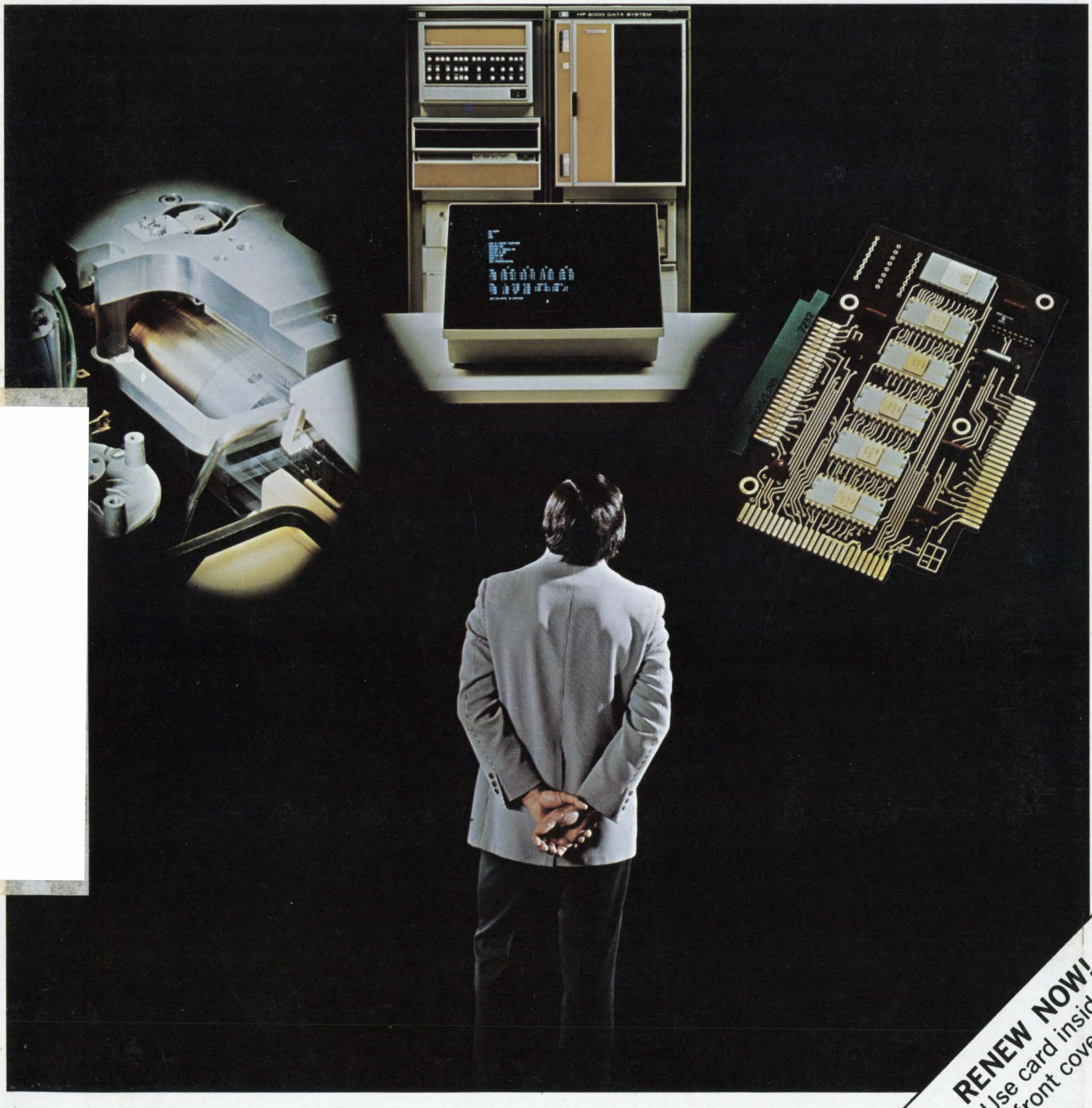
VOL. 22 NO.

Electronic Design 22

FOR ENGINEERS AND ENGINEERING MANAGERS

OCT. 25, 1974

What's in store for computers? Semiconductors will dominate the memory scene, although core technology continues to advance. In peripherals, the accent will be on high-density disc drives and serial printers. Other areas to watch are microprogramming and timesharing. For more on computer design, turn to P.34



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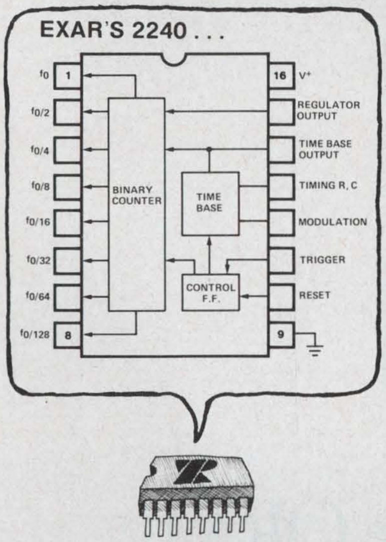

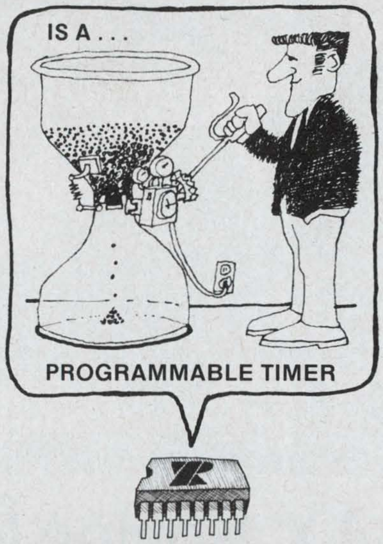

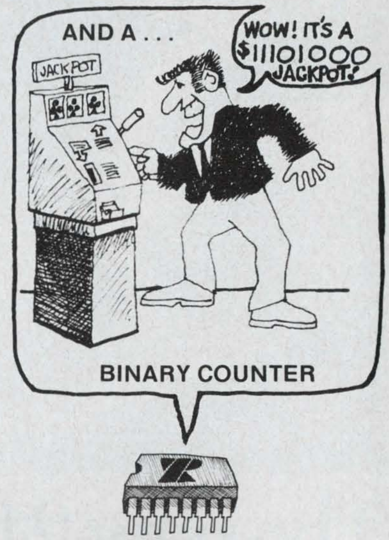

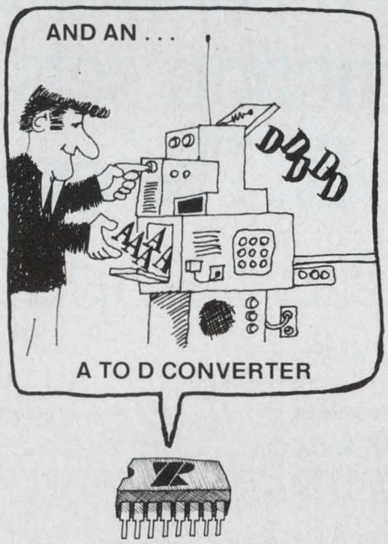

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INFORMATION RETRIEVAL NUMBER 2

INFORMATION RETRIEVAL NUMBER 3

VOL. 22 NO

Electronic Design 22

FOR ENGINEERS AND ENGINEERING MANAGERS

OCT. 25, 1974

NEWS

TECHNOLOGY

PRODUCTS

DEPARTMENTS

Cover: Photo by Hal Smith, courtesy of Hewlett-Packard. The cover shows the moving-head mechanism from a disc memory (left); a scientific data system with a microwave problem shown on the screen (center) and a complete plug-in micro-code instruction set.

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easy does it
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STRIP

A pushbutton system for instant cable installation? It's not here yet, but a Belden wire, cable and cord specialist does have the know-how and product capabilities that can save you time and money all down the line. An important point, if you consider that cable usually costs far less per foot than the man-hours of the people installing it.

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Or write Belden Corporation, 2000 South Batavia Avenue, Geneva, Illinois 60134.

H-1-3

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INFORMATION RETRIEVAL NUMBER 234

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across the desk

More features added to CAD program

With reference to my article "Program Gives Filter Time Response" (ED No. 9, April 26, 1974, p. 192), the following lines should be added to the program:

```
595 NN (I) = NP(I)
1215 N (K+1) = 0
1235 N (DORD +1)
     = NN (DORD + 1)
1245 N(J) = NN(J)
```

In addition five other lines already in the program should be changed as follows:

```
100 REAL N(100), IM, IMD,
    NP(100), IMN, NF(11),
    NN(11)
130 DIMENSION D(100),
    RTR(11), RTJ(11),
    M (11), DP(100),
    ANS(2, 10, 10)
1410 260 CALL PQVAL (RTR,
    RTJ, N, . . .)
1670 SANS = -2.*LL*ANS
    (2, I, (L1+1))
1680 CANS = 2.*ANS
    (1, I, (L1+1))
```

Note that N replaces M in the Call statement.

These modifications allow the program to be used with functions that have more than one higher-order pole. The original restrictions of denominator of 10th order or less and up to fourth-order poles still hold. But the case of

$$\frac{A(S)}{(S+a)^4(S+b)^3(S+c)^2},$$

for example, may now be handled. Due to an oversight in the original program, only one higher-order pole had been considered. Lines 1670 and 1680 were in error, but the mistake did not become apparent until programs involving higher-order, complex poles were attempted.

In addition to these main program alterations, further consideration must be given to the root-finding subroutine—DOWNH. In most root-finding schemes, the accuracy with which higher-order roots can be found is typically much less than for single-order roots. For this reason, the program LAPTR may not treat high-order poles correctly, but rather as closely spaced first-order poles.

The input section of the program may be bypassed if the pole locations are known. For the example

$$F(S) = \frac{1}{S(S+2)^2(S+1+j)^3(S+1-j)^3},$$

the denominator factors were first multiplied and entered into the program through the normal conversational input routine. The roots produced by DOWNH caused the final solution to be about 1% accurate.

The nine poles were then entered directly into arrays RTR and RTJ at statement 900. The coefficients and exponents of the resulting

(continued on p. 17)

TAKE IT OFF!

Peel off the label on this magazine, then affix it to your renewal card inside the front cover of this issue. Fill in and mail the form. In return we'll send you ELECTRONIC DESIGN for another full year. Fair enough?

Electronic Design welcomes the opinions of its readers on the issues raised in the magazine's editorial columns. Address letters to Managing Editor, Electronic Design, 50 Essex St. Rochelle Park, N.J. 07662. Try to keep letters under 200 words. Letters must be signed. Names will be withheld on request.

McMOS is the CMOS source...with

Think of it as a liberator. It's the first CMOS variable length shift register, Motorola's new MC14557, the 1 to 64-bit shift register.

It frees you from the nuisance and cost of controls required when using fixed length registers in odd length applications.

Simplify variable and odd length SR applications

The MC14557 is a static, clocked, serial shift register which is easily programmed for any length between 1 and 64 bits. That means it can be used for variable digital delay lines and other cases where length must vary during system operation, as well as for the implementation of odd length registers.

Because serial data may be selected from either A or B inputs with a select input, recirculation is no problem for the MC14557. There is a clock enable input, too, to provide gating of the clock or negative edge clocking capability. And, the MC14557 has an asynchronous master reset. It's available in standard 16-pin plastic or ceramic dual in-line packages. The plastic (CP) version sells for $6.00 (1K to 4,999).

Think of the MC14557 as a liberator, and as one heck of a shift register.

MC14557 – one of eight SRs

Of course the MC14557 is just the newest among the McMOS* family's line-up of eight different shift registers ranging from the 4-bit MC14035 to the 128-bit MC14562.

Yes, Motorola's broad CMOS family offers more, and not just in shift registers. There's an excellent selection of the older simple circuits, the gates, flip-flops, etc., to go with the widest assortment of more contemporary MSI functions. In addition to the shift registers, the McMOS MSI line serves system logic needs with timers, counters, decoders, latches, buffers, data routers, arithmetic functions, analog multiplexers, and supplies more three-state CMOS logic than any other source. Then there are the ROMs, RAMs, and specialized functions like the priority encoder, parity tree, and dual Schmitt trigger. Motorola's McMOS is, in fact, the broadest line of CMOS available.

Prices have never been so low

As new automated production lines in Austin, Texas add their output, total volume is increased to match continuing yield improvements at all facilities. As a result, availability is the best it has ever been, and after two major price reductions in six months, prices are the lowest. We've said it before. Don't take our word for it. Ask someone who's tried us recently, or better, contact your franchised Motorola distributor and ask about McMOS. Remember, though, if you don't specify MC14000 or MC14500 series device types you may not get the lowest possible quote.

