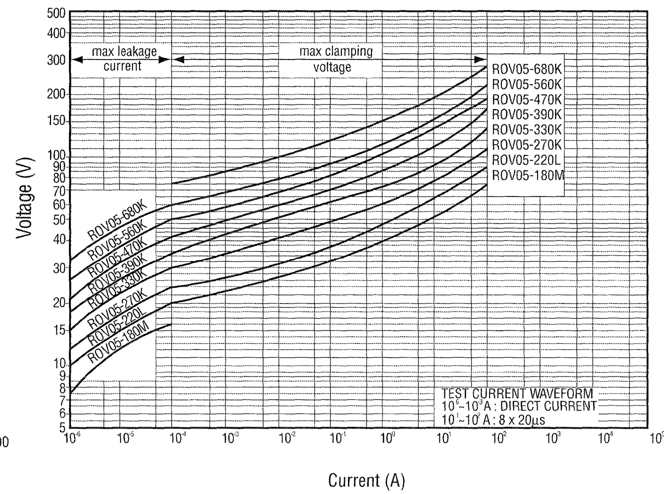
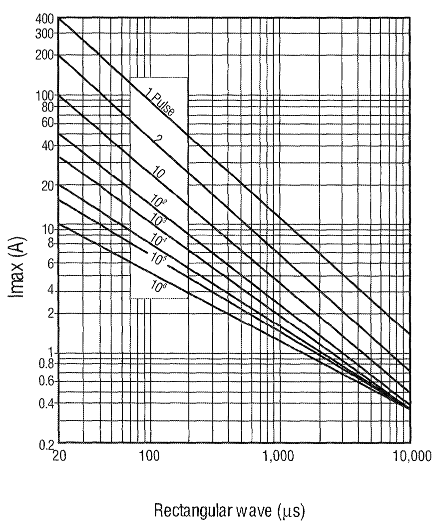
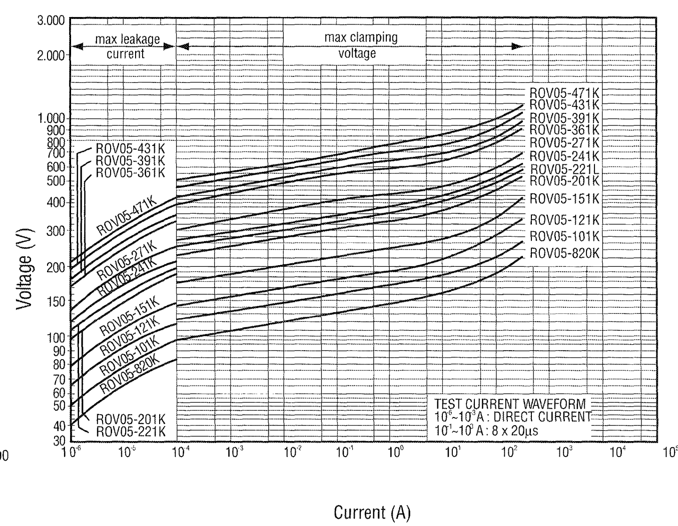


Figure 8. ROV05-820K~ROV05-471K

Pulse Lifetime Ratings



V-I Characteristic Curve



Standard Series Specifications—7mm Devices

Table 5. Rating and Characteristics

Number	Varistor Voltage V@1.0mA DC (V)	Tolerance	Maximum Allowable Voltage AC (V_{RMS})	DC (V)	Maximum Clamping Voltage V@10A (V)	Maximum Surge Current (8x20µs) 1 Time (A)	2 Times (A)	Rated Wattage (W)	Energy (10x1000µs) (J)	Capacitance (Typical) (pF)	Certification*
ROV07-180M	18	±20%	11	14	36[1]	250	125	0.02	1.2	2918	●
ROV07-220L	22	±15%	14	18	43[1]	250	125	0.02	1.4	1933	●
ROV07-270K	27	±10%	17	22	53[1]	250	125	0.02	1.7	2344	●
ROV07-330K	33	±10%	20	26	65[1]	250	125	0.02	2.2	1840	●
ROV07-390K	39	±10%	25	31	77[1]	250	125	0.02	2.4	1817	●
ROV07-470K	47	±10%	30	38	93[1]	250	125	0.02	3.0	1595	●
ROV07-560K	56	±10%	35	45	110[1]	250	125	0.02	3.5	1333	●
ROV07-680K	68	±10%	40	56	135[1]	250	125	0.02	4.3	1119	●
ROV07-820K	82	±10%	50	65	135	1200	600	0.25	5.5	643	● ■
ROV07-101K	100	±10%	60	85	165	1200	600	0.25	7.0	535	● ■
ROV07-121K	120	±10%	75	100	200	1200	600	0.25	8.0	457	● ■
ROV07-151K	150	±10%	95	125	250	1200	600	0.25	11.0	371	● ■
ROV07-181K	180	±10%	115	150	300	1200	600	0.25	13.0	215	● ■
ROV07-201K	200	±10%	130	170	340	1200	600	0.25	14.3	224	●◆▲■
ROV07-221K	220	±10%	140	180	360	1200	600	0.25	15.5	190	●◆▲■
ROV07-241K	240	±10%	150	200	395	1200	600	0.25	16.8	185	●◆▲■
ROV07-271K	270	±10%	175	225	455	1200	600	0.25	19.8	161	●◆▲■
ROV07-301K	300	±10%	195	250	505	1200	600	0.25	21.0	135	●◆▲■
ROV07-331K	330	±10%	210	275	550	1200	600	0.25	23.0	141	●◆▲■
ROV07-361K	360	±10%	230	300	595	1200	600	0.25	26.0	117	●◆▲■
ROV07-391K	390	±10%	250	320	650	1200	600	0.25	30.0	110	●◆▲■
ROV07-431K	430	±10%	275	350	710	1200	600	0.25	33.0	111	●◆▲■
ROV07-471K	470	±10%	300	385	775	1200	600	0.25	35.0	102	●◆▲■
ROV07-511K	510	±10%	320	418	842	1200	600	0.25	37.0	100	●◆▲
ROV07-561K	560	±10%	350	460	920	1200	600	0.25	39.0	87	●◆▲
ROV07-621K	620	±10%	385	505	1025	1200	600	0.25	41.0	80	●◆▲
ROV07-681K	680	±10%	420	560	1120	1200	600	0.25	43.0	82	●◆▲
ROV07-751K	750	±10%	460	615	1240	1200	600	0.25	45.0	74	●◆▲
ROV07-781K	780	±10%	485	640	1290	1200	600	0.25	46.0	70	●◆▲
ROV07-821K	820	±10%	510	670	1355	1200	600	0.25	47.0	70	◆●▲

[1] The clamping voltages from 180M to 680K are tested at 2.5A current.

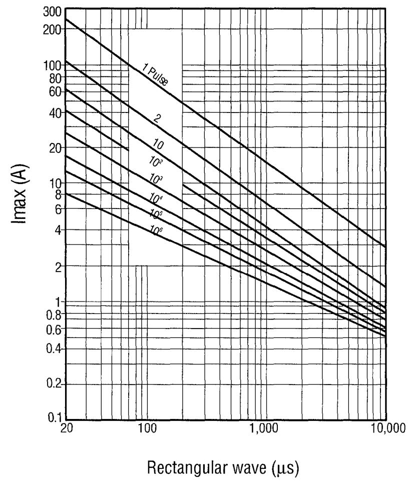
*Certification

Standard	UL1414**	UL1449 (2nd Edition)**	CSA	VDE
Title	Across-the-Line Components	Transient Voltage Surge Suppressors	Accessories and Parts for Electronic Equipment	Varistors for Use in Electronic Equipment
Symbols	◆	●	▲	■
File Number	E223034	E223033	220978	40006997

**For UL1449 (2nd Edition), the maximum clamping voltage is measured at 500A.

Figure 9. ROV07-180M~ROV07-680K

Pulse Lifetime Ratings



V-I Characteristic Curve

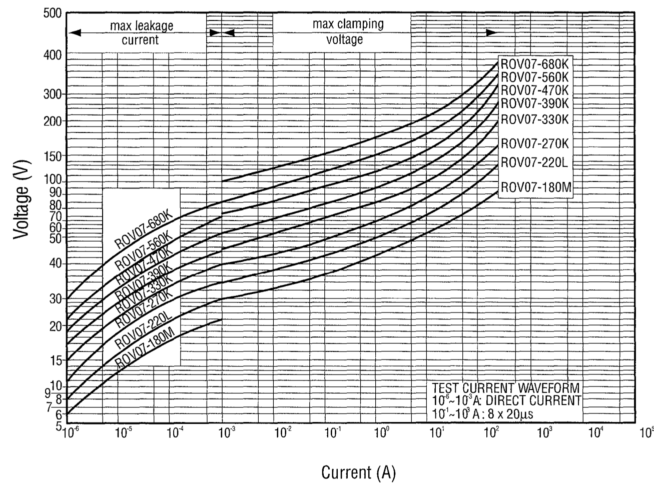
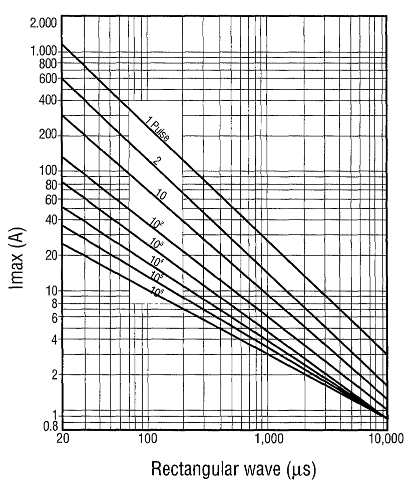
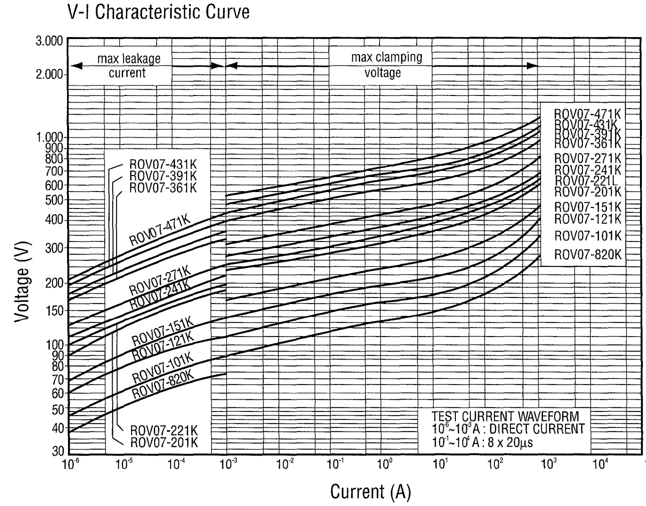


Figure 10. ROV07-820K~ROV07-471K

Pulse Lifetime Ratings



V-I Characteristic Curve



Standard Series Specifications—10mm Devices

Table 6. Rating and Characteristics

Number	Varistor Voltage V@1.0mA DC (V)	Tolerance	Maximum Allowable Voltage AC (V_{RMS})	Maximum Allowable Voltage DC (V)	Maximum Clamping Voltage V@25A (V)	Maximum Surge Current (8x20µs) 1 Time (A)	Maximum Surge Current (8x20µs) 2 Times (A)	Rated Wattage (W)	Energy (10x1000µs) (J)	Capacitance (Typical) (pF)	Certification*
ROV10-180M	18	±20%	11	14	36[1]	500	250	0.05	2.4	6500	● ■
ROV10-220L	22	±15%	14	18	43[1]	500	250	0.05	2.7	5521	● ■
ROV10-270K	27	±10%	17	22	53[1]	500	250	0.05	3.5	4742	● ■
ROV10-330K	33	±10%	20	26	65[1]	500	250	0.05	4.4	4247	● ■
ROV10-390K	39	±10%	25	31	77[1]	500	250	0.05	4.7	3658	● ■
ROV10-470K	47	±10%	30	38	93[1]	500	250	0.05	6.0	3137	● ■
ROV10-560K	56	±10%	35	45	110[1]	500	250	0.05	7.0	2900	● ■
ROV10-680K	68	±10%	40	56	135[1]	500	250	0.05	8.5	2230	● ■
ROV10-820K	82	±10%	50	65	135	2500	1250	0.40	11.0	1261	● ■
ROV10-101K	100	±10%	60	85	165	2500	1250	0.40	14.0	1021	● ■
ROV10-121K	120	±10%	75	100	200	2500	1250	0.40	16.0	946	● ■
ROV10-151K	150	±10%	95	125	250	2500	1250	0.40	22.0	733	● ■
ROV10-181K	180	±10%	115	150	300	2500	1250	0.40	26.0	483	● ■
ROV10-201K	200	±10%	130	170	340	2500	1250	0.40	28.5	400	◆ ● ▲ ■
ROV10-221K	220	±10%	140	180	360	2500	1250	0.40	31.0	393	◆ ● ▲ ■
ROV10-241K	240	±10%	150	200	395	2500	1250	0.40	33.5	325	◆ ● ▲ ■
ROV10-271K	270	±10%	175	225	455	2500	1250	0.40	39.5	334	◆ ● ▲ ■
ROV10-301K	300	±10%	195	250	505	2500	1250	0.40	42.0	278	◆ ● ▲ ■
ROV10-331K	330	±10%	210	275	550	2500	1250	0.40	46.0	275	◆ ● ▲ ■
ROV10-361K	360	±10%	230	300	595	2500	1250	0.40	52.0	231	◆ ● ▲ ■
ROV10-391K	390	±10%	250	320	650	2500	1250	0.40	60.0	247	◆ ● ▲ ■
ROV10-431K	430	±10%	275	350	710	2500	1250	0.40	66.0	216	◆ ● ▲ ■
ROV10-471K	470	±10%	300	385	775	2500	1250	0.40	70.0	210	◆ ● ▲ ■
ROV10-511K	510	±10%	320	418	842	2500	1250	0.40	74.0	187	◆ ● ▲ ■
ROV10-561K	560	±10%	350	460	920	2500	1250	0.40	78.0	186	◆ ● ▲
ROV10-621K	620	±10%	385	505	1025	2500	1250	0.40	82.0	160	◆ ● ▲
ROV10-681K	680	±10%	420	560	1120	2500	1250	0.40	86.0	156	◆ ● ▲
ROV10-751K	750	±10%	460	615	1240	2500	1250	0.40	90.0	133	◆ ● ▲
ROV10-781K	780	±10%	485	640	1290	2500	1250	0.40	92.0	117	◆ ● ▲
ROV10-821K	820	±10%	510	670	1355	2500	1250	0.40	94.0	130	◆ ● ▲
ROV10-911K	910	±10%	550	745	1500	2500	1250	0.40	102.0	111	◆ ● ▲
ROV10-102K	1000	±10%	625	825	1650	2500	1250	0.40	112.0	96	◆ ● ▲
ROV10-112K	1100	±10%	680	895	1815	2500	1250	0.40	124.0	88	———
ROV10-182K	1800	±10%	1000	1465	2970	2500	1250	0.40	174.0	65	———

[1] The clamping voltages from 180M to 680K are tested at 5A current.