For additional technical information on the MC14557 variable length shift register, write to Motorola Semiconductor Products, Inc., P.O. Box 20912, Phoenix, Arizona 85036. For full technical and applications information, the McMOS Data Book and the McMOS Handbook are both on sale at franchised Motorola distributors.

*McMOS is a trademark of Motorola Inc.

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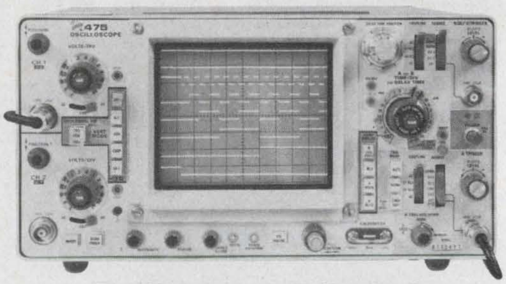
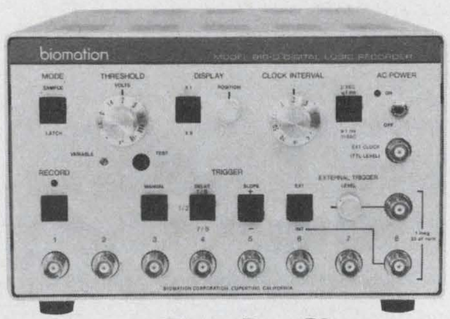


your scope



our glitch fixer™

8 traces of digital logic!

If your world is digital, Biomation's 810-D Glitch Fixer can help you. Mate it to your scope and it captures and displays complex timing events on 8 channels at once. At speeds to 10MHz. *On your bench scope.*

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Features:

- Eight logic signal channels with 1M Ohm inputs.
- Presents 8 x 256 bits of recorded data on scope in easily-interpreted timing-diagram form.
- Input latch mode selection provides detection of random pulses—as narrow as 10ns.
- Selectable logic thresholds include TTL and EIA levels.
- Synchronous clock input to 10MHz.
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- Digital output allows computer analysis or mass storage.

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So if you've got a single trace scope and an 8-trace problem, Biomate it with a Glitch Fixer. Get all the glorious details by calling, writing or circling the reader service number. Biomation, 10411 Bubb Road, Cupertino, CA 95014. (408) 255-9500. TWX 910 338 0226.

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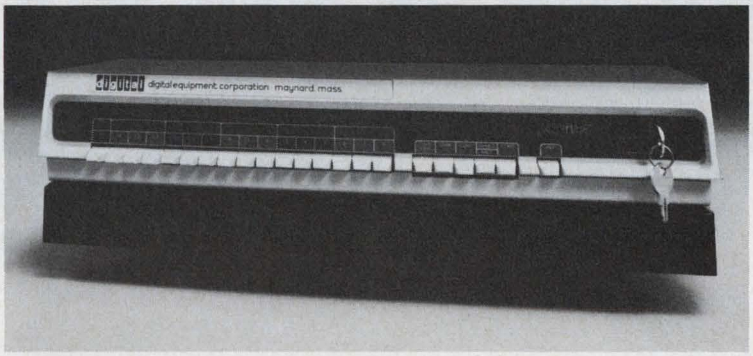

This is what The OEM Factory is all about.

A 23% reduction in price on complete minicomputers with 8K words of memory, programmers console, realtime clock, serial line interface and power fail/restart feature built right in (inset, above).

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And even with this new low price you still get the same quality and service Digital is famous for.

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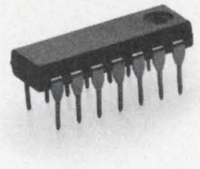
digital

INFORMATION RETRIEVAL NUMBER 11

All those little wires have been pushed around long enough.



Until now, all those wires have been at the mercy of packaging materials that expand when things get hot.

So we developed new Dow Corning® 480 semiconductor molding compound.

Dow Corning 480 has a low coefficient of thermal expansion.

So it virtually eliminates the hot intermittent open. And moisture penetration.

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Dow Corning 480 semiconductor molding compound is the kind of improved product you can expect to keep getting from Dow Corning. Our Technical Service and Development Department has more manpower and greater technical facilities than any other in the industry.

If you want to know more about 480, call us at 517 636-8000, or write Dow Corning Corporation, Dept. A-4334, Midland, Michigan 48640. **DOW CORNING**

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For $395 how many functions should a Function Generator generate?

Fifteen. That's the number of waveforms you can get with Krohn-Hite's Model 5100A. How? A unique Symmetry Control that allows pulse rep rate to be set independently of pulse width and also provides independently adjustable triangle slopes. You can skew any of the basic sine, square, triangle and ramp waveforms by as much as 99% to produce 10 additional functions. Frequency range of 0.002 Hz to 3 MHz can be manually tuned or externally controlled for VC of 1000:1. When you compare the 5100A with the rest, there's quite a generation gap. For fast action, call The Wavemakers at (617) 491-3211, TWX 710-320-6583 Krohn-Hite Corporation, 580 Mass. Ave., Cambridge, Mass. 02139.

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INFORMATION RETRIEVAL NUMBER 13

(continued from page 7)

time-domain function, as printed in the program output, agreed with similar results—laboriously derived by hand—to better than five significant figures.

Thomas H. Lecklider
Design Engineer

Gould Inc.
Instrument Systems Div.
3631 Perkins Ave.
Cleveland, Ohio 44114

Reverse those captions

In the article "Vhf, Uhf and Microwave Systems Reap Cost and Efficiency Benefits" (ED No. 17, Aug. 16, 1974, pp. 44-52), the captions on pp. 48 and 50 were switched. The one on p. 48 should be the parametric amplifier; and on p. 50, the microwave frequency down-converter.

Stay educated; read trade books

I enjoyed your editorial "The Good Boss" (ED No. 16, Aug. 2, 1974, p. 59). I would like to see a follow-up on just how your hero managed to "research the hell out of everything" without missing the budget and the delivery schedule. I'll bet he did much of this "research" by dilligent reading of technical publications like ELECTRONIC DESIGN.

These publications are the most important part of every engineer's continued education. Here are some reasons why:

- The advertising keeps him aware of the competition's latest device design.
- The advertisements for parts cue him into the latest in parts and subassemblies.
- The bingo-card checkoffs help him keep a continuous flow of the latest catalog information for his reference file.
- The technical articles move him up to the latest designs, and to methods of assembly and test.
- The check-off sections, which

(continued on page 22)

Centralab perspectives

FOR USERS OF ELECTRONIC COMPONENTS

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A new concept in thick film hybrid circuits lowers cost and broadens applications.

New resistor paints, automated production and laser trimming aren't the only reasons that the NEW PEC™ circuits from Centralab are the high quality performers engineers demand.

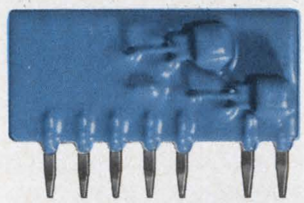
It's not surprising that the announcement of a breakthrough in thick film hybrid technology should come from Centralab. The product of a totally new concept in automated production, NEW PEC employs specially developed resistor paints that give these thick film circuits improved tolerance, better TCR, reduced noise and greater stability during load life. They offer unmatched reliability, through laser trimming and computerized pretest and final testing. Automation means increased production capacity for high volume orders and faster delivery. Complete processing time — from substrate to finished circuit — has been reduced from several days to a matter of hours. Yet, with all these improvements, NEW PEC is price competitive with discrete components.

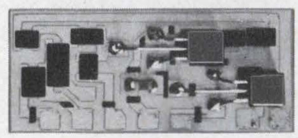
Ever since 1945, when Centralab pioneered thick film microcircuitry, they have continued to make major contributions to the technology and have been a leading supplier of thick film hybrid circuits. With the announcement of the NEW PEC system, they can now meet the increasing demands of present high-volume users and have extended the use of thick film hybrids to a whole new range of applications.

The automated production equipment recently developed by Centralab engineers brings a new degree of sophistication to the art of thick film hybrid microcircuitry. Advanced features like these can help you apply NEW PEC thick film hybrids:

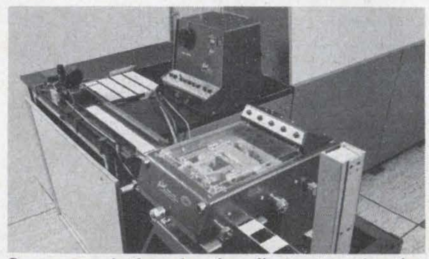
- **TCR reduced from −1700 ppm/°C to −375 ppm/°C.**
- **Resistor tolerance improved from ±10% to ±5%.**
- **Noise reduced from 15 db to 9 db.**
- **Resistor stability improved 35%.**
- **Alumina and steatite substrates for greater strength and better heat sinking for mounting active devices.**
- **Automatic screen printing insures precise metallization and resistor patterns.**
- **Mechanized component and lead attachment improves reliability 86%.**
- **Computer controlled laser pretest and adjustment. No problems of overadjustment, abraded metallizing or contamination from sand abrasion.**
- **All circuits tested before and after encapsulation.**

Centralab's NEW PEC opens new vistas for the user of thick film hybrids. For full details on how they can meet the needs of your application write Centralab for Catalog 1547.

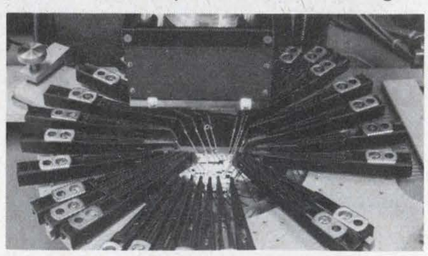




Centralab's NEW PEC is low-cost, high-quality thick film circuitry for a wide range of applications. Automotive electronics, copiers, point-of-sale terminals, peripheral computer equipment, instrumentation and process control are just a few.



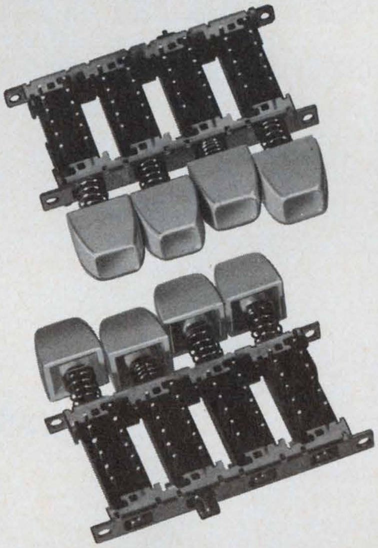
Screen printing is the first step in the NEW PEC automated process. Substrates are automatically fed through the printer where precise metallization patterns are deposited before firing.



Computer controlled laser equipment provides pretest to insure proper screening and curing and precise adjustment of resistors. Resistor trimming is shown in this view of the laser head.

Centralab perspective:

Pushbutton switches.* With 4 lockout options.



Centralab offers four lockout options for its momentary, push-push and interlocking action pushbutton switch modules. Lockout prevents actuating more than one switch at the same time — even if they're *not* adjacent. Another example of design flexibility. Other features include:

- 10, 12.5, 15, 17.5 and 20 mm spacing options.
- Epoxy sealed terminals.
- Modular LINE SWITCH — mounts in any station.
- 25 button styles and 18 colors.

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INFORMATION RETRIEVAL NUMBER 15

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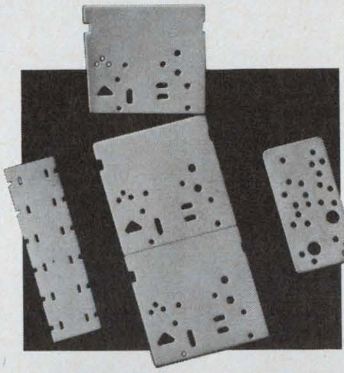

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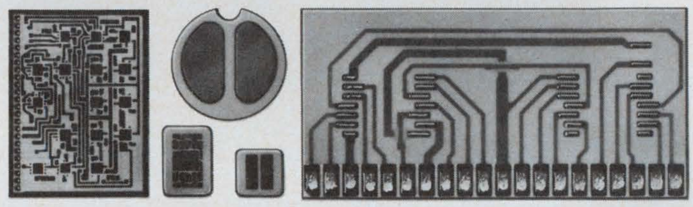

our metallized substrates

We can furnish high alumina substrates in any shape or size. With holes, notches, slots or scorelines — and with your choice of two metallizing systems:

- **Refractory metallization with high temperature molybdenum or tungsten — for applications requiring bond strengths up to 14,000 psi. You get the pattern adhesion necessary for die or wire bonding, metallic seals, metal hardware or lead attachment. Plus excellent stability for high temperature processing in most types of atmospheres.**
- **Noble metallization using silver, palladium silver or palladium gold is ideal for conductive patterns in hybrid circuits. You can have complex patterns with 10 mil lines over large areas — 5 mils over small areas. Bond strengths meet requirements for subsequent soldering and/or die and wire bonding.**

When you need proven metallized substrate capability come to Centralab — first. Our exclusive materials and proprietary production processes are the result of 45 years in ceramics for electronics. Put our technological skills to work for you.

Write Centralab for Bulletin 1057TC

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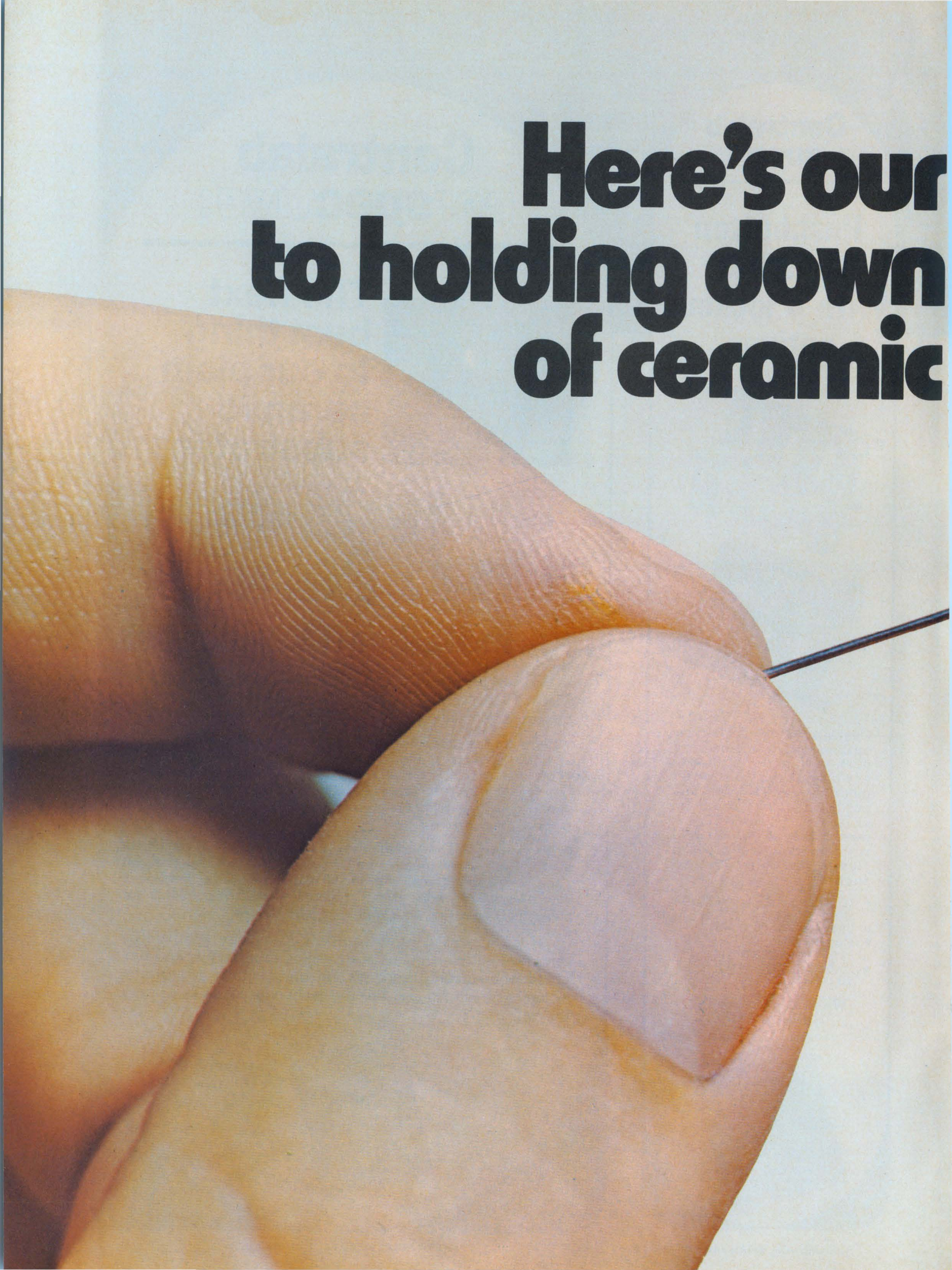

Here's our
to holding down
of ceramic

(continued from page 17)

reference the latest available manufacturers' technical literature, supplement his technical-article file.

Since the information in technical publications is generally not more than three months old, the engineer's updating often far surpasses the two-to-five-year, behind-the-time formal textbook learning of the new engineering graduate.

Fred J. Lingel
Project Engineer
BLH Electronics, Inc.
42 Fourth Ave.
Waltham, Mass. 02154.

Different IC replaces need for this design

This is a negative vote for Roger B. Frank's Idea for Design "Seven-Segment Display Modified to Reduce Readout Confusion" (ED No. 6, March 15, 1974, p. 158). The idea deals with a scheme to add the top and bottom crossbars (respectively) to the decoded numerals 6 and 9 from a 7447 decoder-driver.

It would be much simpler to use Texas Instruments' SN74247N instead of the bandaid approach used to repair the shortcomings of the 7447. Also no extra gates are needed; after all, how many designs can be expected to have half of a 7438 lying around waiting to be used?

Lawrence W. Johnson
Hewlett-Packard
1501 Page Mill Rd.
Palo Alto, Calif. 94304

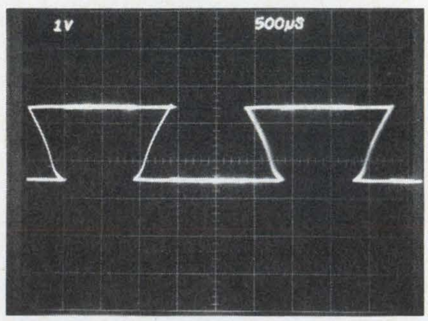
Still another WOM

With a minor modification to the IC and the proper drive signals, the 1103 (1024-bit RAM) can be made into a 1033.5-bit WOM (Write-Only-Memory).

To perform the IC modification, cut off pin 14 ($\overline{\text{data}}$ out); file off the resulting stub and insulate it with a drop of epoxy.

Circuit changes required are as follows:

1. Tie pin 18 (read/write) to pin 11 (V_{DD}).
2. Tie pin 16 (C enable) to pin 5 (precharge).
3. Drive pins 16 and 5 with a 2-V p/p dove-tail waveform (see photo) with an anticipation (leading edge) of 500 μs, a hesitation (trailing edge) of 500 μs and a flare (wide top or bottom) of 2 ms.



Quite surprisingly, the 1103 is easier to use as a WOM than in its intended RAM mode.

Donald P. Parks
President
SWAG Trading Co.
1039 Ivy Lane
Cary, N.C. 27511

If you've been stymied by a limited budget and have a multitude of analog conversions to perform, take heart. Our hybrid 4301 Multifunction Converter can do just about any analog computation you might need. Add a few external resistors and this tiny 14-pin dual-in-line unit can multiply, divide, square, square root, or square a ratio. Add a few inexpensive active and passive devices, and this 3-input hermetically sealed and shielded workhorse can perform true rms, vector sums, sine, cosine, or arctangent conversion functions. It's highly accurate in all configurations, low in cost, and is particularly useful for rapid real-time computations or for signal processing equipment. And if you want to linearize a function by raising a voltage or voltage ratio to an arbitrary power, it will do that too!!

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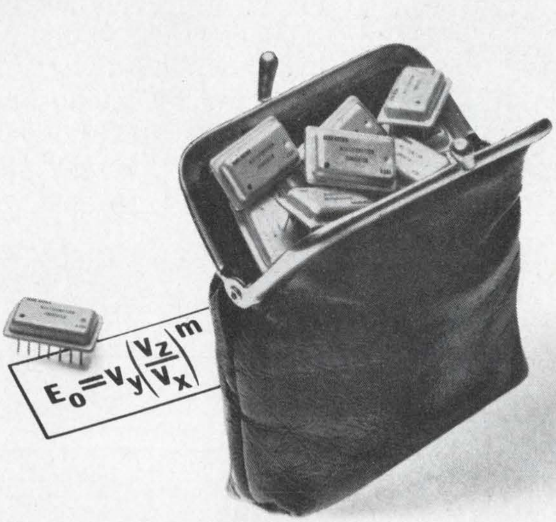
You won't have to give up high quality, versatility, and top performance even if you have a limited budget.

Our Hybrid DIP Analog Multifunction Converter gives you all three, and a low cost, too!!



The 4301....
Another Analog IC from Burr-Brown!

INFORMATION RETRIEVAL NUMBER 20

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When you're the leader in the design of A/D and D/A modules, you've got to break some ground in manufacturing, too.

Take our active abrasive trimming operation, for instance. (That's one of our trimmers on the opposite page.) We put it together ourselves, and we're pretty proud of it. It lets us trim resistor networks in converters while they're under power and operating. This gives us an extremely precise trim, in a fraction of the time it would take to hand select and install discrete resistors. That means we can give you very good performance in a budget-priced module. And we can give you that performance consistently, from order to order, in high volumes.

We also design and build a lot of our own test equipment for incoming inspection, in-process testing and final testing. Our QC and testing groups have a workload you wouldn't believe.

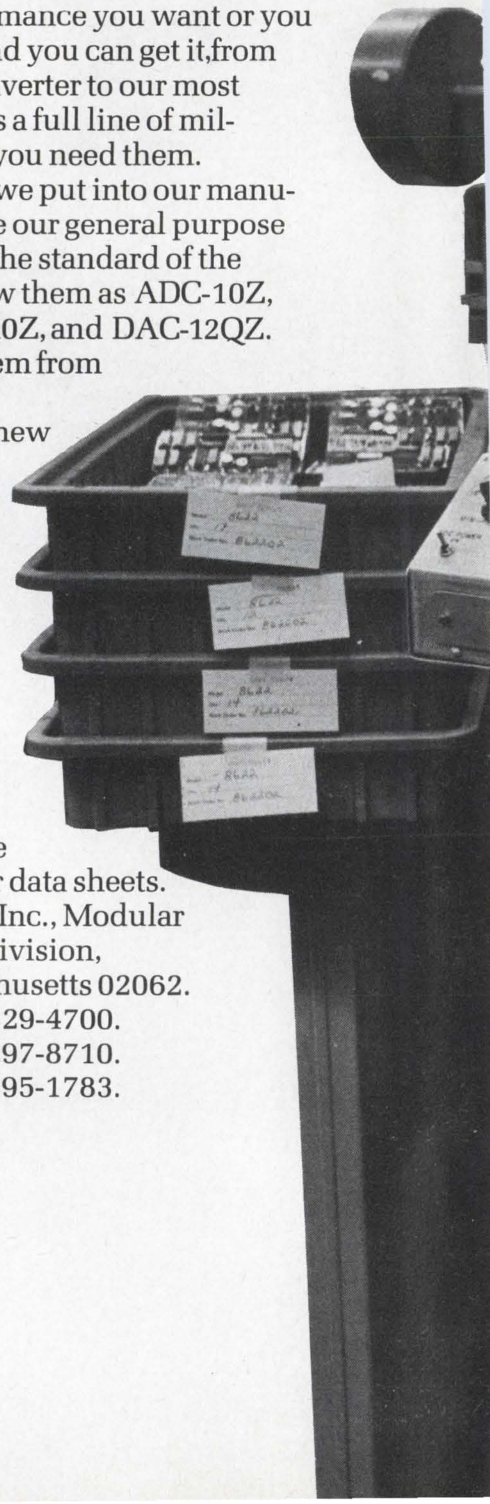
We take a lot of extra care with our individual components, too. We've got an automatic operation for transistor selection and matching. The most stringent PC board requirements in the field. And sophisticated material handling and production scheduling, controlled by a large-scale computer.

With converter circuitry, you've got to build in the performance you want or you just don't get it. And you can get it,from our most basic converter to our most sophisticated. Plus a full line of mil-spec converters if you need them.

The extra effort we put into our manufacturing has made our general purpose line of converters the standard of the industry. You know them as ADC-10Z, ADC-12QZ, DAC-10Z, and DAC-12QZ. Even if you buy them from somebody else.