*Certification

Standard	UL1414**	UL1449 (2nd Edition)**	CSA	VDE
Title	Across-the-Line Components	Transient Voltage Surge Suppressors	Accessories and Parts for Electronic Equipment	Varistors for Use in Electronic Equipment
Symbols	◆	●	▲	■
File Number	E223034	E223033	220978	40006997

**For UL1449 (2nd Edition), the maximum clamping voltage is measured at 500A.

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Standard Series Specifications—10mm Devices Pulse Lifetime Ratings and V-I Characteristic Curves

Figure 11. ROV10-180M~ROV10-680K

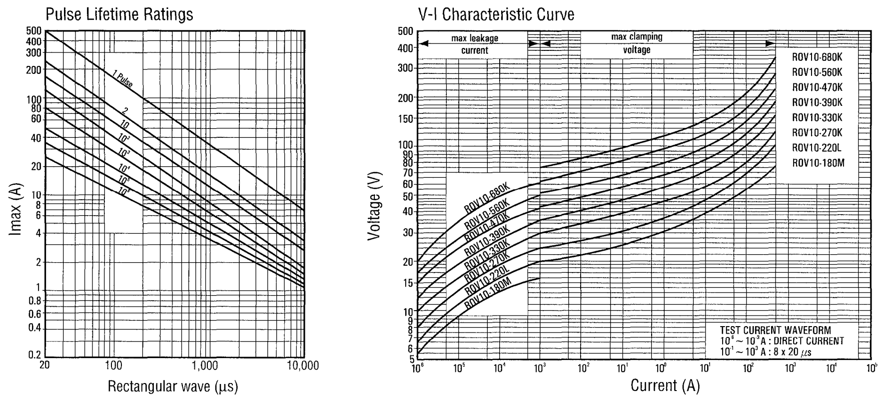


Figure 12. ROV10-820K~ROV10-511K

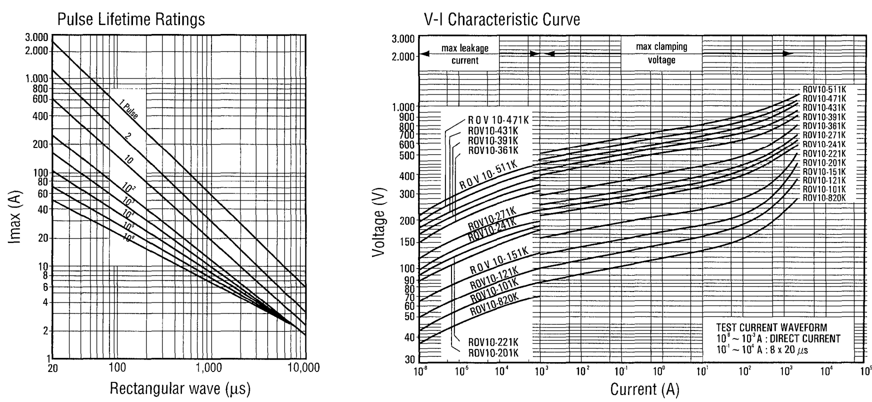
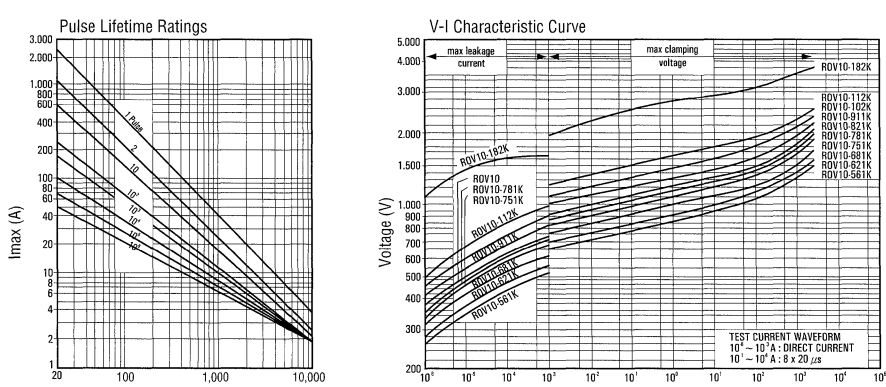


Figure 13. ROV10-561K~ROV10-182K



Standard Series Specifications—14mm Devices

Table 7. Rating and Characteristics

	Varistor Voltage V@1.0mA		Maximum Allowable Voltage		Maximum Clamping Voltage	Maximum Surge Current (8x20µs)		Rated Wattage	Energy (10x1000µs)	Capacitance (Typical)	Certification*
Number	DC (V)	Tolerance	AC (V_{RMS})	DC (V)	V@50A (V)	1 Time (A)	2 Times (A)	(W)	(J)	(pF)	
ROV14-180M	18	±20%	11	14	36[1]	1000	500	0.1	4.7	14898	● ■
ROV14-220L	22	±15%	14	18	43[1]	1000	500	0.1	5.4	11957	● ■
ROV14-270K	27	±10%	17	22	53[1]	1000	500	0.1	6.9	9731	● ■
ROV14-330K	33	±10%	20	26	65[1]	1000	500	0.1	8.8	7704	● ■
ROV14-390K	39	±10%	25	31	77[1]	1000	500	0.1	9.4	7622	● ■
ROV14-470K	47	±10%	30	38	93[1]	1000	500	0.1	12.0	6417	● ■
ROV14-560K	56	±10%	35	45	110[1]	1000	500	0.1	14.0	5184	● ■
ROV14-680K	68	±10%	40	56	135[1]	1000	500	0.1	17.0	5099	● ■
ROV14-820K	82	±10%	50	65	135	4500	2500	0.6	22.0	2965	● ■
ROV14-101K	100	±10%	60	85	165	4500	2500	0.6	28.0	2221	● ■
ROV14-121K	120	±10%	75	100	200	4500	2500	0.6	32.0	1742	● ■
ROV14-151K	150	±10%	95	125	250	4500	2500	0.6	44.0	1510	● ■
ROV14-181K	180	±10%	115	150	300	4500	2500	0.6	52.0	922	● ■
ROV14-201K	200	±10%	130	170	340	4500	2500	0.6	57.0	845	◆●▲■
ROV14-221K	220	±10%	140	180	360	4500	2500	0.6	62.0	713	◆●▲■
ROV14-241K	240	±10%	150	200	395	4500	2500	0.6	67.0	769	◆●▲■
ROV14-271K	270	±10%	175	225	455	4500	2500	0.6	79.0	655	◆●▲■
ROV14-301K	300	±10%	195	250	505	4500	2500	0.6	84.0	650	◆●▲■
ROV14-331K	330	±10%	210	275	550	4500	2500	0.6	92.0	613	◆●▲■
ROV14-361K	360	±10%	230	300	595	4500	2500	0.6	104.0	465	◆●▲■
ROV14-391K	390	±10%	250	320	650	4500	2500	0.6	120.0	458	◆●▲■
ROV14-431K	430	±10%	275	350	710	4500	2500	0.6	132.0	454	◆●▲■
ROV14-471K	470	±10%	300	385	775	4500	2500	0.6	140.0	413	◆●▲■
ROV14-511K	510	±10%	320	418	842	4500	2500	0.6	148.0	374	◆●▲■
ROV14-561K	560	±10%	350	460	920	4500	2500	0.6	156.0	398	◆●▲■
ROV14-621K	620	±10%	385	505	1025	4500	2500	0.6	164.0	305	◆●▲■
ROV14-681K	680	±10%	420	560	1120	4500	2500	0.6	172.0	312	◆●▲■
ROV14-751K	750	±10%	460	615	1240	4500	2500	0.6	180.0	270	◆●▲■
ROV14-781K	780	±10%	485	640	1290	4500	2500	0.6	184.0	252	◆●▲■
ROV14-821K	820	±10%	510	670	1355	4500	2500	0.6	188.0	265	◆●▲■
ROV14-911K	910	±10%	550	745	1500	4500	2500	0.6	204.0	240	◆●▲■
ROV14-102K	1000	±10%	625	825	1650	4500	2500	0.6	224.0	200	◆●▲■
ROV14-112K	1100	±10%	680	895	1815	4500	2500	0.6	248.0	180	◆●▲■
ROV14-182K	1800	±10%	1000	1465	2970	4500	2500	0.6	348.0	118	———

[1] The clamping voltages from 180M to 680K are tested at 10A current.

*Certification

Standard	UL1414**	UL1449 (2nd Edition)**	CSA	VDE
Title	Across-the-Line Components	Transient Voltage Surge Suppressors	Accessories and Parts for Electronic Equipment	Varistors for Use in Electronic Equipment
Symbols	◆	●	▲	■
File Number	E223034	E223033	220978	40006997

**For UL1449 (2nd Edition), the maximum clamping voltage is measured at 500A.

Standard Series Specifications—14mm Devices Pulse Lifetime Ratings and V-I Characteristic Curves

Figure 14. ROV14-180M~ROV14-680K

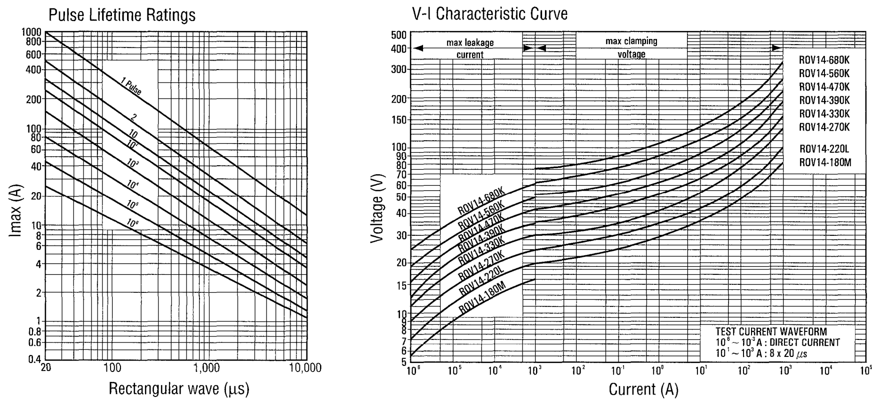


Figure 15. ROV14-820K~ROV14-511K

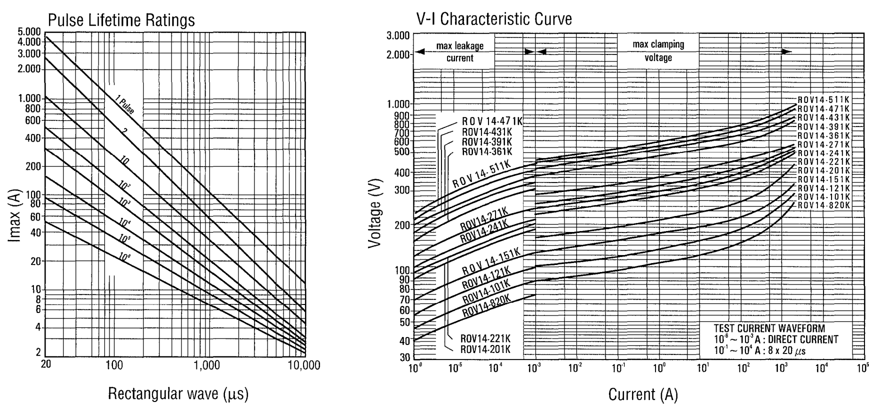
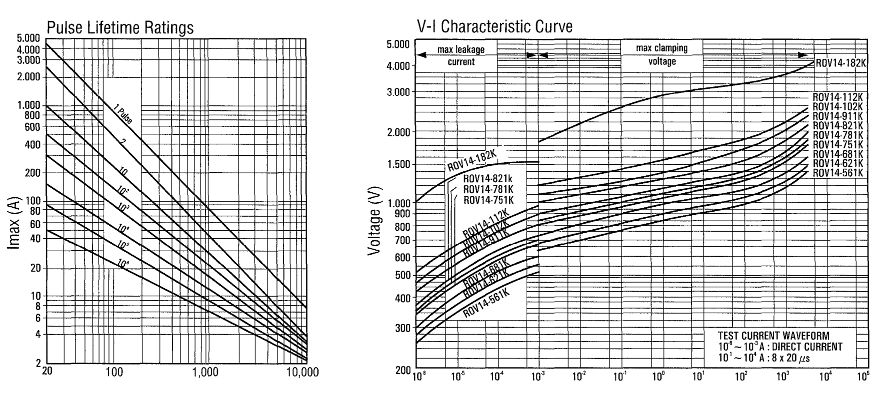