And our brand new DAC1118 and DAC1009 are coming on fast.

When you're looking for a modular converter, look beyond the specs. And if you're ever in the neighborhood, drop in. We'll show you the muscle behind our data sheets.



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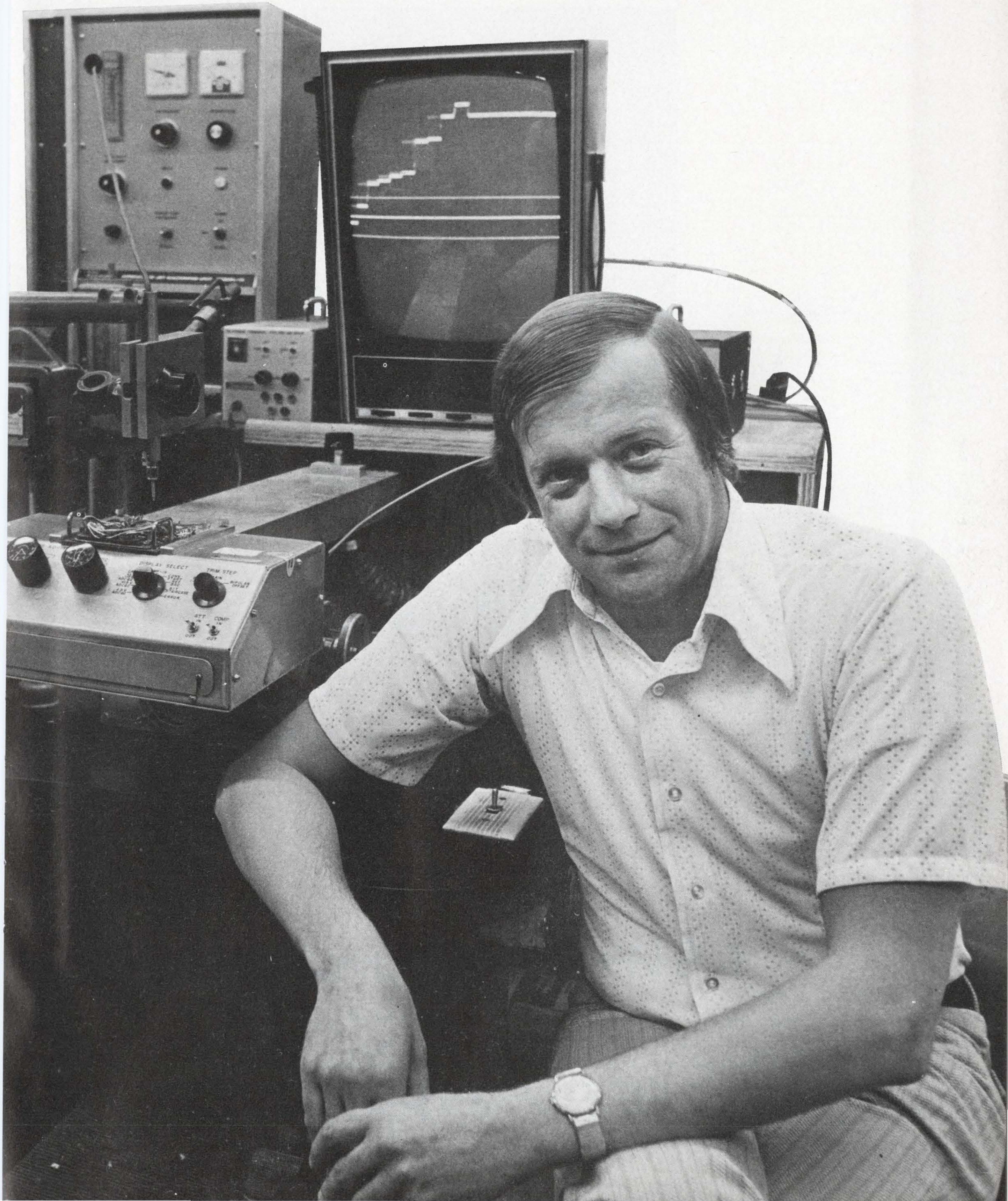
ANALOG DEVICES


DISPLAY SELECT
TRIM STEP

Magnetic bubbles produced in thin films by evaporation

Magnetic bubbles have been produced for the first time in amorphous thin-film alloys by use of evaporation techniques, scientists at IBM's Research Laboratory in San Jose, CA, report. They say the thin-film alloys proved to have the uniaxial anisotropy and magnetic properties suitable for generation of magnetic bubbles.

Evaporation offers the most inexpensive way to fabricate magnetic-bubble films. Two other methods used—sputtering and crystal-film growth—are more difficult.

The new evaporated, magnetic-bubble alloys are holmium-cobalt, holmium-nickel and holmium-iron, according to Dr. Neil Heiman and Dr. Kenneth Lee. They prepared the alloy films in a study of magnetism in amorphous materials—substances with atoms arranged in a random fashion. The films, all about 1000Å thick, were able to support magnetic bubbles.

To date, sputtering has been the favored way to prepare amorphous magnetic-bubble films, according to Lee. The main difference between evaporation and sputtering is the way in which the atoms are obtained and deposited to form the alloy film.

In sputtering, groups of atoms are chipped away electrically from the surface of a target material. In evaporation, high temperatures shake the atoms loose from the surface of the liquid samples of the alloy constituents. The alloy is created on a cold substrate surface, on which the element vapors are condensed.

A prime cost advantage of evaporation, Lee points out, is that it eliminates the hard job of making a sputtering target that has the same proportion of alloyed elements throughout its volume. And once this target is made it's difficult to vary the composition of the alloy films.

Lee reports the key to IBM's successful fabrication of evaporated magnetic films is "the maintenance of a high vacuum and the ability to keep the substrates cool —from about 0 C down to −50 C or greater." He adds:

"We're also using a vacuum about three orders of magnitude higher than previously employed by others. In the past, workers tended to oxidize their films or contaminate them during the process because of lower vacuum. We're getting purer materials with our methods."

HP introduces versatile time-sharing system

A second-generation version of Hewlett-Packard's 3000 scientific time-sharing minicomputer has been introduced. It features multiprogramming, which permits it to be tailored to the requirements of both the scientific and business user in stand-alone, time-sharing and distributed computer systems.

The computer, dubbed the 3000-CX, has a newly developed Basic compiler as well as the ability to handle programs in Cobol, Fortran IV, SPL (HP's systems programming language) and RPG—a business language.

According to Paul C. Ely, general manager of HP's new computer group in Cupertino, CA: "It is the first time we have addressed ourselves to the needs of the business community as well as our traditional scientific and engineering customers.

"When used as a time-sharing central processor, scientific and business users can solve problems in their respective languages simultaneously."

The computer has also been configured to permit easy interconnection, so a number of processors can be working on independent tasks while they share data base and interchange information.

In conjunction with the new computer, HP has introduced three peripherals: The 2640, a "smart" microprocessor-controlled CRT terminal; the 2894A, a card reader/punch capable of 200-cards-per-minute input and 75-CPM output, and a new line printer capable of 300-to-1250 lines per minute.

According to Ely, versions of the computer are available with 96 kbytes to 128 kbytes of core memory, and they are priced from $100,000 to $200,000.

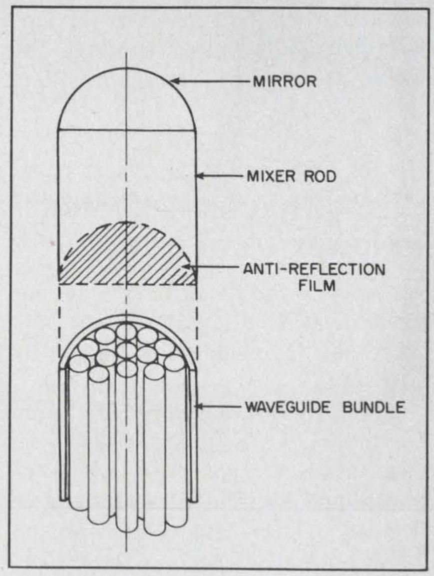
CIRCLE NUMBER 630

Fiber-optic signal losses reduced by star coupler

A device called a star coupler eases a problem that has seriously hampered the development of fiber-optic communication systems: how to connect the fibers without undue signal losses.

With the star coupler, many bundles of optical fibers can be connected with less signal loss than heretofore, according to the developer, Dr. Frank Thiel, supervisor of the Applied Electrophysics Dept. of Corning Glass Works, Corning, NY.

The device consists of a cylindrical housing that contains a glass



Low-loss star coupler for optical fibers permits two-way data communication on all fiber bundles.

mixer rod with a mirror endface.

The coupler permits a multimode optical waveguide system to perform the same function as a tapped trunk or data bus in an electrical network. It allows each terminal in a system to transmit and receive data from any or all of the other terminals.

The coupler was recently tested by Hughes Aircraft in a seven-port aircraft optical-control system. The results were optical losses more than 50% lower than an equivalent T-coupler system.

Theil explains that radiation from any single waveguide fiber is reflected off the walls of the mixer rod and the endface mirror. When the radiation returns to the waveguide bundle, it uniformly irradiates all of the other waveguide fibers. In this way, only one coupler loss is developed, no matter how many bundles are connected.

Until now, however, T couplers were used. And if many bundles were to be connected, many couplers were required, with each one contributing to the system loss. Theil points out that for a 20-terminal system, a total loss of 28 dB would be developed with star couplers, while a loss of 130 dB would occur with T couplers.

Theil is quick to point out, however, that for some short runs it is possible to obtain T-coupler losses that are similar to those of the star-coupler. This occurs, he continues, because losses developed with the star coupler are logarithmic in nature, while those associatea with T couplers are linear. In general the longer the run, the worse it is for T couplers Thiel says.

Disc diffusion expected to lower semi costs

A new process promises to cut silicon-wafer diffusion costs and increase semiconductor yield by 40%.

The process, developed by Carborundum at Niagara Falls, NY, uses discs composed of boron or phosphorous as the diffusant source instead of the usual chemical and vapor-source diffusion systems.

Dave Ott, marketing manager for Carborundum, reports that until now phosphorous has not been available in disc form. The results of the new process, he says, will be lower semiconductor prices and more consistent device characteristics from batch to batch—4% matching instead of the present 15 to 20%.

The diffusant wafers are placed in the same boat with the silicon wafers and are alternated between two back-to-back silicon wafers. Thus a diffusant source is placed equidistant from each silicon slice and from every point on the slice. The need for carrier gas (and the turbulence it causes) is also eliminated.

Use of both diffusant wafers can yield a sheet resistance within ±2% across individual slices, ±3% slice to slice and ±4% run to run.

Phosphorous wafers have a recommended life of 250 hours at typical oven temperatures, while boron has a 300-hour life. And phosphorous costs about $10 a wafer and boron about $15.

Device simulates effects of heat on human tissue

Spurred by the need to determine whether or not an object is hot enough to cause burns or injury, the National Bureau of Standards, Washington, DC, has developed a new instrument, called a thermesthesiometer, that can duplicate and measure the response of human finger tissue to heated surfaces.

According to Louis A. Marzetta, a research engineer at NBS and the designer of the new instrument, simple temperature measurements are not sufficient. He says, "It's heat, not temperature that causes burns. Thus to know if an object is hot enough to cause burn, you must know the heat-flow characteristic and the temperature of the object's surface.

To illustrate, Marzetta notes that the plastic handle of a pan of boiling water can be at nearly the same temperature as the metal pan itself. It's safe to touch the handle and not the metal pan, he explains, because heat flows more readily from metal to human tissue than from plastic. Thus if a simple temperature measurement is taken to determine if it's safe to touch the handle, the results will indicate that it's not.

On the other hand, the thermesthesiometer contains a probe that duplicates the thermal properties of human finger tissue. The probe would indicate a temperature substantially lower for the plastic than for the metal. This is caused by the difference in the thermal inertia of the two materials.

Marzetta describes the thermesthesiometer as a digital readout that displays the skin-contact temperature and a probe with a thermocouple imbedded in a metal-doped silicone rubber. The metal dopant, he explains, is used to adjust the thermal inertia of the probe to that of the human finger.

In operation, the temperature of the probe is controlled so it is normally at 33 C, the finger's temperature. When placed against a surface the probe conducts heat to the thermocouple in the same way that finger tissue would conduct heat to the nerve endings. Thus the temperature displayed on the readout is the same temperature that a person would experience.