Figure 16. ROV14-561K~ROV14-182K



Standard Series Specifications—20mm Devices

Table 8. Rating and Characteristics

	Varistor Voltage V@1.0mA		Maximum Allowable Voltage		Maximum Clamping Voltage	Maximum Surge Current (8x20μs)		Rated Wattage	Energy (10x1000μs)	Capacitance (Typical)	Certification*
Number	DC (V)	Tolerance	AC (V_{RMS})	DC (V)	V@100A (V)	1 Time (A)	2 Times (A)	(W)	(J)	(pF)	
ROV20-180M	18	±20%	11	14	36[1]	2000	1000	0.2	7.0	27100	● ■
ROV20-220M	22	±20%	14	18	43[1]	2000	1000	0.2	8.0	21200	● ■
ROV20-270M	27	±20%	17	22	53[1]	2000	1000	0.2	10.0	20000	● ■
ROV20-330M	33	±20%	20	26	65[1]	2000	1000	0.2	12.0	17200	● ■
ROV20-390L	39	±15%	25	31	77[1]	2000	1000	0.2	14.0	15003	● ■
ROV20-470L	47	±15%	30	38	93[1]	2000	1000	0.2	17.0	12080	● ■
ROV20-560L	56	±15%	35	45	110[1]	2000	1000	0.2	20.0	11600	● ■
ROV20-680L	68	±15%	40	56	135[1]	2000	1000	0.2	24.0	9600	● ■
ROV20-820K	82	±10%	50	65	135	6500	4000	1.0	44.0	5200	● ■
ROV20-101K	100	±10%	60	85	165	6500	4000	1.0	56.0	4000	● ■
ROV20-121K	120	±10%	75	100	200	6500	4000	1.0	64.0	3800	● ■
ROV20-151K	150	±10%	95	125	250	6500	4000	1.0	88.0	3000	● ■
ROV20-181K	180	±10%	115	150	300	6500	4000	1.0	104.0	2400	● ■
ROV20-201K	200	±10%	130	170	340	6500	4000	1.0	114.0	1829	◆ ● ▲ ■
ROV20-221K	220	±10%	140	180	360	6500	4000	1.0	124.0	1600	◆ ● ▲ ■
ROV20-241K	240	±10%	150	200	395	6500	4000	1.0	134.0	1422	◆ ● ▲ ■
ROV20-271K	270	±10%	175	225	455	6500	4000	1.0	158.0	1261	◆ ● ▲ ■
ROV20-301K	300	±10%	195	250	505	6500	4000	1.0	168.0	1100	◆ ● ▲ ■
ROV20-331K	330	±10%	210	275	550	6500	4000	1.0	184.0	1106	◆ ● ▲ ■
ROV20-361K	360	±10%	230	300	595	6500	4000	1.0	208.0	987	◆ ● ▲ ■
ROV20-391K	390	±10%	250	320	650	6500	4000	1.0	240.0	975	◆ ● ▲ ■
ROV20-431K	430	±10%	275	350	710	6500	4000	1.0	264.0	858	◆ ● ▲ ■
ROV20-471K	470	±10%	300	385	775	6500	4000	1.0	280.0	761	◆ ● ▲ ■
ROV20-511K	510	±10%	320	418	842	6500	4000	1.0	296.0	792	◆ ● ▲ ■
ROV20-561K	560	±10%	350	460	920	6500	4000	1.0	312.0	679	◆ ● ▲ ■
ROV20-621K	620	±10%	385	505	1025	6500	4000	1.0	328.0	605	◆ ● ▲ ■
ROV20-681K	680	±10%	420	560	1120	6500	4000	1.0	344.0	553	◆ ● ▲ ■
ROV20-751K	750	±10%	460	615	1240	6500	4000	1.0	360.0	554	◆ ● ▲ ■
ROV20-781K	780	±10%	485	640	1290	6500	4000	1.0	368.0	481	◆ ● ▲ ■
ROV20-821K	820	±10%	510	670	1355	6500	4000	1.0	376.0	519	◆ ● ▲ ■
ROV20-911K	910	±10%	550	745	1500	6500	4000	1.0	408.0	444	◆ ● ▲ ■
ROV20-102K	1000	±10%	625	825	1650	6500	4000	1.0	448.0	400	◆ ● ▲ ■
ROV20-112K	1100	±10%	680	895	1815	6500	4000	1.0	496.0	360	◆ ● ▲ ■
ROV20-182K	1800	±10%	1000	1465	2970	6500	4000	1.0	695.0	260	—

[1] The clamping voltages from 180M to 680L are tested at 20A current.

*Certification

Standard	UL1414**	UL1449 (2nd Edition)**	CSA	VDE
Title	Across-the-Line Components	Transient Voltage Surge Suppressors	Accessories and Parts for Electronic Equipment	Varistors for Use in Electronic Equipment
Symbols	◆	●	▲	■
File Number	E223034	E223033	220978	40006997

**For UL1449 (2nd Edition), the maximum clamping voltage is measured at 500A.

Standard Series Specifications—20mm Devices Pulse Lifetime Ratings and V-I Characteristic Curves

Figure 17. ROV20-180M~ROV20-680L

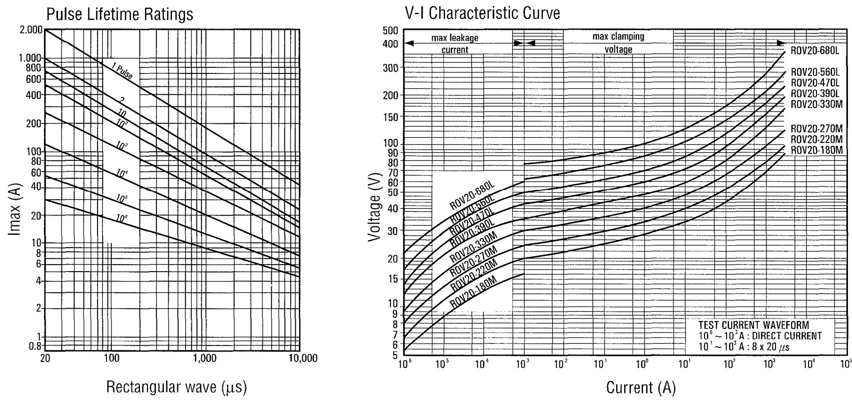


Figure 18. ROV20-820K~ROV20-511K

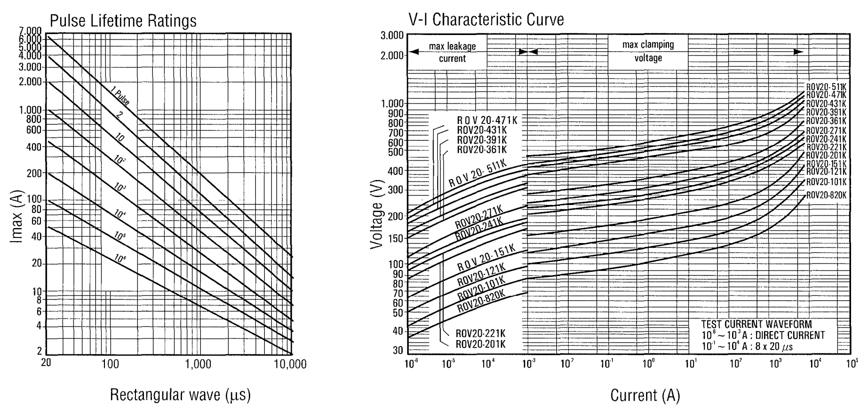
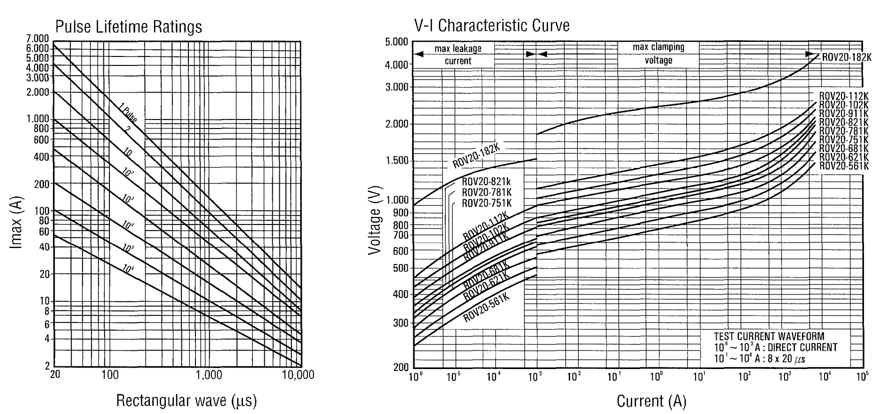


Figure 19. ROV20-561K-ROV20-182K



H Series Specifications—5mm Devices

Table 9. Rating and Characteristics

	Varistor Voltage V@0.1mA		Maximum Allowable Voltage		Maximum Clamping Voltage	Maximum Surge Current (8x20μs)		Rated Wattage	Energy (10x1000μs)	Capacitance (Typical)	Certification*
Number	DC (V)	Tolerance	AC (V_{RMS})	DC (V)	V@5A (V)	1 Time (A)	2 Times (A)	(W)	(J)	(pF)	
ROV05H180M	18	±20%	11	14	40[1]	250	125	0.01	0.7	1120	●
ROV05H220L	22	±15%	14	18	48[1]	250	125	0.01	0.8	1230	●
ROV05H270K	27	±10%	17	22	60[1]	250	125	0.01	1.1	1070	●
ROV05H330K	33	±10%	20	26	73[1]	250	125	0.01	1.3	830	●
ROV05H390K	39	±10%	25	31	86[1]	250	125	0.01	1.5	880	●
ROV05H470K	47	±10%	30	38	104[1]	250	125	0.01	1.8	720	●
ROV05H560K	56	±10%	35	45	123[1]	250	125	0.01	2.2	640	●
ROV05H680K	68	±10%	40	56	150[1]	250	125	0.01	2.6	500	●
ROV05H820K	82	±10%	50	65	145	800	600	0.10	3.5	270	●
ROV05H101K	100	±10%	60	85	175	800	600	0.10	4.5	260	●
ROV05H121K	120	±10%	75	100	210	800	600	0.10	5.5	180	●
ROV05H151K	150	±10%	95	125	260	800	600	0.10	6.5	180	●
ROV05H181K	180	±10%	115	150	320	800	600	0.10	8.0	95	●
ROV05H201K	200	±10%	130	170	355	800	600	0.10	8.5	85	◆●▲
ROV05H221K	220	±10%	140	180	380	800	600	0.10	9.0	80	◆●▲
ROV05H241K	240	±10%	150	200	415	800	600	0.10	10.5	75	◆●▲
ROV05H271K	270	±10%	175	225	475	800	600	0.10	11.0	70	◆●▲
ROV05H301K	300	±10%	195	250	525	800	600	0.10	12.0	65	◆●▲
ROV05H331K	330	±10%	210	275	575	800	600	0.10	13.0	60	◆●▲
ROV05H361K	360	±10%	230	300	620	800	600	0.10	16.0	70	◆●▲
ROV05H391K	390	±10%	250	320	675	800	600	0.10	17.0	55	◆●▲
ROV05H431K	430	±10%	275	350	745	800	600	0.10	20.0	45	◆●▲
ROV05H471K	470	±10%	300	385	810	800	600	0.10	21.0	50	◆●▲
ROV05H511K	510	±10%	320	418	880	800	600	0.10	22.0	50	◆●▲
ROV05H561K	560	±10%	350	460	940	800	600	0.10	25.0	50	◆●▲
ROV05H621K	620	±10%	385	505	1050	800	600	0.10	27.0	50	◆●▲
ROV05H681K	680	±10%	420	560	1150	800	600	0.10	28.0	40	◆●▲
ROV05H751K	750	±10%	460	615	1290	800	600	0.10	29.0	45	◆●▲

[1] The clamping voltages from 180M to 680K are tested at 1A current.