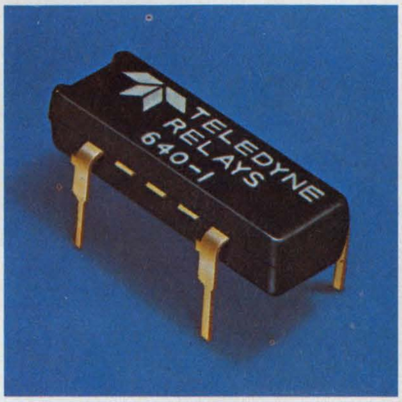
Air-traffic radar trainer contains several "firsts"

A new air-traffic-control simulator has increased the number of planes that can be presented and tracked on Air Force radar training scopes from two planes to 50.

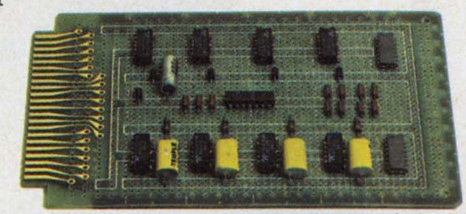
Other new features that have been incorporated in the system—the AN/GPN-T3, developed by the Electronic Systems Div. of the Air Force Systems Command, Hanscom Field, MA—include:

- Simulation of weather systems across the area scanned by traffic controllers. This covers both the airport-surveillance radar, with a range of 60 miles, and the precision-approach radar, which scans a radius of 10 miles.
- Provision for displaying adjacent radar interference, or simulated "fruit," on radar displays.
- Simulation of ground clutter.
- Simulation of a drop of 200 bundles of chaff from a plane.
- Presentation of both primary radar returns—those from the aircraft skin and secondary returns—those from altitude-reporting transponders.

Solid state dip relays... make good cents



And dollars too, when you're designing point of sale terminals and other business machines. Teledyne's Seren-DIP® relays are totally silent, reliable, long life components that can replace a surprising amount of expensive discrete circuits. Our 641 is a low profile TO-116 DIP; one small PC board holds all you need for control and switching a POS terminal or medium size business machine. But small size can mean big performance. The 641 is a small AC powerhouse: 1 AMP triac output with a 10 AMP surge rating; 140 or 280 volts, AC. It'll easily drive lamps, solenoids, stepping motors, transformers, or any inductive load – without noise or misfire errors. The Teledyne 641 is U.L. recognized. We also make high level DC and Bi-polar Seren-DIPs.



Seren-DIP solid-state DIP relays – they make design sense and their dependability and cost effectiveness may help you make POS sales, too. Ask your distributor or call our applications engineers.

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3155 West El Segundo Boulevard, Hawthorne, California 90250
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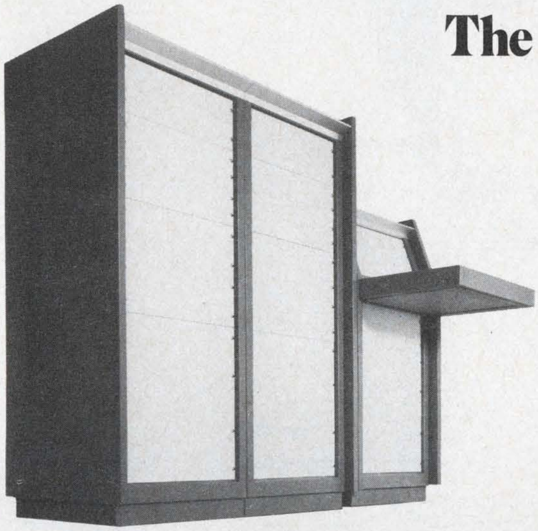
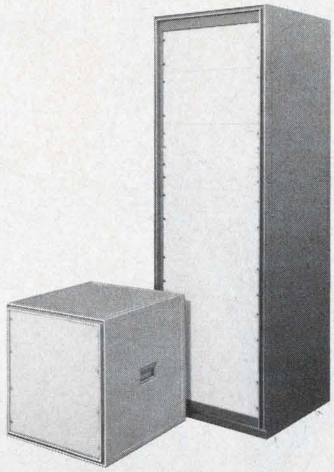
INFORMATION RETRIEVAL NUMBER 23

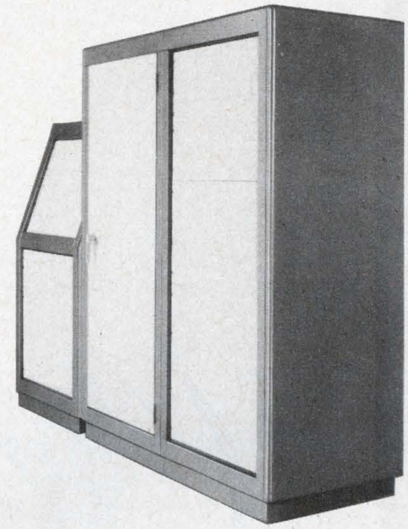

First everywhere.

The simple, functional and innovative styling of these cabinets and cabinet racks more than satisfies your application and value requirements. And it's this combination that sets The Designers' Group on a plane rarely attained in the industry. For the name of the Bud Distributor or Representative in your area... the men who'll give you facts and fast delivery on The Designers' Group... call (800)645-9200, toll free.

The Designers' Group.







Series 2000

These cabinet racks are produced to meet the highest quality standards; are designed to enhance the function and value of your products.

Standard upright cabinet racks come in 16 sizes; clear inside depths 20-1/2" and 24". Eight extra-deep units have a clear inside depth of 29-1/4". Frame is 14 gauge steel; doors, sides and tops, 18 gauge. "U" braces add strength and rigidity to sides and also support mounting rails which can be adjusted horizontally.

Inclined panel cabinet racks come in three sizes; clear inside depth, 20-1/2". Three extra-deep units are also available with a clear inside depth of 29-1/4". Front panel is positioned 20 degrees off vertical and all panel mounting rails are adjustable, including those in the inclined section.

Inclined units can be used in conjunction with upright cabinet racks and a wide choice of accessories are available to help make the Series 2000 even more functional.

Classic II

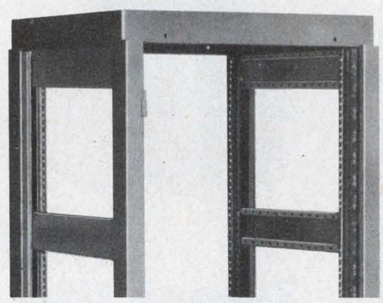
They may look like custom-made enclosures, but Classic II cabinets and cabinet racks are standard products immediately available from your Bud Distributor.

Cabinets come in 14 sizes with a clear inside depth of 20-9/16". Top, bottom and side panels are .060 aluminum. Carrying safety is provided by recessed, brushed chrome finish handles attached to two steel supports extending the length of each side thereby adding extra support.

Cabinet racks have a clear inside depth of 21-1/8" and come in four sizes. Side panels and doors are 18 gauge steel; top and bottom 16 gauge. Set up cabinets and racks in a series and their over-all styling and, too, the brushed aluminum extrusion which frames the fronts of both units offer a visually harmonious installation. And like all Designers' Group enclosures, they come completely assembled, ready for use.

Series 60

Both upright and inclined panel cabinet racks are a prime example of Bud's craftsmanship and design capability. Although styling is important, so is construction. And these Series 60 cabinet racks are built to give years of use.



Frames are 14 gauge steel, all-welded construction. Doors, sides and tops, 18 gauge. "U" braces welded to sides of frame provide extra strength and rigidity.

Upright cabinet racks come in 14 sizes; clear inside depths 20-1/2" and 24". Seven extra-deep units have an inside depth of 29-1/4".

Inclined panel cabinet racks come in three sizes; clear inside depth, 20-1/2". Three extra-deep units are also available; clear inside depth, 29-1/4".

All Series 60 cabinet racks have adjustable mounting rails; are accessible from both front and rear for easy installation of components... and can be combined into a bank of two or more with the Bud Add-A-Rack system.

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INFORMATION RETRIEVAL NUMBER 25

Improved solid-state memories and microprocessors altering the structure of computers

Larger, faster and cheaper solid-state memories and the explosive growth of microprocessor technology are changing the architectures of computers and computer systems.

While the most far-reaching effects will be on large systems, immediate and less dramatic changes are occurring in the minicomputer field.

With respect to large systems, Dr. Ugo O. Gagliardi, director of the Honeywell Information Systems Technical Office, Waltham, Mass., says: "Memory technologies that are being developed are going to have a very significant impact on the structure of computing systems."

The solid-state memories, Gagliardi points out, will reduce the access times now required by electromechanical storage devices, such as discs and tapes. To the computer designer, this access time has, for the last 20 years, posed "an enormous number of design choices in the system," he explains.

The concept of a memory hierarchy will become more commonplace, Gagliardi says, with arrangements like fast MOS and bipolar memories at the very top. In an intermediate position, he predicts, will be some block-oriented, solid-state RAMs, which might be magnetic bubbles, charge-coupled devices or the slower MOS shift registers. The lowest level will still be discs, he says, pointing out that they are good if the frequency of access is not very high.

Jim McDermott
Eastern Editor

The KL-10 central processor for the DECsystem 1080, a large-scale interactive computer, uses ECL logic and a cache memory for operation at very high speed. Typical of an architectural trend, the KL-10 features a PDP-11/40 as a control/diagnostic console that troubleshoots the entire system.

"The introduction of intermediate storage technology and storage devices should make it possible to have very large virtual memories, because you can achieve large capacities at reasonable cost."

The first impact of microprocessors on large systems will be in the I/O controllers, Gagliardi believes. The controllers will be capable of more functions, and this will allow decentralization of the system.

Gagliardi sees the large computer emerging as a central-memory system with many processors addressing it.

Some snags noted

Prof. C. V. Ramamoorthy, of the Dept. of Electrical Engineering and Computer Sciences at the University of California at Berkeley, also foresees distributed processing architecture for large systems. However, he has substantial reservations about when this will be accomplished.

"There are a number of problems in the microprocessor area now," he points out. "Unfortunately there is no standardization among them, and programming these microprocessors has become a tough problem, because each manufacturer has his own unique system."

Mini survival predicted

Earl C. Joseph, staff scientist at Sperry Univac Computer Systems, St. Paul, Minn., see changes in the architectures of the mini, the small, medium and large scale computers through use of microprocessors and microcontrollers.

"We see a large swing that way in the minicomputer field at the present time," Joseph says. "A big question in the field is: Is the microprocessor going to wipe out the minicomputer? I think future minicomputers will be made from micros, but we'll still have the minicomputer class."

Others in the field support Joseph's opinion. Gary Sawyer, microprocessor applications engineer at Motorola Semiconductor Products, Phoenix, Ariz., says: "Minicomputer manufacturers are now building boards using microprocessors. I see micros moving into minicomputer capability, and minis will move into the larger machine areas."

Omri Serlin, director of product planning at Systems Engineering Laboratories, Ft. Lauderdale, Fla., predicts: "I think that microcomputers will wipe out what is today called the low end of the minicomputer market. The only thing that will remain is what is known today as a megamini. The megamini will serve essentially the same functions that the medium-scale computers are performing."

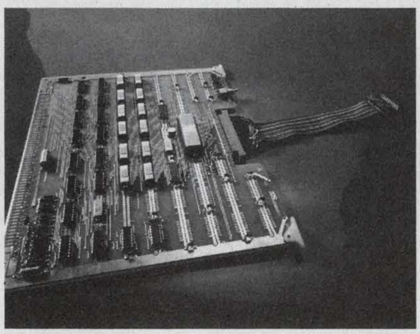
More intelligent computers

Joseph sees mass use of microprocessors and microcomputers in a new class of dedicated consumer applications, such as in the automobile or home appliances.

"You can call them intelligent adjuncts," he says. "And with these devices, we can look at upgrading the next wave of computer architecture by attaching these types of dedicated modules to present architectures. It will give us a very-low-cost method of growing into the next generation."

Joseph's forecast of the intelligent-adjunct system is supported by Dr. William Davidow, manager of microcomputer systems at Intel, Santa Clara, Calif.

"With our announcement of the bipolar microcomputer, we've increased the performance, in a period of three or four years, by some three orders of magnitude. This means that users can put arbitrarily large amounts of intelligence of almost arbitrarily high performance throughout the system, at low cost.



A trend in microprocessor development is the incorporation of microprogramming. The microprogram control logic above, by National Semiconductor, duplicates the functions of National's mask-programmed CROM and uses fusible-link pROMs for custom microprogram implementation.

"The architecture of the future will feature computation functions distributed throughout the system," Davidow notes.

Because of the ultimate low cost of micro devices, Davidow says, designers are going to feel free to incorporate significant amounts of processing into any type of computer equipment.

The newer generations of microprocessors are incorporating architectural concepts from both the minicomputers and the larger systems, according to George Reyling, project manager of the microprocessing group at National Semiconductor, Santa Clara, Calif.

"I haven't yet seen any announced microprocessors that are, in my opinion, significant departures from what's been done before," he says. "Architectural concepts that are being put into proposed designs include pipelining. And microprogramming, which has certainly been used before, is being incorporated.

"While the general organization of the registers and instruction sets is similar to what's been done in minis, there probably will be more emphasis on things that make instruction sets—particularly address information—convenient for systems that are implemented entirely with read-only memory. This will involve registers designed for that purpose.

"While minicomputers use read/write memories for their program stores and have the ability to alter the contents of memory location. many applications of microprocessors don't require a read/write memory so long as there are sufficient registers on the chips."

Motorola's Sawyer sees micros incorporating better addressing capabilities: "We will be coming out with machines that have direct, extended, indexed—all types of—addressing modes."

Index addressing is becoming popular, Sawyer says, adding: "We also have direct-addressing modes that are extended scratch pads." This, he says, provides a faster memory fetch than a fully extended addressing mode.

For users who need to save much data and are running out of registers, the data can be put in the direct-addressing range as a two-byte transfer, Sawyer says.

Off-the-shelf interfaces

To meet the needs of users who don't understand how to link peripherals to a microprocessor-based system, off-the-shelf interface devices can be purchased, Sawyer points out. Motorola makes the Peripheral Interface Adapter (PIA) and the Asynchronous Communications Interface Adapter (ACIA), both of which are essentially general-purpose program registers. With the proper addressing mode, these off-the-shelf interface devices look like memory.

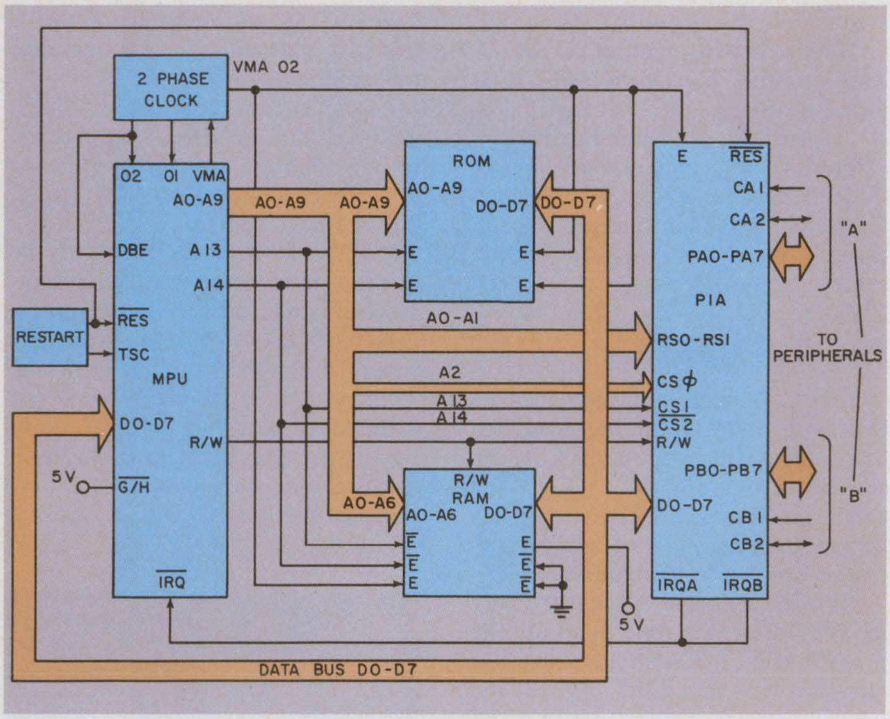
As a result, Sawyer says, the user is now limited only by the addressing range in his I/O unit.

In another area, both Motorola and Intel have altered microcomputer architectures by pulling the memory stack out of the microprocessor, putting it into memory and adding a 16-bit stack pointer register.

Use of the stack pointer saves both instruction time and memory and gives the user virtually unlimited interrupts that can be piled one upon the other, Sawyer says.

For those architectures that leave the memory stack inside the machine, service interruptions can be made a little faster. But that saving is offset by the cost of stacking of interrupts or data.

One trend beginning to appear in microprocessors is the use of single-voltage supplies, as exemplified by both Motorola and Signetics with their TTL-compatible, 5-V units. A principal advantage is the saving in real estate.



Better interfacing is provided in the newer microcomputer architectures. Motorola's M6800 uses an MC6820 Peripheral Interface Adapter (PIA) to interface the microprocessor to peripherals with two 8-bit bidirectional data busses and four control lines. No external logic is required.

Limitations noted

Raymond Mattson, head of development of hardware and software for Modulator Computer Systems, Ft. Lauderdale, Fla., is concerned with the limitations of present microprocessors.

"The microprocessor itself is reasonably useful in a real-time environment," he says. "But it does allow you to do more high-level local computation in controllers and in what ModComp calls modular bus control planes.

"While it reduces the component count today, it does not offer cost-performance advantages, although at some point in time it will. Today we are integrating some micros for ancillary functions. For example, we have communications processors, which are a relatively sophisticated hardware set that overlays our basic computer and optimizes it for handling communications data."

Mattson sees solid-state RAMs providing significantly faster cycle time, or throughput, than core memories do.

"Also," he says, "you're going to get more memory in a smaller space, and this implies larger memory configurations. But this will present a problem in protecting the memory against power failure and consequent loss of the data in the memories. For small memory systems, you can use batteries for a backup supply.

"But as you get into the larger arrays, you're going to architecturally have to back up some portion of the array that you can support. The rest of it you're going to have to let die if the power is lost."

"You need microprocessors and RAMs to carry a lot of parameters per channel and for handling a lot of channels simultaneously," Mattson points out. "When you're handling or interfacing communications lines—particularly batch communications—you need to be able to move large amounts of data that are transparent to the program—that is, you don't want the operating program to move every byte of data in and out of memory.

"So you like to have block transfers, and consequently need to be examining the data for the protocol information that is buried in the data stream. This requires active logic in the data stream—independent of the computer—which is provided by the microprocessors and RAMs."

Mini designers adapt

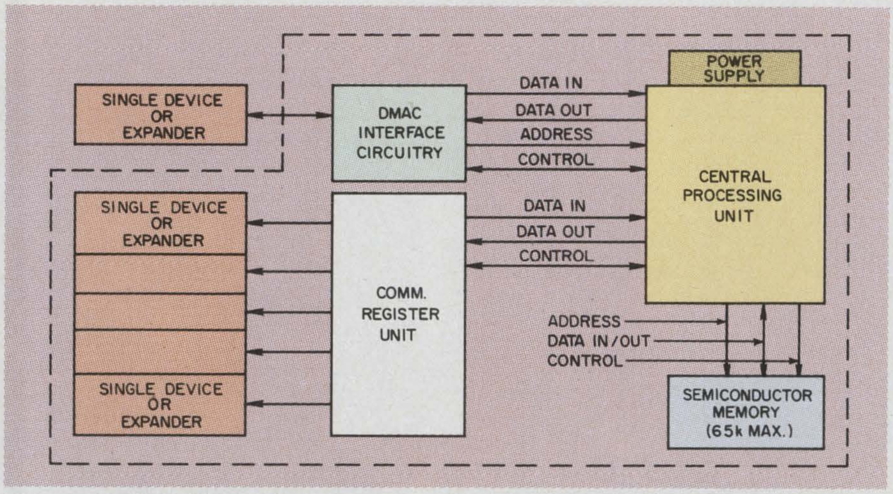
Minicomputer designers are continuing to adapt proven features from larger machines to smaller machine architecture. William Poduska, vice president of programming and engineering at Prime Computer, Framingham, Mass., points out that "things like virtual memory, stack mechanisms for field procedures and cache memories are being incorporated in small computers.

"Microprogramming, which has made its appearance in the small machines," Poduska says, "is likely to expand—especially with writable control stores—because with it, a knotty processing problem can be reduced to a microcoded instruction for improved performance.

"We see the extended use of virtual memory, using segmentation, and not paging. We also believe that the cache memory is going to be very important for the small computer. The reasons for this are silicon-oriented."

To begin with, Poduska says, "the 4-k memory chip makes very large MOS memories feasible.

"But the memory is not as fast as we'd like," he stresses. "Consequently, to get higher performance out of a slower, but bigger memory, you need an acceleration technique—the cache memory, which is made possible by fast, low-cost, 1-k bipolar memories with access times of 50 to 100 ns."



A unique architectural feature for minicomputers, a communication register unit, is provided for TI's 960B in process-control or manufacturing-control operations. This register is used instead of an I/O unit to permit bit-by-bit input and output in serial form.

The cache memory is placed between the processor and the main memory.

'Memory management' advised

When there are many users tied into one machine, a big problem is to make efficient use of the memory capacity.

"Memory management is necessary," says Ronald Gruner, electrical engineer at Data General, Southboro, Mass. "This means management of both the main memory and secondary storage.

"We'll see hardware developed in that direction. One basic architectural approach is to build a large memory out of a number of autonomous separate modules, each of which can be run separately.

"There is also a trend to have a number of separate data ports on a memory, so that more than one processor can be tied into the memory system."

One advance in minicomputer architecture is the incorporation of more error-checking and diagnostic capabilities. With the DECsystem 1080, the KL-10 processor uses a DEC PDP-11/40 as a control/diagnostic console. The console can diagnose failures in the main machine, according to Paul Guglielmi, principal logic design engineer.

Use of the PDP 11/40 for diagnostics also provides the system with an independent, stand-alone processor, Guglielmi points out. Even if the main processor fails, the 11/40 can be used for diagnostics, whereas if the main processor in another machine fails, it loses its diagnostic capability.

Considerable parity checking was built into the KL-10 architecture, Guglielmi says. All the RAMs are checked, including the microprogram control store, the cache and the accumulators.

In addition memory control in the cache is checked before use. This prevents unintentional modification of data when a bad instruction is present.

The KL-10 has a loadable microcode that permits engineering changes to be made easily, Guglielmi points out.

"We can ship the machine out, and if a few months later we find some bug, there's a good chance we can fix it by just changing the microcode."

More memories in minis

With the price of solid-state memories dropping steadily, one industry trend is to incorporate more memories in minis.

"If you look at where we're going to be in three or four years from now, it looks as if we'll be seeing huge memories of 4, 8 or 16 megabytes," says William Sweet, product line manager for Interdata, Oceanport, N.J. "To try and get something out of a memory of that size with 16-bit architecture doesn't make sense.

"It requires the full addressing power of a 32-bit architecture, which we have incorporated in two of our machines. The 32-bit architecture gives 16 megabytes in direct addressability. But while we can't build a 16-megabit memory now, we can build a single-megabit machine."

In microprogramming, Hewlett-Packard's emphasis has been to structure the architecture to make the machines more easily user-programmable. It is using narrow word widths and supporting them with both micro-assemblers and debug editors. In addition, hardware is being incorporated to give the user writable control stores as well as fixed program.