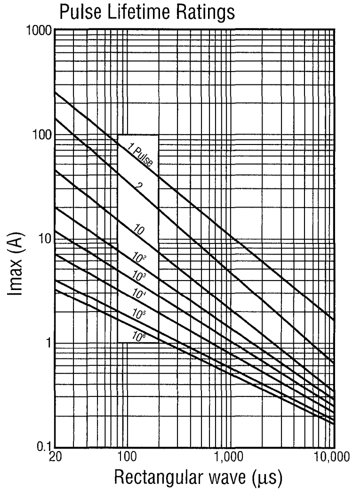
*Certification

Standard	UL1414**	UL1449 (2nd Edition)**	CSA	VDE
Title	Across-the-Line Components	Transient Voltage Surge Suppressors	Accessories and Parts for Electronic Equipment	Varistors for Use in Electronic Equipment
Symbols	◆	●	▲	■
File Number	E223034	E223033	220978	40007001

**For UL1449 (2nd Edition), the maximum clamping voltage is measured at 500A.

Figure 20. ROV05H180M~ROV05H680K

Pulse Lifetime Ratings



V-I Characteristic Curve

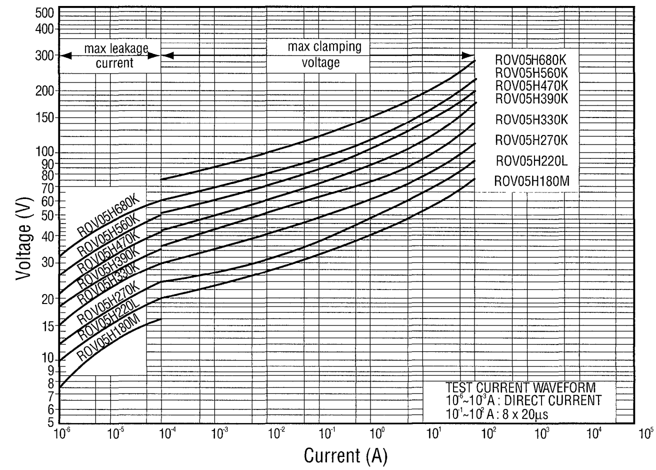
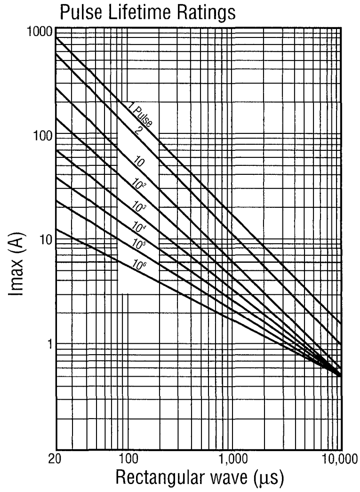
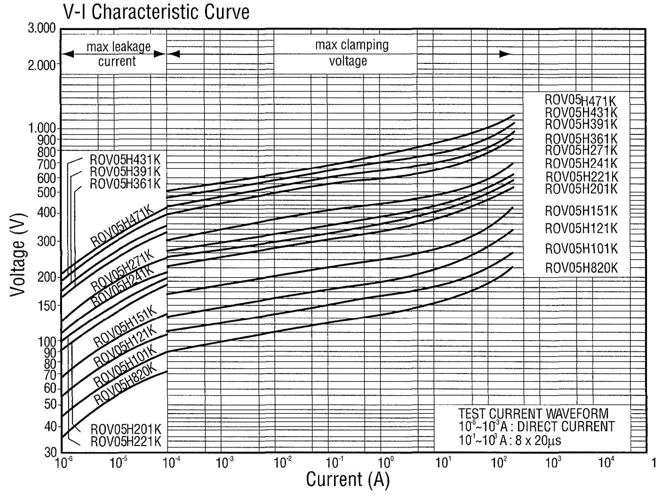


Figure 21. ROV05H820K~ROV05H471K

Pulse Lifetime Ratings



V-I Characteristic Curve



H Series Specifications—7mm Devices

Table 10. Rating and Characteristics

	Varistor Voltage V@1.0mA		Maximum Allowable Voltage		Maximum Clamping Voltage	Maximum Surge Current (8x20μs)		Rated Wattage	Energy (10x1000μs)	Capacitance (Typical)	Certification*
Number	DC (V)	Tolerance	AC (V_{RMS})	DC (V)	V@10A (V)	1 Time (A)	2 Times (A)	(W)	(J)	(pF)	
ROV07H180M	18	±20%	11	14	36[1]	500	250	0.02	1.5	2920	● ■
ROV07H220L	22	±15%	14	18	43[1]	500	250	0.02	1.7	2930	● ■
ROV07H270K	27	±10%	17	22	53[1]	500	250	0.02	2.1	2340	● ■
ROV07H330K	33	±10%	20	26	65[1]	500	250	0.02	2.8	1840	● ■
ROV07H390K	39	±10%	25	31	77[1]	500	250	0.02	3.0	1820	● ■
ROV07H470K	47	±10%	30	38	93[1]	500	250	0.02	3.8	1600	● ■
ROV07H560K	56	±10%	35	45	110[1]	500	250	0.02	4.4	1330	● ■
ROV07H680K	68	±10%	40	56	135[1]	500	250	0.02	5.4	1120	● ■
ROV07H820K	82	±10%	50	65	135	1750	1250	0.25	7.0	640	● ■
ROV07H101K	100	±10%	60	85	165	1750	1250	0.25	9.0	540	● ■
ROV07H121K	120	±10%	75	100	200	1750	1250	0.25	11.0	460	● ■
ROV07H151K	150	±10%	95	125	250	1750	1250	0.25	13.0	370	● ■
ROV07H181K	180	±10%	115	150	300	1750	1250	0.25	16.0	220	● ■
ROV07H201K	200	±10%	130	170	340	1750	1250	0.25	17.5	220	◆●▲■
ROV07H221K	220	±10%	140	180	360	1750	1250	0.25	19.0	190	◆●▲■
ROV07H241K	240	±10%	150	200	395	1750	1250	0.25	21.0	190	◆●▲■
ROV07H271K	270	±10%	175	225	455	1750	1250	0.25	24.0	160	◆●▲■
ROV07H301K	300	±10%	195	250	505	1750	1250	0.25	26.0	140	◆●▲■
ROV07H331K	330	±10%	210	275	550	1750	1250	0.25	28.0	140	◆●▲■
ROV07H361K	360	±10%	230	300	595	1750	1250	0.25	32.0	120	◆●▲■
ROV07H391K	390	±10%	250	320	650	1750	1250	0.25	35.0	110	◆●▲■
ROV07H431K	430	±10%	275	350	710	1750	1250	0.25	40.0	110	◆●▲■
ROV07H471K	470	±10%	300	385	775	1750	1250	0.25	42.0	100	◆●▲■
ROV07H511K	510	±10%	320	418	842	1750	1250	0.25	45.0	100	◆●▲■
ROV07H561K	560	±10%	350	460	920	1750	1250	0.25	51.0	85	◆●▲■
ROV07H621K	620	±10%	385	505	1025	1750	1250	0.25	54.0	80	◆●▲
ROV07H681K	680	±10%	420	560	1120	1750	1250	0.25	56.0	80	◆●▲
ROV07H751K	750	±10%	460	615	1240	1750	1250	0.25	58.0	75	◆●▲
ROV07H781K	780	±10%	485	640	1290	1750	1250	0.25	59.0	70	◆●▲
ROV07H821K	820	±10%	510	670	1355	1750	1250	0.25	60.0	70	◆●▲

[1] The clamping voltages from 180M to 680K are tested at 2.5A current.

*Certification

Standard	UL1414**	UL1449 (2nd Edition)**	CSA	VDE
Title	Across-the-Line Components	Transient Voltage Surge Suppressors	Accessories and Parts for Electronic Equipment	Varistors for Use in Electronic Equipment
Symbols	◆	●	▲	■
File Number	E223034	E223033	220978	40007001

**For UL1449 (2nd Edition), the maximum clamping voltage is measured at 500A.

H Series Specifications—7mm Devices Pulse Lifetime Ratings and V-I Characteristic Curves

Figure 22. ROV07H180M~ROV07H680K

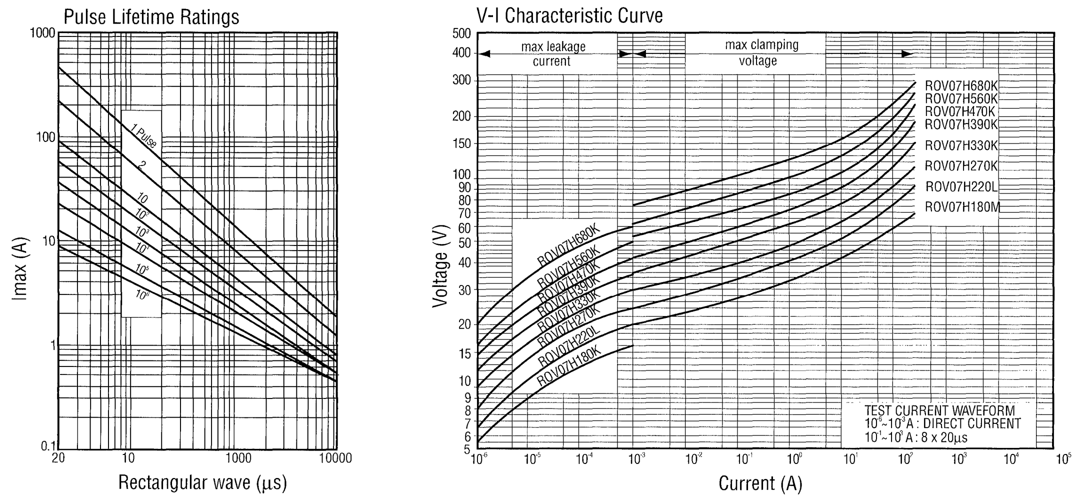
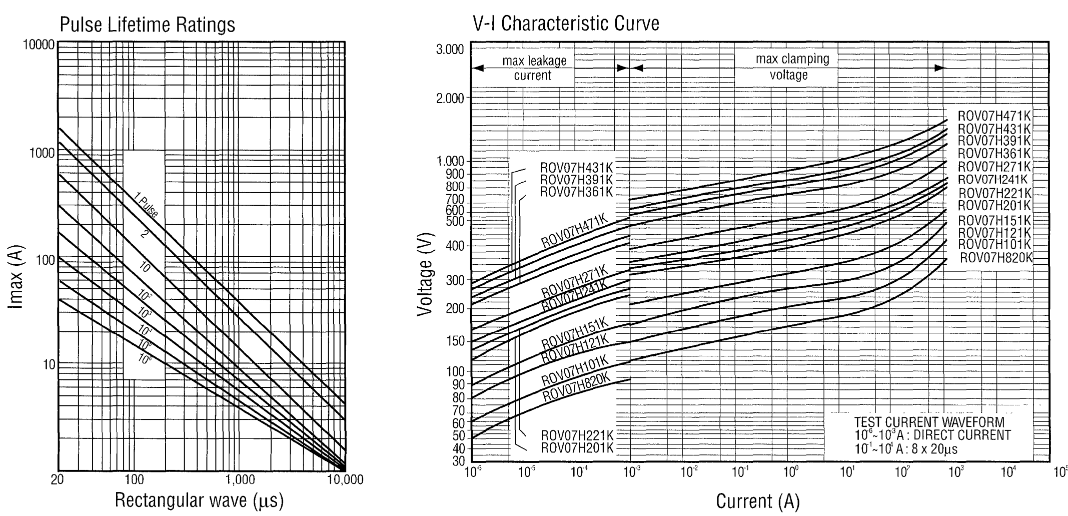


Figure 23. ROV07H820K~ROV07H471K



H Series Specifications—10mm Devices

Table 11. Rating and Characteristics

	Varistor Voltage V@1.0mA		Maximum Allowable Voltage		Maximum Clamping Voltage	Maximum Surge Current (8x20µs)		Rated Wattage	Energy (10x1000µs)	Capacitance (Typical)	Certification*
Number	DC (V)	Tolerance	AC (V_{RMS})	DC (V)	V@25A (V)	1 Time (A)	2 Times (A)	(W)	(J)	(pF)	
ROV10H180M	18	±20%	11	14	36[1]	1000	500	0.05	2.6	6500	● ■
ROV10H220L	22	±15%	14	18	43[1]	1000	500	0.05	3.2	5520	● ■
ROV10H270K	27	±10%	17	22	53[1]	1000	500	0.05	3.9	4740	● ■
ROV10H330K	33	±10%	20	26	65[1]	1000	500	0.05	4.8	4250	● ■
ROV10H390K	39	±10%	25	31	77[1]	1000	500	0.05	5.6	3660	● ■
ROV10H470K	47	±10%	30	38	93[1]	1000	500	0.05	6.8	3140	● ■
ROV10H560K	56	±10%	35	45	110[1]	1000	500	0.05	8.1	2900	● ■
ROV10H680K	68	±10%	40	56	135[1]	1000	500	0.05	9.8	2230	● ■
ROV10H820K	82	±10%	50	65	135	3500	2500	0.40	14.0	1260	● ■
ROV10H101K	100	±10%	60	85	165	3500	2500	0.40	18.0	1020	● ■
ROV10H121K	120	±10%	75	100	200	3500	2500	0.40	22.0	950	● ■
ROV10H151K	150	±10%	95	125	250	3500	2500	0.40	25.0	730	● ■
ROV10H181K	180	±10%	115	150	300	3500	2500	0.40	32.0	480	● ■
ROV10H201K	200	±10%	130	170	340	3500	2500	0.40	35.0	400	◆●▲■
ROV10H221K	220	±10%	140	180	360	3500	2500	0.40	39.0	390	◆●▲■
ROV10H241K	240	±10%	150	200	395	3500	2500	0.40	42.0	330	◆●▲■
ROV10H271K	270	±10%	175	225	455	3500	2500	0.40	49.0	330	◆●▲■
ROV10H301K	300	±10%	195	250	505	3500	2500	0.40	52.0	280	◆●▲■
ROV10H331K	330	±10%	210	275	550	3500	2500	0.40	58.0	280	◆●▲■
ROV10H361K	360	±10%	230	300	595	3500	2500	0.40	65.0	230	◆●▲■
ROV10H391K	390	±10%	250	320	650	3500	2500	0.40	70.0	250	◆●▲■
ROV10H431K	430	±10%	275	350	710	3500	2500	0.40	80.0	220	◆●▲■
ROV10H471K	470	±10%	300	385	775	3500	2500	0.40	85.0	210	◆●▲■
ROV10H511K	510	±10%	320	418	842	3500	2500	0.40	92.0	190	◆●▲■
ROV10H561K	560	±10%	350	460	920	3500	2500	0.40	102.0	190	◆●▲■
ROV10H621K	620	±10%	385	505	1025	3500	2500	0.40	107.0	160	◆●▲■
ROV10H681K	680	±10%	420	560	1120	3500	2500	0.40	112.0	160	◆●▲■
ROV10H751K	750	±10%	460	615	1240	3500	2500	0.40	115.0	130	◆●▲■
ROV10H781K	780	±10%	485	640	1290	3500	2500	0.40	116.0	120	◆●▲■
ROV10H821K	820	±10%	510	670	1355	3500	2500	0.40	118.0	130	◆●▲■
ROV10H911K	910	±10%	550	745	1500	3500	2500	0.40	127.0	110	◆●▲■
ROV10H102K	1000	±10%	625	825	1650	3500	2500	0.40	140.0	95	◆●▲■
ROV10H112K	1100	±10%	680	895	1815	3500	2500	0.40	155.0	90	◆●▲■

[1] The clamping voltages from 180M to 680K are tested at 5A current.

*Certification

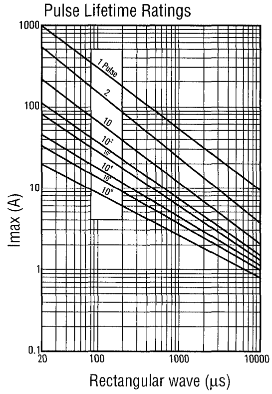
Standard	UL1414**	UL1449 (2nd Edition)**	CSA	VDE
Title	Across-the-Line Components	Transient Voltage Surge Suppressors	Accessories and Parts for Electronic Equipment	Varistors for Use in Electronic Equipment
Symbols	◆	●	▲	■
File Number	E223034	E223033	220978	40007001

**For UL1449 (2nd Edition), the maximum clamping voltage is measured at 500A.

H Series Specifications—10mm Devices Pulse Lifetime Ratings and V-I Characteristic Curves

Figure 24. ROV10H180M~ROV10H680K

Pulse Lifetime Ratings



V-I Characteristic Curve

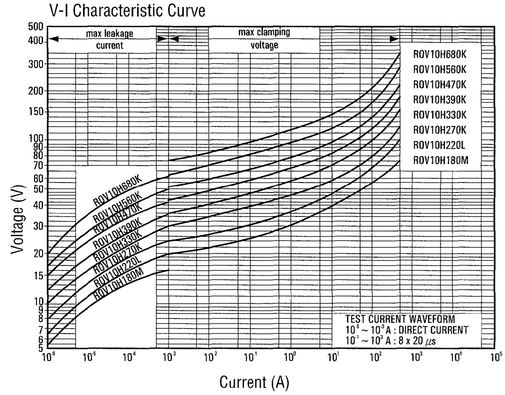
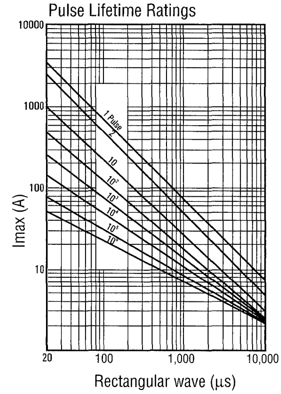


Figure 25. ROV10H820K~ROV10H511K

Pulse Lifetime Ratings



V-I Characteristic Curve

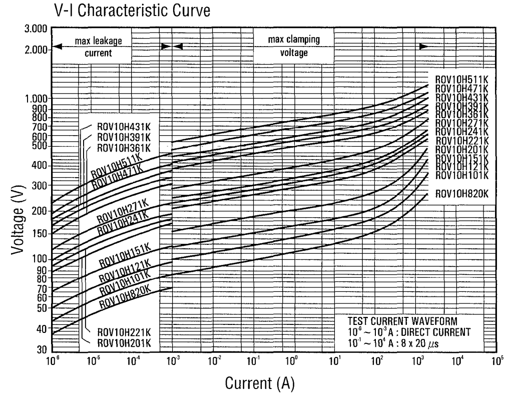
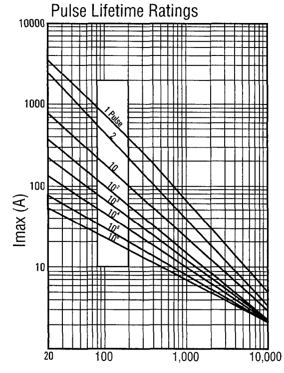
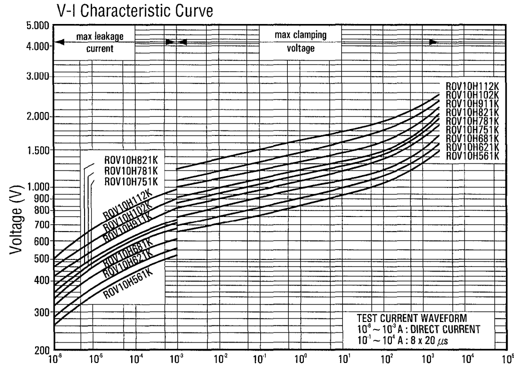


Figure 26. ROV10H561K~ROV10H112K

Pulse Lifetime Ratings



V-I Characteristic Curve



H Series Specifications—14mm Devices

Table 12. Rating and Characteristics

Number	Varistor Voltage V@1.0mA DC (V)	Tolerance	Maximum Allowable Voltage AC (V_{RMS})	Maximum Allowable Voltage DC (V)	Maximum Clamping Voltage V@50A (V)	Maximum Surge Current (8x20μs) 1 Time (A)	Maximum Surge Current (8x20μs) 2 Times (A)	Rated Wattage (W)	Energy (10x1000μs) (J)	Capacitance (Typical) (pF)	Certification*
ROV14H180M	18	±20%	11	14	36[1]	2000	1000	0.10	5.2	14890	● ■
ROV14H220L	22	±15%	14	18	43[1]	2000	1000	0.10	6.3	11960	● ■
ROV14H270K	27	±10%	17	22	53[1]	2000	1000	0.10	7.8	9730	● ■
ROV14H330K	33	±10%	20	26	65[1]	2000	1000	0.10	9.5	7700	● ■
ROV14H390K	39	±10%	25	31	77[1]	2000	1000	0.10	11.0	7620	● ■
ROV14H470K	47	±10%	30	38	93[1]	2000	1000	0.10	14.0	6420	● ■
ROV14H560K	56	±10%	35	45	110[1]	2000	1000	0.10	16.0	5180	● ■
ROV14H680K	68	±10%	40	56	135[1]	2000	1000	0.10	20.0	5100	● ■
ROV14H820K	82	±10%	50	65	135	6000	4500	0.6	28.0	2970	● ■
ROV14H101K	100	±10%	60	85	165	6000	4500	0.6	36.0	2220	● ■
ROV14H121K	120	±10%	75	100	200	6000	4500	0.6	44.0	1740	● ■
ROV14H151K	150	±10%	95	125	250	6000	4500	0.6	53.0	1510	● ■
ROV14H181K	180	±10%	115	150	300	6000	4500	0.6	65.0	920	● ■
ROV14H201K	200	±10%	130	170	340	6000	4500	0.6	70.0	840	◆●▲■
ROV14H221K	220	±10%	140	180	360	6000	4500	0.6	78.0	710	◆●▲■
ROV14H241K	240	±10%	150	200	395	6000	4500	0.6	84.0	770	◆●▲■
ROV14H271K	270	±10%	175	225	455	6000	4500	0.6	99.0	650	◆●▲■
ROV14H301K	300	±10%	195	250	505	6000	4500	0.6	105.0	650	◆●▲■
ROV14H331K	330	±10%	210	275	550	6000	4500	0.6	115.0	610	◆●▲■
ROV14H361K	360	±10%	230	300	595	6000	4500	0.6	130.0	470	◆●▲■
ROV14H391K	390	±10%	250	320	650	6000	4500	0.6	140.0	460	◆●▲■
ROV14H431K	430	±10%	275	350	710	6000	4500	0.6	155.0	450	◆●▲■
ROV14H471K	470	±10%	300	385	775	6000	4500	0.6	175.0	420	◆●▲■
ROV14H511K	510	±10%	320	418	842	6000	4500	0.6	190.0	370	◆●▲■
ROV14H561K	560	±10%	350	460	920	6000	4500	0.6	205.0	400	◆●▲■
ROV14H621K	620	±10%	385	505	1025	6000	4500	0.6	215.0	300	◆●▲■
ROV14H681K	680	±10%	420	560	1120	6000	4500	0.6	225.0	310	◆●▲■
ROV14H751K	750	±10%	460	615	1240	6000	4500	0.6	230.0	270	◆●▲■
ROV14H781K	780	±10%	485	640	1290	6000	4500	0.6	233.0	250	◆●▲■
ROV14H821K	820	±10%	510	670	1355	6000	4500	0.6	235.0	260	◆●▲■
ROV14H911K	910	±10%	550	745	1500	6000	4500	0.6	255.0	240	◆●▲■
ROV14H102K	1000	±10%	625	825	1650	6000	4500	0.6	283.0	200	◆●▲■
ROV14H112K	1100	±10%	680	895	1815	6000	4500	0.6	310.0	180	◆●▲■

[1] The clamping voltages from 180M to 680K are tested at 10A current.

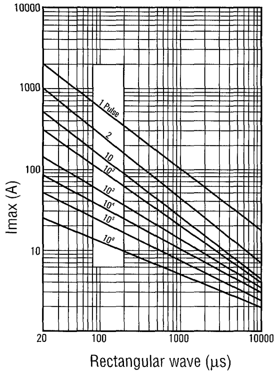
*Certification

Standard	UL1414**	UL1449 (2nd Edition)**	CSA	VDE
Title	Across-the-Line Components	Transient Voltage Surge Suppressors	Accessories and Parts for Electronic Equipment	Varistors for Use in Electronic Equipment
Symbols	◆	●	▲	■
File Number	E223034	E223033	220978	40007001

**For UL1449 (2nd Edition), the maximum clamping voltage is measured at 500A.

Figure 27. ROV14H180M~ROV14H680K

Pulse Lifetime Ratings



V-I Characteristic Curve

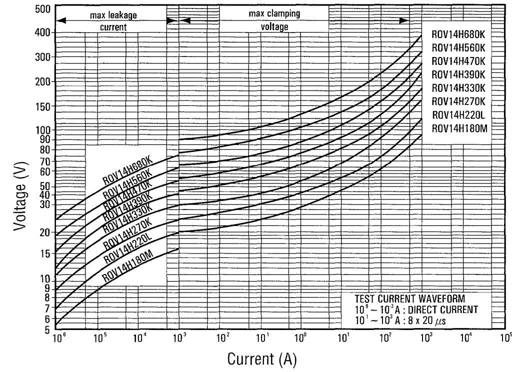
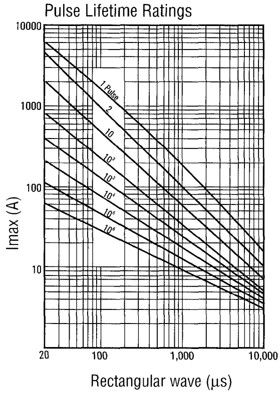


Figure 28. ROV14H820K~ROV14H511K

Pulse Lifetime Ratings



V-I Characteristic Curve

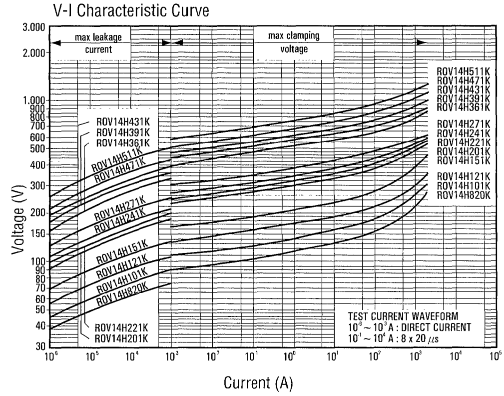
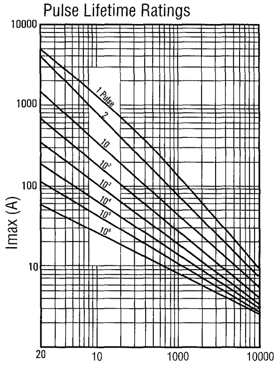
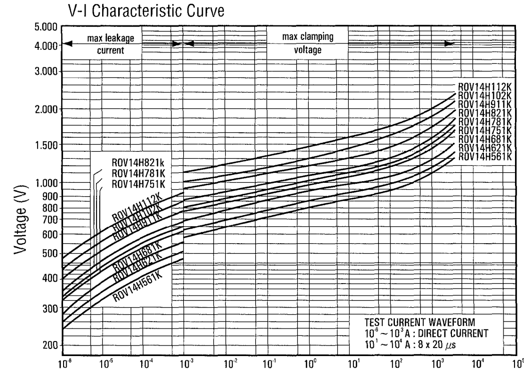