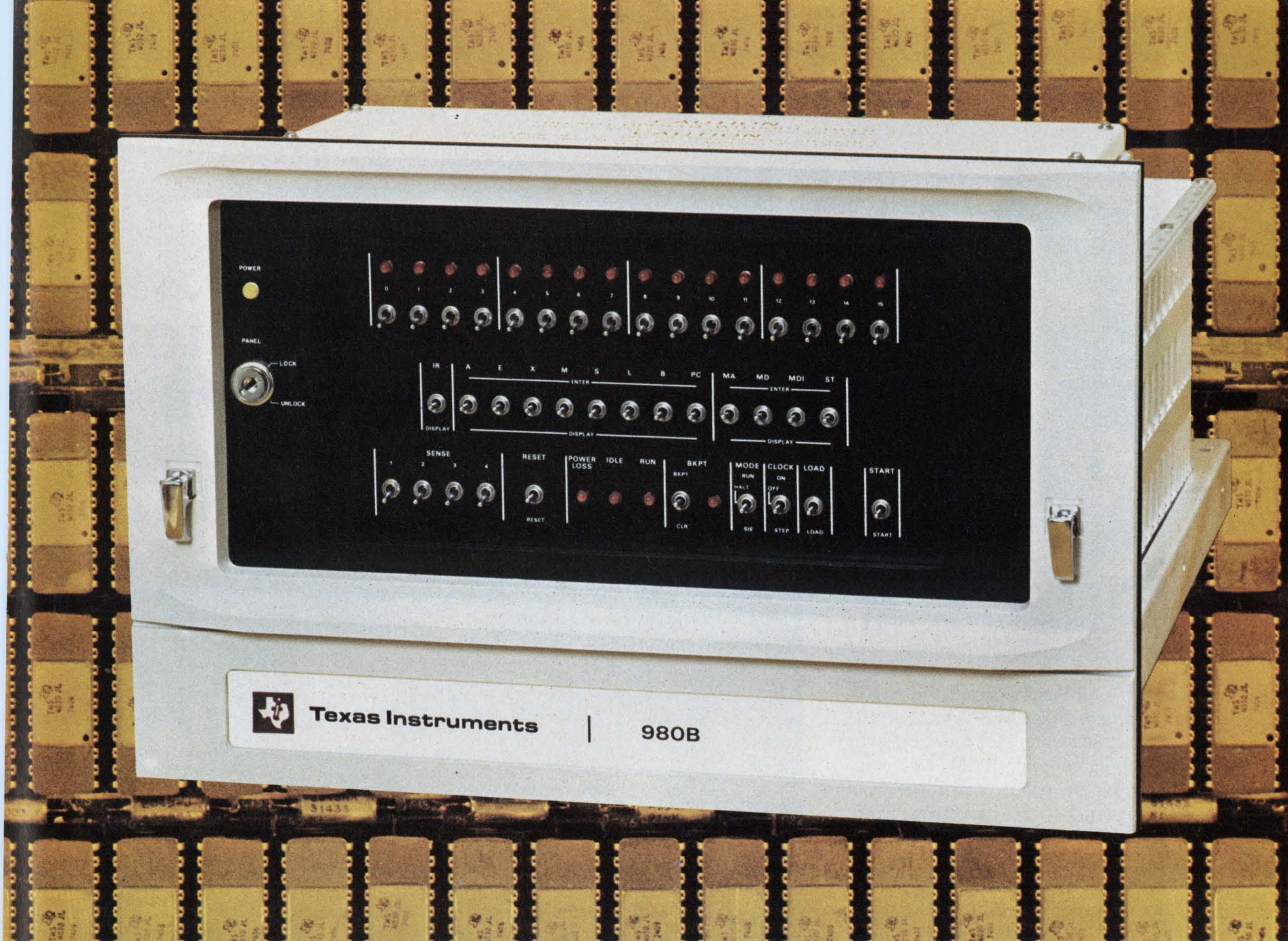
In the recent HP 21MX computer, indexing has been added for bit and byte manipulation—particularly essential in data communication. Another significant feature of the 21MX is a new dynamic memory-management scheme that expands the computer's memory-addressing capability to 1 million words.

Robert Frankenburg, project manager of the 21MX series, points out that while HP will not be building the 1-megaword capability, the logic addressing capability is there. Right now, 192 k words is the maximum offered.

In contrast with 16 and 32-bit minicomputer architecture, Texas Instruments in Austin has incorporated in its 960B a "communication register" that is unique to the industry. This register, explains Gerry Guillemaud, manager of computer marketing, is used instead of an I/O unit. The register has an input-output port that allows bit-by-bit input as well as output in serial form.

This architecture is designed to let the user optimize the number of bits required for any data transaction. For example, although the 960B uses standard 16 or 32-bit words for the software, it permits a user who might have, say, 9000 single-bit inputs or outputs to use all of the bits effectively, without having to mask out part of a 16-bit word.

All of the bits are directly addressable, he points out, with a maximum of 9000 inputs. ■■



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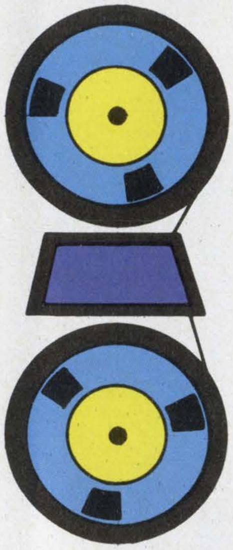


The Great Memory Battle goes on, but semiconductors appear the ultimate victors

For a long time the semiconductor memory has been closing in on the well-established core memory, threatening to replace it as the No. 1 component for mainframe memories. And now that the higher-performance, lower-power 4-k semiconductor RAM has completed its introductory stage, the battle seems to be just about won.

"By the end of the year, 40% of the memories designed into computers will be semiconductor memories," says Mike Markkula, marketing manager for Intel Corp., Santa Clara, Calif.

By 1976, some industry sources say, the penetration of semiconductors into the memory market will reach 70%.

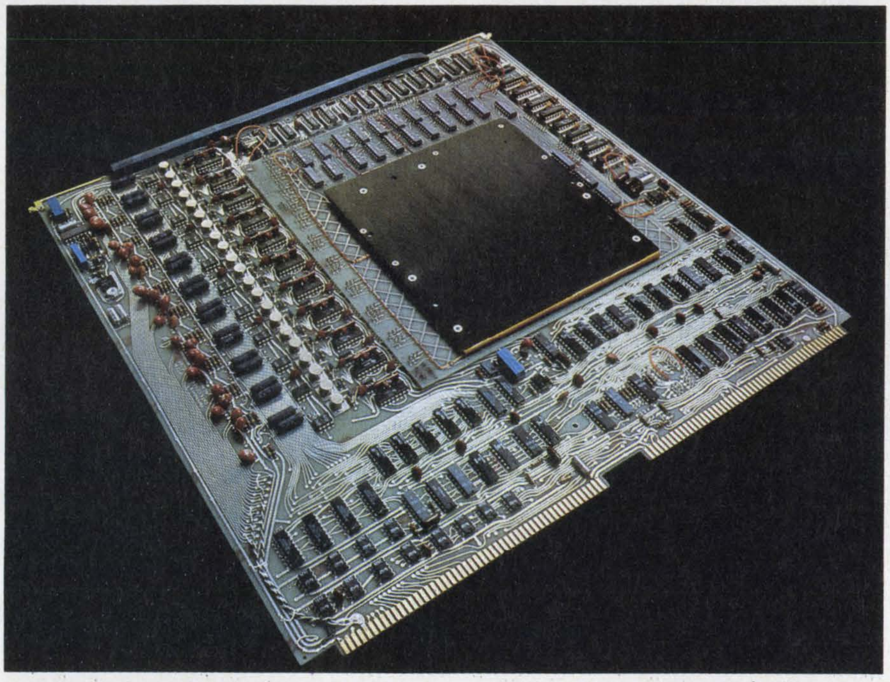
The feeling throughout the memory industry is that once semiconductors become No. 1, they will remain so for quite a while. The reason: Many improvements can be made in the technology to slash costs and enhance performance.

Industry experts believe that semi memories are still one to four orders of magnitude away from fundamental limits on information storage density, cost, power consumption and reliability. In addition a reduction in cycle and access times by at least one order of magnitude seems possible.

Most core memory makers concede that the bulk of the market will go to semiconductors eventually. But they are not about to sit back and let their memories die graciously. In an effort to retain their current narrow lead, core manufacturers are developing advanced production techniques that will further reduce the already low price of core components. In addition they are taking advantage of new developments in semiconductor technology to replace scores of discrete components with MSI or hybrid equivalents. They are also minimizing additional parts by using more sensitive amplifiers, so 16 k or 32 k of core can be sensed with a single amplifier.

This reduction in parts count will improve reliability, reduce assembly time and hence cost and allow room to expand core memory planes so larger memories can be fabricated without an increase in the size of the board.

As an extra precaution against being left out of the memory market, a number of companies now turning out core are hedging their bets by keeping up with, and in some cases getting into, the semiconductor business. Companies in this category include Electronic Memories and Magnetics, Digital Equipment Corp., Data General and Ampex.



This 8-k core memory board is used in Data General's new Eclipse series of computers. It provides for correction of single-bit errors with five extra bits in the memory word and a modified Hamming code.

Jules H. Gilder
Associate Editor

Meanwhile developments in peripheral memories, discs and tapes are unfolding at a much slower pace. Evolutionary improvements in disc technology have pushed recording track densities to 400 tracks per inch, and bit densities have already reached 4000 per inch. Discs still have a long way to go before they reach their maximum limits, and so challenges by other technologies are not expected to be successful until at least the end of the decade.

On the tape front, mass memories are being refined and new ones are being introduced. Possibilities for increased density and data rate include improved tape guidance, the use of error correction circuitry to reduce data redundancy and to increase tape-to-head speeds.

Cassette and cartridge tapes are getting stiff competition from the floppy disc, a flexible magnetic record that has been accepted by IBM.

4-k RAM wins acceptance

The 4-k RAM, the device that should seal the fate of the core industry, has reached the point where several companies have already committed themselves to its use, according to Intel's Markkula.

Challengers to the conventional semiconductor RAM, such as magnetic bubbles and CCDs, are not expected to succeed because they don't offer any major advantages in density or tolerance of defect features. However, bubbles and CCDs are expected to make significant inroads into the rotating memory market, but not before the end of the decade.

But even when semis dominate the market in 1976, there will still be a requirement for 60 billion bits of core memory, Markkula says.

Joe Kroeger, manager of MOS Systems Applications for Signetics in Sunnyvale, Calif., agrees. "I don't see core memories ever going away," he says. He cites an increasing trend toward combining core and semiconductor into a cache type of memory.

A cache memory is an arrangement whereby large chunks of data are transferred from a large, slow core memory to a smaller, faster semiconductor memory. Since most processors fetch instructions sequentially, it is possible to reduce the cycle time by keeping the instructions in a medium with a fast access time.

Core makers say one big factor against semi memories is that they are volatile. Semi makers reply:

"So what?" The memories can be backed up with a battery, they point out, so there is no loss of data in power failures. Core makers counter: "Sure you can use a battery, but you need a huge one to drive large memories."

That's true, but also misleading. For backup operation, it is not necessary to drive a semiconductor memory; it is only necessary to refresh it, a process that requires considerably less power.

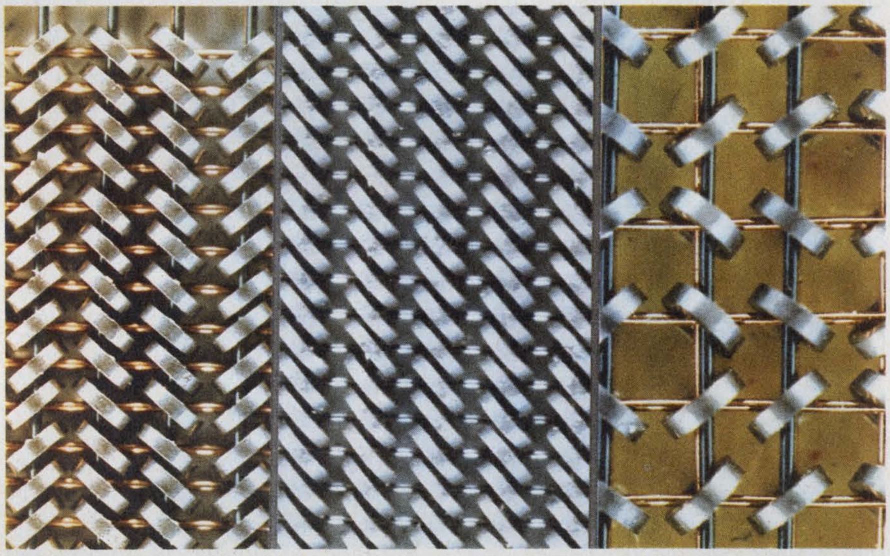
Kroeger says the question is academic. In all but the small minicomputer systems, users naturally assume that data have been wiped out, and they reload. That goes for systems that use core memories as well as semis.

Michael Rodin, marketing manager for Datacraft Corp., Fort Lauderdale, Fla., spoke to several semi manufacturers recently, because he's interested in using the 4-k RAM. He found that several problems must be overcome before semis will make it in mainframes.

Foremost, in his opinion, is the need for semiconductor manufacturers to change their philosphy a little. "They're putting out a little memory on a chip, a 4-k-by-1 RAM," Rodin explains. "Their attitude is that it's a device and you buy it according to the spec sheet. As long as it meets that spec sheet, it's your baby."

When asked what would happen if the device ran into pattern-sensitivity problems in the field, Rodin says the semi makers tend to hedge and never say whether they will guarantee the memory under all memory-pattern conditions.