Figure 29. ROV14H561K~ROV14H112K

Pulse Lifetime Ratings



V-I Characteristic Curve



H Series Specifications—20mm Devices

Table 13. Rating and Characteristics

	Varistor Voltage V@1.0mA		Maximum Allowable Voltage		Maximum Clamping Voltage	Maximum Surge Current (8x20µs)		Rated Wattage	Energy (10x1000µs)	Capacitance (Typical)	Certification*
Number	DC (V)	Tolerance	AC (V_{RMS})	DC (V)	V@100A (V)	1 Time (A)	2 Times (A)	(W)	(J)	(pF)	
ROV20H180M	18	±20%	11	14	36[1]	3000	2000	0.2	13.0	27100	● ■
ROV20H220M	22	±20%	14	18	43[1]	3000	2000	0.2	16.0	21200	● ■
ROV20H270M	27	±20%	17	22	53[1]	3000	2000	0.2	19.0	20000	● ■
ROV20H330M	33	±20%	20	26	65[1]	3000	2000	0.2	24.0	17200	● ■
ROV20H390L	39	±15%	25	31	77[1]	3000	2000	0.2	28.0	15000	● ■
ROV20H470L	47	±15%	30	38	93[1]	3000	2000	0.2	34.0	12100	● ■
ROV20H560L	56	±15%	35	45	110[1]	3000	2000	0.2	41.0	11600	● ■
ROV20H680L	68	±15%	40	56	135[1]	3000	2000	0.2	49.0	9600	● ■
ROV20H820K	82	±10%	50	65	135	10000	6500	1.0	56.0	5200	● ■
ROV20H101K	100	±10%	60	85	165	10000	6500	1.0	72.0	4000	● ■
ROV20H121K	120	±10%	75	100	200	10000	6500	1.0	88.0	3800	● ■
ROV20H151K	150	±10%	95	125	250	10000	6500	1.0	106.0	3000	● ■
ROV20H181K	180	±10%	115	150	300	10000	6500	1.0	130.0	2400	● ■
ROV20H201K	200	±10%	130	170	340	10000	6500	1.0	140.0	1830	◆ ● ▲ ■
ROV20H221K	220	±10%	140	180	360	10000	6500	1.0	155.0	1600	◆ ● ▲ ■
ROV20H241K	240	±10%	150	200	395	10000	6500	1.0	168.0	1420	◆ ● ▲ ■
ROV20H271K	270	±10%	175	225	455	10000	6500	1.0	190.0	1260	◆ ● ▲ ■
ROV20H301K	300	±10%	195	250	505	10000	6500	1.0	210.0	1100	◆ ● ▲ ■
ROV20H331K	330	±10%	210	275	550	10000	6500	1.0	228.0	1110	◆ ● ▲ ■
ROV20H361K	360	±10%	230	300	595	10000	6500	1.0	255.0	990	◆ ● ▲ ■
ROV20H391K	390	±10%	250	320	650	10000	6500	1.0	275.0	980	◆ ● ▲ ■
ROV20H431K	430	±10%	275	350	710	10000	6500	1.0	303.0	860	◆ ● ▲ ■
ROV20H471K	470	±10%	300	385	775	10000	6500	1.0	350.0	760	◆ ● ▲ ■
ROV20H511K	510	±10%	320	418	842	10000	6500	1.0	382.0	790	◆ ● ▲ ■
ROV20H561K	560	±10%	350	460	920	10000	6500	1.0	410.0	680	◆ ● ▲ ■
ROV20H621K	620	±10%	385	505	1025	10000	6500	1.0	420.0	600	◆ ● ▲ ■
ROV20H681K	680	±10%	420	560	1120	10000	6500	1.0	430.0	550	◆ ● ▲ ■
ROV20H751K	750	±10%	460	615	1240	10000	6500	1.0	440.0	550	◆ ● ▲ ■
ROV20H781K	780	±10%	485	640	1290	10000	6500	1.0	450.0	480	◆ ● ▲ ■
ROV20H821K	820	±10%	510	670	1355	10000	6500	1.0	460.0	520	◆ ● ▲ ■
ROV20H911K	910	±10%	550	745	1500	10000	6500	1.0	510.0	440	◆ ● ▲ ■
ROV20H102K	1000	±10%	625	825	1650	10000	6500	1.0	556.0	400	◆ ● ▲ ■
ROV20H112K	1100	±10%	680	895	1815	10000	6500	1.0	620.0	360	◆ ● ▲ ■

[1] The clamping voltages from 180M to 680L are tested at 20A current.

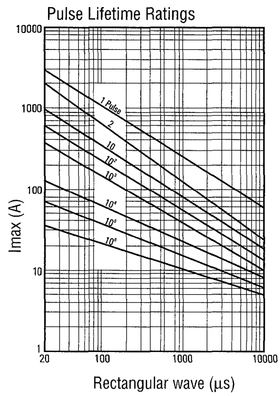
*Certification

Standard	UL1414**	UL1449 (2nd Edition)**	CSA	VDE
Title	Across-the-Line Components	Transient Voltage Surge Suppressors	Accessories and Parts for Electronic Equipment	Varistors for Use in Electronic Equipment
Symbols	◆	●	▲	■
File Number	E223034	E223033	220978	40007001

**For UL1449 (2nd Edition), the maximum clamping voltage is measured at 500A.

H Series Specifications—20mm Devices Pulse Lifetime Ratings and V-I Characteristic Curves

Figure 30. ROV20H180M~ROV20H680L



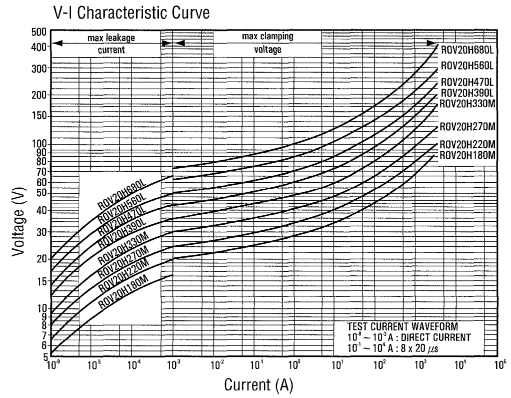
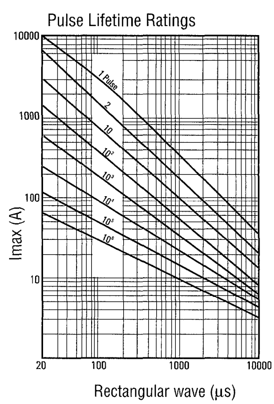


Figure 31. ROV20H820K~ROV20H511K



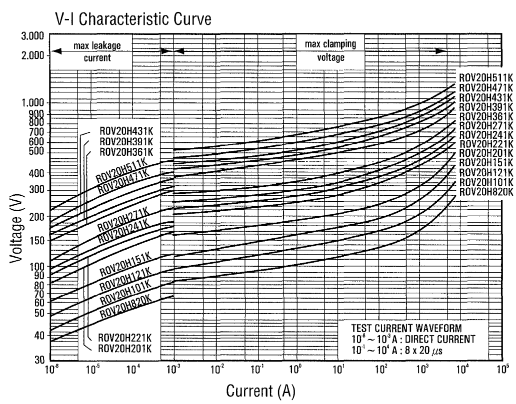
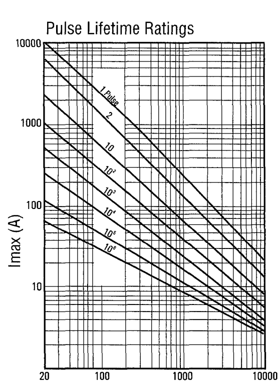
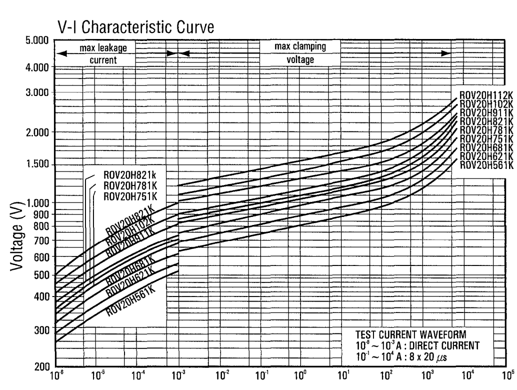


Figure 32. ROV20H561K~ROV20H112K





E Series Specifications

Table 14. Rating and Characteristics—14mm Devices

	Varistor Voltage V@1.0mA		Maximum Allowable Voltage		Maximum Clamping Voltage	Maximum Surge Current (8x20μs)		Rated Wattage	Energy (10x1000μs)	Capacitance (Typical)	Certification*
Number	DC (V)	Tolerance	AC (V_{RMS})	DC (V)	V@50A (V)	1 Time (A)	2 Times (A)	(W)	(J)	(pF)	
ROV14E201K	200	±10%	130	170	340	6500	6000	0.6	84.0	840	● ▲
ROV14E221K	220	±10%	140	180	360	6500	6000	0.6	93.0	710	● ▲
ROV14E241K	240	±10%	150	200	395	6500	6000	0.6	101.0	770	● ▲
ROV14E271K	270	±10%	175	225	455	6500	6000	0.6	113.0	—	—
ROV14E301K	300	±10%	195	250	505	6500	6000	0.6	126.0	—	—
ROV14E331K	330	±10%	210	275	550	6500	6000	0.6	138.0	—	—
ROV14E361K	360	±10%	230	300	595	6500	6000	0.6	151.0	—	—

Table 15. Rating and Characteristics—20mm Devices

	Varistor Voltage V@1.0mA		Maximum Allowable Voltage		Maximum Clamping Voltage	Maximum Surge Current (8x20μs)		Rated Wattage	Energy (10x1000μs)	Capacitance (Typical)	Certification*
Number	DC (V)	Tolerance	AC (V_{RMS})	DC (V)	V@50A (V)	1 Time (A)	2 Times (A)	(W)	(J)	(pF)	
ROV20E201K	200	±10%	130	170	340	12500	10000	1.0	168.0	2250	
ROV20E221K	220	±10%	140	180	360	12500	10000	1.0	186.0	2050	● ▲
ROV20E241K	240	±10%	150	200	395	12500	10000	1.0	202.0	1870	● ▲
ROV20E271K	270	±10%	175	225	455	12500	10000	1.0	113.0	—	—
ROV20E301K	300	±10%	195	250	505	12500	10000	1.0	126.0	—	—
ROV20E331K	330	±10%	210	275	550	12500	10000	1.0	138.0	—	—
ROV20E361K	360	±10%	230	300	595	12500	10000	1.0	151.0	—	—

4

*Certification

Standard	UL1414**	UL1449 (2nd Edition)**	CSA	VDE
Title	Across-the-Line Components	Transient Voltage Surge Suppressors	Accessories and Parts for Electronic Equipment	Varistors for Use in Electronic Equipment
Symbols	◆	●	▲	■
File Number	E223034	E223033	220978	40007001

**For UL1449 (2nd Edition), the maximum clamping voltage is measured at 500A.

Mechanical and Environmental Tests

Humidity
The part is subjected to 40±2˚C, 90 to 95% R.H. for 1000 hours without load and then stored at room temperature and ambient humidity for 1 to 2 hours. The change of V_B, (ΔV_B), is then measured and must meet the requirement of $\Delta V_B/V_B \leq \pm$ 5%; where V_B is the initial value.

Impulse Life
The maximum surge current (8 x 20µs) listed in this databook is applied 1000 times continuously with an interval of 30 seconds at room temperature. The change of V_B, (ΔV_B), is then measured and must meet the requirement of $\Delta V_B/V_B \leq \pm$10%, where V_B is the initial value.

Low Temperature Storage
The part is subjected to –40±2°C without load for 1000 hours and then stored at room temperature and ambient humidity for 1 to 2 hours. The change of V_B, (ΔV_B), is then measured and must meet the requirement of $\Delta V_B/V_B \leq \pm$5%, where V_B is the initial value.

High Temperature Load
After the Maximum Allowable Voltage is applied at 85±2°C for 1000 hours, the part is stored at room temperature and ambient humidity for 1 to 2 hours. The change of V_B, (ΔV_B), is then measured and must meet the requirement of $\Delta V_B/V_B \leq \pm$10%, where V_B is the initial value.

High Temperature Storage
The part is subjected to 125±2°C for 1000 hours in a drying oven without load and then stored at room temperature and ambient humidity for 1 to 2 hours. The change of V_B, (ΔV_B), is then measured and must meet the requirement of $\Delta V_B/V_B \leq \pm$5%, where V_B is the initial value.

Mechanical and Environmental Tests

Maximum Voltage

The specified voltage is applied between the terminals of the part for 1 minute. No mechanical damage should be noticeable.

	Classification (Nominal Varistor Voltage)	Test Voltage (AC)
Dielectric Withstand	5mm devices: V@ 0.1mA ≦330V	2500 V_{RMS}
	7,10,14,20mm devices: V@ 1.0mA ≦330V	2500 V_{RMS}
	5mm devices: V@ 0.1mA >330V	2500 V_{RMS}
	7,10,14,20mm devices: V@ 1.0mA >330V	2500 V_{RMS}

Terminal Pull Strength

After gradually applying the load specified below and keeping the unit fixed for 10 ±1s, no mechanical damage should be noticeable.

Terminal Diameter	Loading Weight in Pull Strength
0.6mm	10N (1.02Kg)
0.8mm	10N (1.02Kg)
1.0mm	20N (2.04Kg)

Terminal Bending Strength

The device is secured with one terminal in vertical position and the weight specified below is applied to the other terminal. The terminal is gradually bent by 90° in one direction, then 90° in the opposite direction and again back to the original position. This is repeated two times. No mechanical damage should be noticeable.

Terminal Diameter	Loading Weight in Pull Strength
0.6mm	5N (0.51Kg)
0.8mm	5N (0.51Kg)
1.0mm	10N (1.02Kg)

Vibration

The device is subjected to a simple harmonic motion of 0.75mm amplitude with 1.5mm maximum total excursion between limits. A 10-55Hz frequency scan is traversed in 1 minute. This motion is applied for a period of 2 hours in each of 3 mutually perpendicular directions. No mechanical damage should be noticeable.

Solderability

After dipping the terminal to a depth of approximately 3mm from the body in a soldering bath of 235 ±5°C for 2 ±0.5s, the terminal is visually examined. Approximately 95% of the terminals should be uniformly covered with new solder.

Resistance to Soldering Heat

The terminal is dipped into a soldering bath with a temperature of 260±5°C to a point of 2~2.5mm from the body of the unit. It is held there for 10±1s (5 Standard series: 5±1s) and then stored at room temperature and normal humidity for 1 to 2 hours. The change of V_B, (ΔV_B), is then measured and must meet the requirement of $\Delta V_B/V_B \leqq \pm5\%$, (where V_B is the initial value) with no noticeable mechanical damage.

Damp Heat Load

The device is subjected to 40±2°C, 90 to 95% R.H. and the maximum allowable voltage for 1000 hours and then stored at room temperature and ambient humidity for 1 to 2 hours. The change of V_B, (ΔV_B), is then measured and must meet the requirement of $\Delta V_B/V_B \leqq 10\%$, where V_B is the initial value.

Temperature Cycle

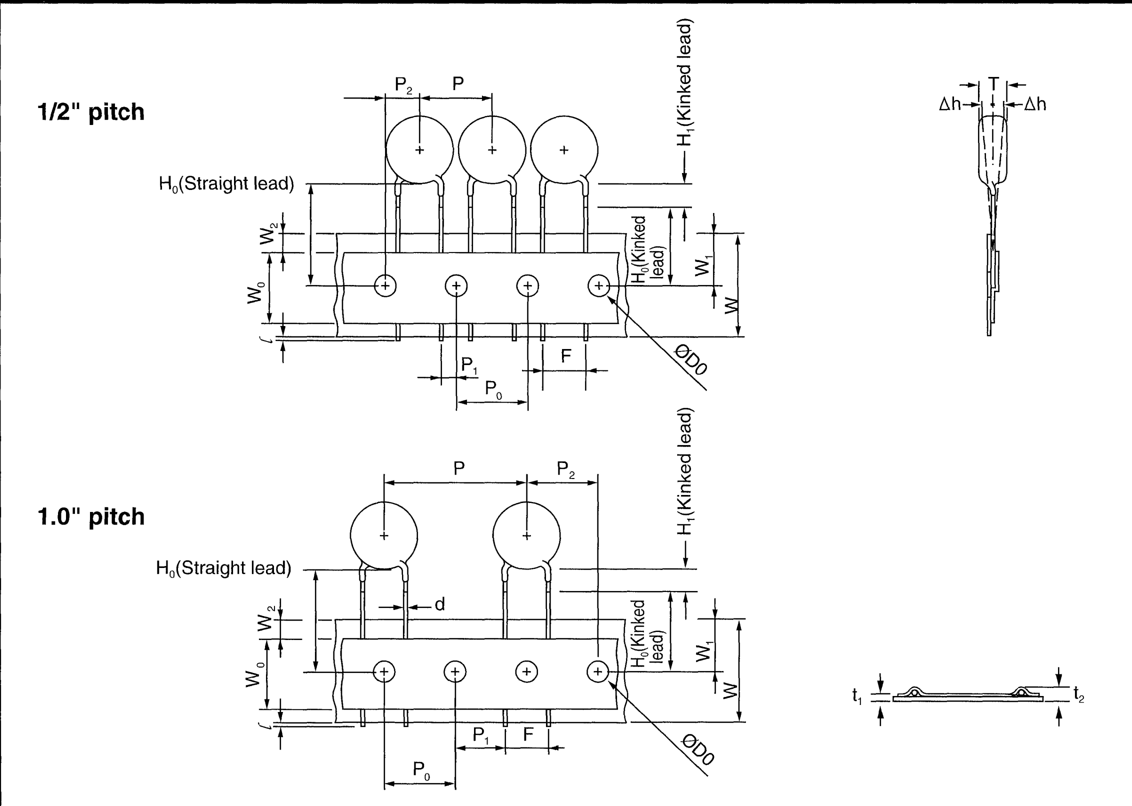
The following temperature cycle is repeated 5 times:

1. –40±3°C for 30±3 minutes
2. Room temperature for 15±3 minutes
3. 125±2°C for 30±3 minute.
4. Room temperature for 15±3 minutes

Afterwards, the part is stored at room temperature and ambient humidity for 1 to 2 hours. The change of V_B, (ΔV_B), is then measured and must meet the requirement of $\Delta V_B/V_B \leqq \pm5\%$, (where V_B is the initial value) with no noticeable mechanical damage.

Tape and reel specifications

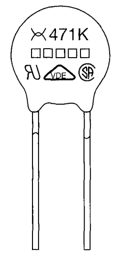
Figure 33. Tape and Reel Dimensions



Symbols	Item	5mm, 7mm	10mm, 14mm	20mm
ℓ	Cut out length	1.1mm max.	1.1mm max.	
H1(Kinked lead)	Height of kink	3.5mm max.	5.0mm max.	
H0(Kinked lead)	Height to seating plane	16.0 ± 0.5mm	16.0 ± 0.5mm	
H0(Straight lead)	Height of component from hole center	16.0–21.0mm	16.0–21.0mm	
Δh	Front to back deviation	0 ± 2.0mm	0 ± 2.0mm	
W	Carrier tape width	$18.0\ ^{+1.0}_{-0.5}$mm	$18.0\ ^{+1.0}_{-0.5}$mm	
W_0	Hold down tape width	10.0mm	12.0mm	
W_1	Sprocket hole position	$9.0\ ^{+0.75}_{-0.5}$mm	$9.0\ ^{+0.75}_{-0.5}$mm	
W_2	Adhesive tape position	3.0mm max.	3.0mm max.	
F	Component lead spacing	$5.0\ ^{+0.8}_{-0.2}$mm	$7.5\ ^{+0.8}_{-0.2}$mm	$10.0\ ^{+0.8}_{-0.2}$mm
P	Pitch of component	12.7 ± 1.0mm	25.4 ± 1.0mm	
P_0	Sprocket hole pitch	12.7 ± 0.3mm	12.7 ± 0.3mm	
P_1	Lead length from hole center to lead	3.85 ± 0.7mm	8.95 ± 0.7mm	7.7 ± 0.7mm
P_2	Length from hole center to disk center	6.35 ± 1.3mm	12.7 ± 1.3mm	
D_0	Sprocket hole diameter	4.0 ± 0.2mm	4.0 ± 0.2mm	
d	Lead wire diameter	0.6 ± 0.05mm	0.8 ± 0.05mm	1.0 ± 0.05mm
T	Disk thickness	See C max. Table (pg. 359)	See C max. Table (pg. 359)	
t_1	Total thickness tape	0.7 ± 0.05mm	0.7 ± 0.05mm	
t_2	Total thickness	1.6mm max.	1.8mm max.	

Marking and Packaging Specifications

Figure 34. Marking



⋊ : Raychem Circuit Protection Logo
471 : Varistor Voltage Indicator
K : Varistor Voltage Tolerance
□□□□□ : Lot Identification

Figure 35. Packaging (in mm)

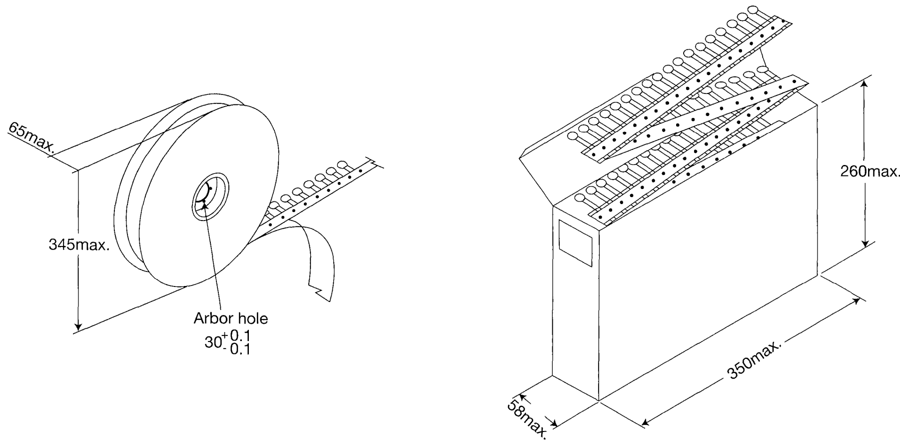


Table 16. Packaging Quantity (in pcs.)

	Series														
	5mm			7mm			10mm			14mm			20mm		
Part Number	Bulk (box)	Reel	Ammo	Bulk (box)	Reel	Ammo	Bulk (box)	Reel	Ammo	Bulk	Reel	Ammo	Bulk	Reel	Ammo
180M~470K	5000	1500	1500	5000	1500	1500	2500	1000	500	1500	750	500	750	500	500
560K~680K	5000	1500	1000	5000	1500	1000	2500	1000	500	1500	750	500	750	500	500
820K~331K	5000	1500	1500	5000	1500	1500	2500	1000	500	1500	750	500	750	500	500
361K~391K	5000	1500	1000	5000	1500	1000	2500	1000	500	1500	750	500	750	500	500
431K~471K	5000	1500	1000	5000	1000	1000	2000	750	500	1500	750	500	750	500	500
511K~751K	4000	1000	1000	4000	1000	1000	1500	500	500	750	500	500	450	—	—
781K~182K	—	—	—	—	—	—	1500	—	—	750	—	—	450	—	—

Packaging	Bulk (box)	Reel	Reel (14mm, 20mm)	Ammo (5mm, 7mm)	Ammo (10mm, 14mm) 180K-471K	Ammo (10mm, 14mm) 471K-751K	Ammo (20mm) 180K-471K
Box size (mm)	290 x 155 x 110	350 x 350 x 108	350 x 350 x 74	330 x 240 x 46	343 x 210 x 52	343 x 260 x 52	343 x 220 x 58
Carton size (mm)	310 x 328 x 250	371 x 371 x 590	370 x 370 x 468	350 x 500 x 270	363 x 440 x 250	363 x 540 x 250	363 x 460 x 250
One carton with	4 Boxes	5 Boxes (10 reels)	6 Boxes (6 reels)	10 Boxes	8 Boxes	8 Boxes	8 Boxes

Part Numbering System

ROV 14 – 221 K -S -10 1 -2

Radial-leaded Metal Oxide Varistor — ROV

Diameter of disc — 14

05 : 5mm
07 : 7mm
10 : 10mm
14 : 14mm
20 : 20mm

Surge series — –

– : Standard series (Standard surge series)
H : H series (High surge series)
E : E series (Extra high surge series)

Varistor voltage indicator — 221

The first two digits indicate voltage.
The third digit signifies the power of ten.
For example:
220 : $22 \times 10^0 = 22V$
221 : $22 \times 10^1 = 220V$
112 : $11 \times 10^2 = 1100V$

Varistor voltage tolerance — K

K : ± 10%
L : ± 15%
M : ± 20%

4

Lead configuration — -S

No suffix : Kinked lead
-S : Straight lead
-A : Inside crimp "Type A"
-B : Inside crimp "Type B"
-C : Outside crimp "Type C"
-D : Outside crimp "Type D"

Lead spacing — -10

No suffix : standard spacing (see table on page 359)
-5 : 5mm
-7 : 7.5mm
-10 : 10mm

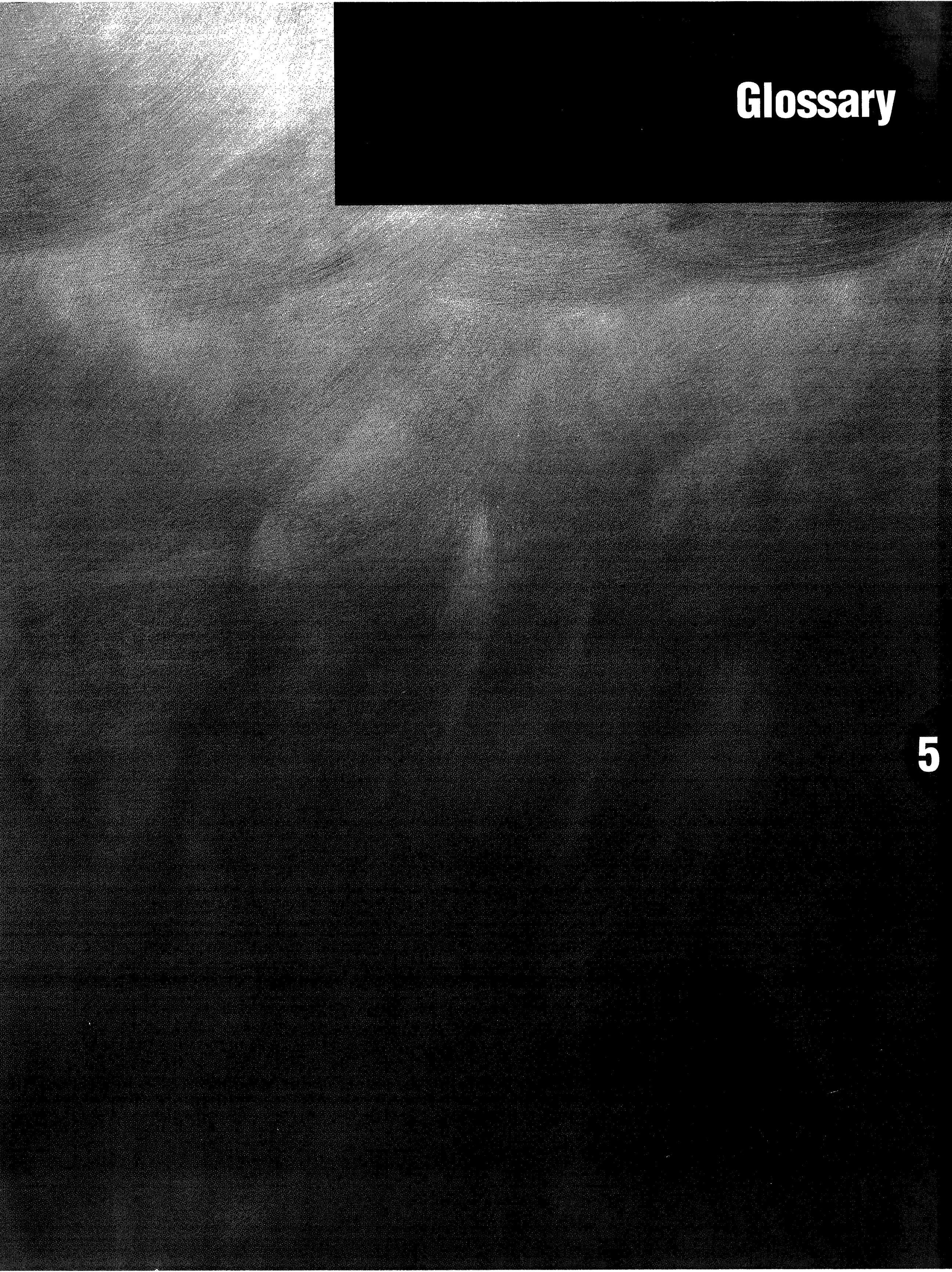
Lead diameter — 1

No suffix : standard diameter (see table on page 359)
6 : 0.6mm
8 : 0.8mm
1 : 1.0mm

Packaging — -2

No Suffix : Bulk
-2 : Tape & reel
-AP : Ammo pack

Glossary



5

5

Glossary

Active High
Power switch enable input voltage must exceed the device's defined threshold voltage for the device to turn on (typically 1.5V). Conversely, enable input voltage must fall below the threshold voltage to turn the device off.

Active Low
Power switch enable input voltage must fall below the device's defined threshold voltage (typically 1.5V) for the device to turn on. Conversely, enable input voltage must exceed the threshold voltage to turn the device off.

Breakover Voltage (V_{BO})
Maximum voltage across a SiBar thyristor at breakdown measured under a specified voltage rate of rise and current rate of rise.

Bus-Powered
Class of devices that derive their power from the main hub. Examples include USB hubs, keyboards, mice, and internet cameras.

Breakover Current (I_{BO})
Instantaneous current flowing at the breakover voltage, V_{BO}.

Conductive Polymer
A dispersion of conductive particles in an insulating organic polymer.

Controller (USB)
Device that provides the direct interface between the power switch device and the microprocessor. Enable and flag pin outputs connect directly into the power switch device.

Critical Rate of Rise of Off-State Voltage
Maximum voltage rate of rise that will not cause a SiBar thyristor to turn on.

Critical Rate of Rise of On-State Current
Maximum current rate of rise a SiBar thyristor can withstand without damage.

Current, Hold (I_H or I_{HOLD})
The largest steady-state current that, under specified ambient conditions, can be passed through a PolySwitch device without causing the device to trip. For SiBar thyristors, the current at which the device resets to a high-impedance state once the surge current dissipates. *See also* Hold Current.

Current Limit
Maximum steady-state current level at which the power switch output is regulated in response to an overcurrent fault.

Current, Maximum Interrupt (I_{MAX})
The highest fault current that can safely be used to trip a PolySwitch device under specified conditions. Typically the lower the voltage dropped across the PolySwitch device in its tripped state, the higher the maximum interrupt current. Maximum interrupt currents are usually shown in this Databook at the maximum voltage. It may be possible to use a PolySwitch device at a higher interrupt current, but each such use must be individually qualified.

Current, Normal Operating
The highest steady state current that is expected to flow in a circuit under normal operating conditions. At the maximum ambient operating temperature of the circuit, the hold current of a PolySwitch device used to help protect the circuit is typically greater than the normal operating current.

Current, Operating Range
The range of normal operating currents in a circuit containing a PolySwitch device. Typically the hold current of the PolySwitch device should be greater than the top of the operating current range.

Current, Trip (I_T)
The smallest steady state current that, if passed through a PolySwitch device, will cause the device to trip, under specified conditions.

Disable
The act of de-asserting the enable signal to turn off the device. In the case of an EN low device, the EN signal must exceed the typical threshold voltage of 1.5V.

Enable (EN)
The act of asserting the enable signal to turn on the device. In the case of an EN low device, the EN signal must fall below the typical threshold voltage of 1.5V.

Flag (FLG)
Power switch output that provides the USB controller the power switch device status. When FLG = High, the output MOSFET allows power to flow from the supply rail.

Flag Delay Time
Design feature that delays the FLG notification signal in response to an abnormal condition (e.g., hot-plug event, overcurrent surge, overtemperature condition). This feature minimizes unnecessary nuisance "trips" caused by the inrush current of high-capacitive loads.

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Functions
Class of devices designed to perform a specific task. Examples include USB internet cameras, joysticks, mice, and digital cameras.

Ganged Port Protection
Protection method where one circuit protection device is used to protect more than one output port.

Hold Current (I_H or I_{HOLD})
The largest steady-state current that, under specified ambient conditions, can be passed through a PolySwitch device without causing the device to trip. For SiBar thyristors, the current at which the device resets to a high-impedence state once the surge current dissipates. *See also* Current, Hold.

Host
The root of the USB architecture which provides signal/data and power (for bus-powered peripherals). In a USB application, the host is typically within the main CPU.

Hot-Plug
The act of making a connection to the output port of a functioning peripheral or host. USB architecture is designed to recognize the connected function and enable it by providing necessary power and loading all necessary drivers.

Hub
Class of USB equipment that attaches to the host and provides additional USB output connections for other hubs or functions. May be classified as self-powered hubs or bus- and self-powered hubs.

Humidity Aging Test
See Test, Humidity Aging.

I_H
See Current, Hold.

I_{HOLD}
See Current, Hold.

I_{MAX}
See Current, Maximum Interrupt.

$I_{SC\ MAX}$
The maximum short circuit when a PolySwitch device is tested at the maximum operating voltage under specified conditions.

I_T
See Current, Trip.

Individual Port Protection
Protection method where each output is protected by one circuit protection device. For devices with multiple outputs, isolation is provided so that a port can respond to a fault condition without impacting the performance of the other port(s).

Initial Resistance
See Resistance.

Maximum Ambient Operating Temperature
See Temperature, Maximum Ambient Operating.

Maximum Device Voltage
See Voltage, Maximum.

Maximum Interrupt Current
See Current, Maximum Interrupt.

Maximum Interrupt Voltage
See Voltage, Maximum.

Maximum Operating Voltage
See Voltage, Maximum Operating.

Maximum Voltage
See Voltage, Maximum.

Normal Operating Current
See Current, Normal Operating.

Off-State Capacitance
Capacitance in the off-state measured at a specified frequency, amplitude, and DC bias.

Off-State Current (ID)
DC value of the current through a SiBar thyristor that results from the application of the off-state voltage, V_D. I_{DM} designates the maximum off-state current.

Off-State Voltage (V_D)
DC voltage when a SiBar thyristor is in the off-state. V_{DM} designates the maximum off-state voltage.

On-State Current (I_T)
Current through a SiBar thyristor in the on-state condition I_T.

On-State Voltage
Voltage across a SiBar thyristor in the on-state condition at a specified current, I_T.

Operating Range Current
See Current, Operating Range.

Overtemperature Protection
For power switch devices, design feature that protects the silicon die from exceeding its designed operating temperature range. The device will thermally cycle until the abnormal condition is corrected.

Overvoltage Lockout (OVLO)
Design feature that protects the silicon die and downstream peripherals from supply voltage conditions that exceed its operating voltage limits.

P_D
See Power Dissipation.

Passive Aging Test
See Test, Passive Aging.

Peak Pulse Current
Rated maximum value of peak pulse current of specified amplitude and waveshape.

Positive Temperature Coefficient (PTC)
A term used to describe a material whose resistivity increases as temperature increases. PolySwitch devices use conductive polymers that show nonlinear PTC behavior.

Post-Reflow Resistance
See Resistance, Post-Reflow.

Post-Trip Resistance
See Resistance, Post-Trip.

Power Dissipation (P_D)
The power (in watts) dissipated by a PolySwitch device in its tripped state. The power dissipation is the product of the current flowing through the device and the voltage across the device in the tripped state.

Power Switch
MOSFET-based switch that controls the flow of power through its output using an enable (EN) signal from a system controller. Advanced designs will include integrated pull-up resistors and capacitors to minimize board space and cost. PS300, PS400.

PTC
See Positive Temperature Coefficient.

R_{MAX}
See Resistance.

R_{MIN}
See Resistance.

R_{1MAX}
See Resistance, Maximum.

RA_{MAX}
Maximum functional resistance of device before and after defined stress tests.

RA_{MIN}
Minimum functional resistance of device before and after defined stress tests.

5

Resistance (or Initial Resistance, Base Resistance, R_{MIN}, or R_{MAX})
The resistance of a PolySwitch device under specified conditions (e.g., 20°C) before connection into a circuit. Devices of a particular type will be delivered with a range of resistances; therefore, a minimum value, RMIN, and/or a maximum value, RMAX, are often given.

Resistance Binned Devices
Resistance binned devices are supplied such that all parts in one package are within 0.5Ω of each other. Individual binned packages are supplied from the full resistance range of the specified product/series.

Resistance, Maximum (R_{1MAX})
The maximum resistance of a PolySwitch device at room temperature one hour after being tripped or after reflow soldering.

Resistance, Post-Reflow
The resistance of a PolySwitch device at room temperature one hour after it has been connected to a circuit board by reflow soldering under specified conditions.

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Resistance, Post-Trip
The resistance of a PolySwitch device at room temperature one hour after the device has been tripped for the first time, under specified conditions.

Resistance Sorted Devices
Resistance sorted devices (part number suffix "Rx") are supplied with resistance values that are within specified limits of the product's full range of resistance.

Self-Powered Hub
Class of devices which derive power from their own source. Examples include monitors and self-powered USB hubs.

Solvent Resistance Test
See Test, Solvent Resistance.

Supply Current
For power switch devices, the rated output current of a given device. Power switch devices have been designed to support a continuous load (supply) current of 0.6A at ambient temperature.

Supply Voltage
Voltage level of the power switch input. Raychem power switch devices have been designed to operate using supply voltage levels from 3.0V to 5.5V.

Temperature, Maximum Ambient Operating
The highest ambient temperature at which a circuit is expected to operate.

Temperature Range
The ambient temperature range of the air (or other medium) surrounding a PolySwitch device under normal operating conditions.

Test, Humidity Aging
A test described in Raychem's PS300 publication in which the resistance of a PolySwitch device at room temperature is measured before and after aging at an elevated temperature (e.g., 40°C) and high humidity (e.g., 95% RH) for an extended time (e.g., 1000 hours).

Test, Passive Aging
A test described in Raychem's PS300 publication in which the resistance of a PolySwitch device at room temperature is measured before and after aging at an elevated temperature (e.g., 70°C or 85°C) for an extended time (e.g., 1000 hours).

Test, Solvent Resistance
A test described in Raychem's PS300 publication to test the durability of the markings on PolySwitch devices when exposed to various solvents.

Test, Thermal Shock
A test in which the resistance of a PolySwitch device at room temperature is measured before and after a temperature cycling treatment (e.g., cycled 10 times between –55°C and +125°C).

Thermal Cut-Off
The temperature at which a PolySwitch device will trip when sourced with a specific current.

Thermal Derating
The change in the hold current and trip current of a PolySwitch device that takes place when there is a change in the ambient temperature of the air (or other medium) surrounding the device. An increase in ambient temperature decreases the hold current (and the trip current). A decrease in ambient temperature increases the trip current (and the hold current).

Thermal Shock Test
See Test, Thermal Shock.

Time-to-Trip
See Trip Time.

Trip
Switching of a PolySwitch device from a low resistance to a high resistance. In its low-resistance state, the device permits normal currents to flow in a circuit. Occurrence of a fault drives the device to its high-resistance (or "tripped") state, and this reduces the current in the circuit to a low level.

Trip Current
See Current, Trip.

Trip Cycle
The tripping and resetting of a PolySwitch device under specified conditions.

Trip Cycle Life
The number of trip cycles that a PolySwitch device will undergo without failure, with failure being defined in a specified way.

Trip Time (or Time-to-Trip or T+T)
The time needed, from the onset of a fault current, to trip a PolySwitch device. For any particular type of PolySwitch device, trip time depends upon the size of the fault current and the ambient temperature. The higher the fault current and/or the higher the temperature, the shorter the trip time.

Undervoltage Lockout (UVLO)
Design feature that helps regulate the quality of the output voltage by turning the device OFF in response to supply voltages that fall below its UVLO level.

USB
Universal Serial Bus interoperability standard that defines the electrical power and signal transfer requirements in computing and multi-media applications. USB power requirements define a supply and output voltage of 5V, with output currents rated at 0.5A for self-powered equipment and 0.1A output for bus-powered equipment.

V_{MAX}
See Voltage, Maximum.

Voltage, Maximum (V_{MAX}) or Maximum Device Voltage or Maximum Interrupt Voltage
The highest voltage that can safely be dropped across a PolySwitch device in its tripped state under specified fault conditions.

Voltage, Maximum Operating
The maximum voltage across a PolySwitch device under a typical fault condition. In many circuits, this is the voltage of the power source in the circuit. It may be possible to use a PolySwitch device at a higher voltage, but each such use must be individually qualified.

NOTES

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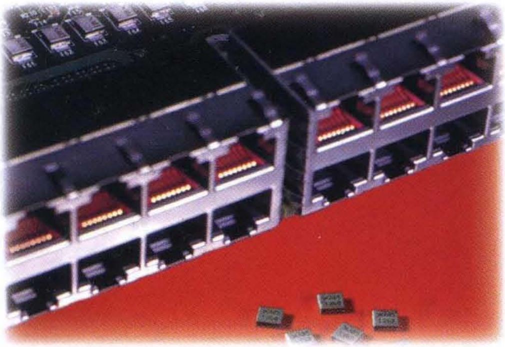
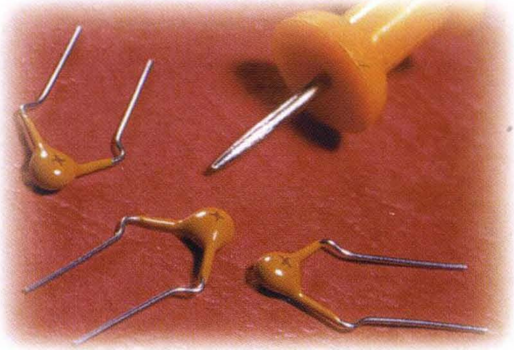


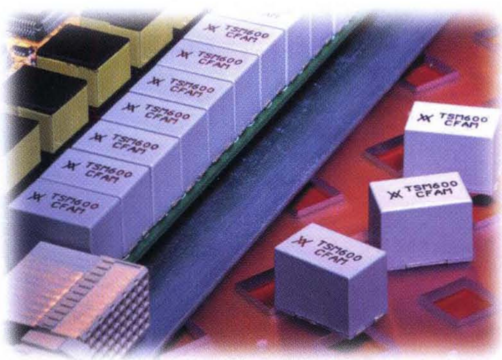

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