The 1103 is a good example, Rodin says. It was tested by the manufacturer under "worst-case" patterns. The device passed the test and when some customers put it into their systems, it didn't work. The device developed cross talk and leakage problems, which were eventually corrected.



Obsolete core spacing used until 1970 (right) yielded 1678 cores per sq. in.; higher-density spacing introduced in 1970 gave 5276 cores per sq. in. (left). In 1973 density was upped to 6469 (middle).

Rodin, as a potential user of semi memory chips, fears the same thing may happen again with the 4-k chip. Initial reliability predictions for the chip are poor, he reports, and he has been told by manufacturers to consider using error-correction techniques and parity codes if he wants to use the chip in a system.

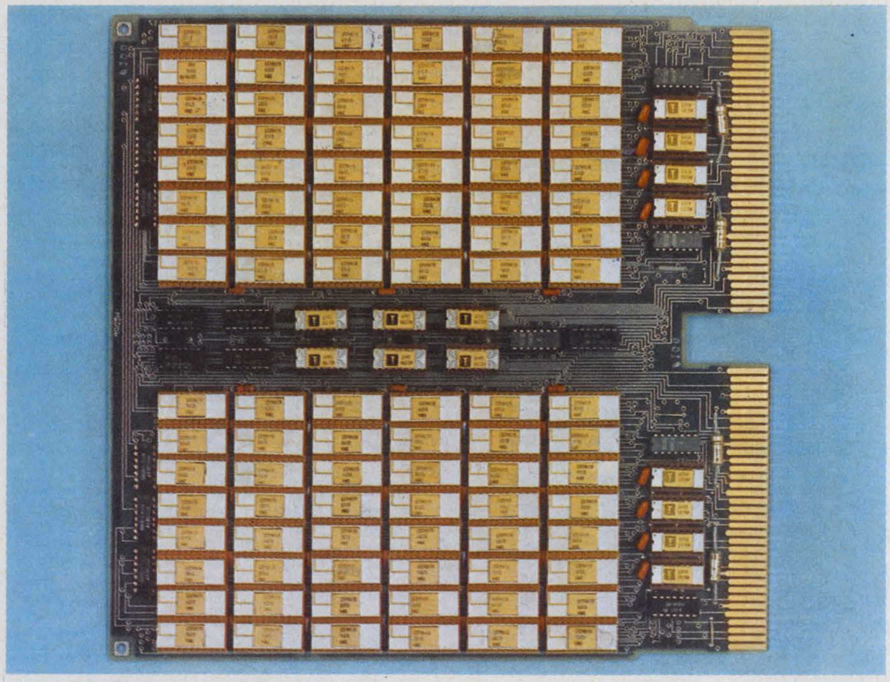
Putting in error-correction logic means higher costs, and that's what 4-k RAMs were supposed to reduce in the first place.

Markkula agrees that there were problems with the 1103 chip, as there are with any new product, but he says they were ironed out.

As for the 4-k device, he says that semi makers have learned from the 1103 and now have the expertise required to overcome pattern-sensitivity problems.

Computer manufacturers are also starting to apply some core techniques to semiconductors to increase mainframe performance. An example of this is a new semiconductor memory from Data General that combines 2-k MOS RAMs that have a 600-to-700-ns cycle time with a bipolar cache memory. The result is a cycle time of 200 ns.

This new memory can also accommodate both cores and semis in an interleaved design. Another feature is that the memory is capable of detecting and correcting all single-bit errors and some multiple-bit. This is done with the help of a modified Hamming code that uses 5 of the 21 bits in the memory's word. The remaining 16 bits are used in a conventional manner.



A semiconductor memory array board used in Honeywell's Series 64 main memory consists of 16,000 12-bit words of dynamic MOS RAM storage. Each of the chips contains 2048 bits of memory.

Core demand is up

While semi makers perfect the 4-k memory, core is an outstanding buy today.

"The core-memory business is booming," says Herbert Listerman, applications engineer for Ferroxcube Corp., Saugerties, N.Y. "Most core manufacturers are working at full capacity and still can't meet the demand for parts. People are gobbling up bits by the billions."

According to Listerman, more people are asking for core than ever before. Why? High-volume quantities of the 4-k semiconductor RAM are not available, and the cost of core is plunging. Since 1970 a bare stack has decreased in price 0.5-cent per bit to 0.26 cent per bit today.

Another factor that has kept interest in cores alive is the improvement in density. Four years ago most cores were 30 mils in diameter. Today, Listerman says, 80% of all the memory cores used are 18 mils in diameter.

Core manufacturers are increasing the density of their memories by developing new layout patterns that permit the closer placement of cores and by going from the current three-wire designs back to two-wire ones.

Spacing between cores has also decreased significantly. The older cores were spaced on 30-mil centers. Today the 18-mil cores are placed on 10-by-17.5 centers. This closer spacing, Listerman reports, can be partly attributed to the fact that cores are now bonded in room-temperature vulcanizing rubber.

Another factor that has increased density—and probably cost, as well—is the switch back to hand stringing of cores. According to Listerman, machine stringing was tried for a while, but it soon became evident that hand stringing yielded higher density.

Other techniques that have resulted in higher-density core memories are pointed out by Arnaldo Hernandez, vice president of engineering for Digital Computer Controls, Fairfield, N. J. Improved layout patterns, such as the double herring bone, allow cores to be packed closer together. In addition advances in semiconductor technology that led to the availability of integrated-circuit core drivers and sense amps, have greatly reduced the number of peripheral components needed to make a core stack into a memory.

Also, there is a trend toward the driving and sensing of more cores per amplifier. At present the industry is driving 16 k of core with one amplifier and sensing 8 k. Within a year those numbers are likely to increase to 32 k or even 64 k per driver and sense amp.

Rodin of Datacraft says that in addition to the monolithic IC sense amps and drivers, his company has used hybrid technology to reduce from 180 to 6 the number of components needed for the inhibit circuitry in a three-wire core memory. Linear pulse transformers that are generally associated with core memories have also been eliminated by use of a direct coupling approach.

What about going to smaller cores to increase density? With few exceptions, the consensus of industry experts is that going to a 12 or 14-mil core would not yield any substantial improvements in the over-all memory system. As Rodin put it: "The smaller cores will give you headaches." They are much more fragile; so they must be handled more carefully.

Since the output of the smaller cores is lower, more sensitive amplifiers are needed. Also, the pulse width of the strobe must be controlled to a finer degree, which requires more sophisticated circuitry. Finally, notes Rodin, the gain in speed is not that significant.

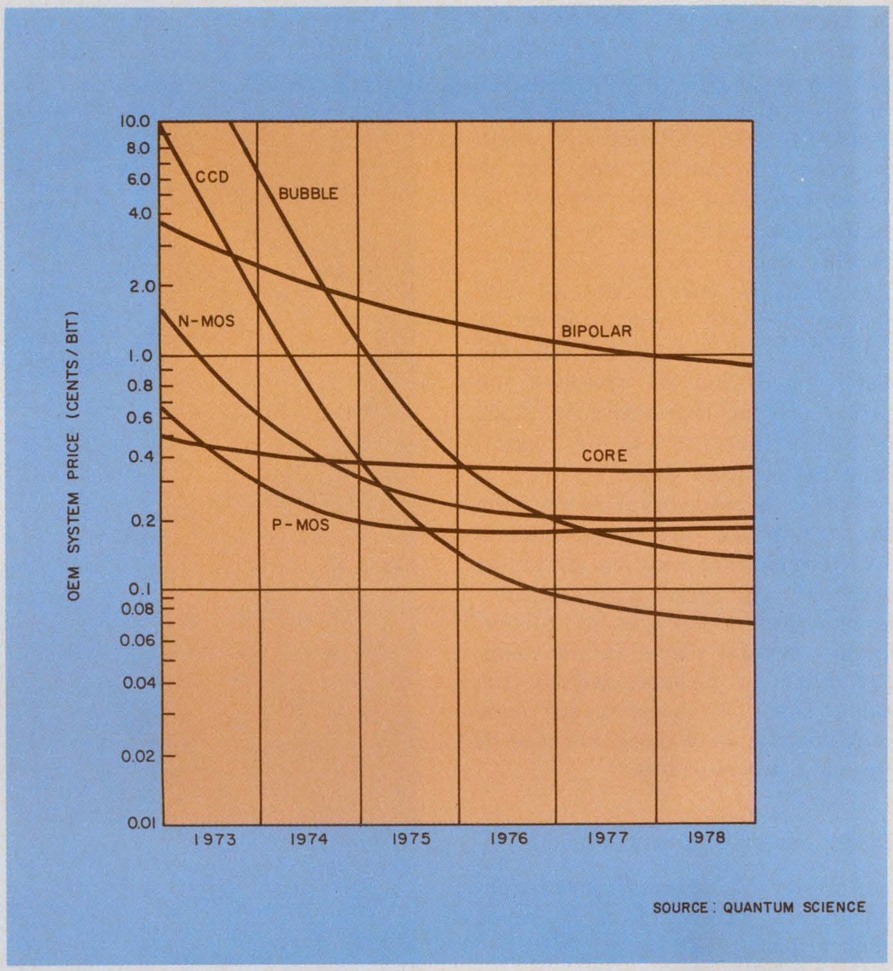
Ferroxcube's Listerman agrees and adds that if the increased speed is really necessary, it is possible to drive the 18-mil cores a little harder and reduce their switching time from 180 to 140 ns.

Victor Sell, assistant general manager for Ampex's Memory Products Div. in Marina del Rey, Calif., disagrees with most industry specialists on the future of the smaller 12 or 13-mil cores. He thinks their future is bright. Ampex will soon produce the smaller cores for a special memory system that will allow the cores to switch in 30 ns, Sell says.

To achieve this high speed—and it's higher than is generally available—partial flux switching will be used, he reports. This is a technique for overdriving a core by use of pulses that are about half as wide as those normally required to switch core.

Two other factors will contribute to the dramatic increase in core switching speed: linear selection and the return to two-wire memories. Linear selection is an addressing technique that allows individual words in a memory to be addressed without disturbing the cores. The resurrection of two-wire technology will, in addition to making core memories competitive with high-speed bipolar types, also make it possible to return to automated stringing techniques, because of the ease with which this can be done.

Datacraft's Rodin agrees that two-wire technology is beginning to look attractive again, particularly since the more complex circuitry needed with two-wire core memories can be conveniently constructed from MSI devices. He also says that his company is working on a 32-k core memory that will use the two-wire approach.

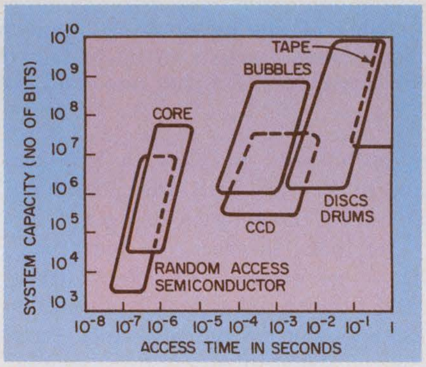


Projected memory prices for the major technologies through 1978 show that by that time charge-coupled device memories will have the lowest cost.

Production of core soars

While the semi makers are learning how to make their devices in large volumes, the core manufacturers are also busy improving production capabilities and looking for new applications.

According to Sell, Ampex is developing a process that could produce sufficient core material to make a billion cores an hour. Sell is quick to point out, however, that there is no current need for such volume. Ampex is setting up facil-



Memory performance can be judged by comparing access time and system capacity for the different technologies.

ities that should be ready by the end of this year to produce a billion cores a week, he says.

In describing the advance in material fabrication, Sell notes that core material is deposited on a 2-ft-wide Mylar tape base at a rate of 100 ft/min in much the same way that magnetic recording tapes are coated. In fact, he points out, modified tape equipment is used in this process.

After the material has been deposited on the Mylar and hardened, the tape is peeled away, and the sheets of material are sent to presses to be stamped out as cores. A big advantage of the process, he reports, is that it produces cores with almost perfect uniformity and thus eliminates a lot of testing.

In searching for new application areas, core manufacturers are proposing that their memories replace rotating discs and drums. While semiconductor replacements for rotating memories have been discussed throughout the industry, little if anything has been said about core replacements. But eight prototype units of such a device have already been delivered to the military to replace drum memories in airborne applications, and 22 more are on order.

This core memory is being built by Ampex with a capacity of 4.5 million bits arranged into 131-k words, each 33 bits long. Sell acknowledges that such a memory will be more expensive than the disc it replaces, noting that core costs 0.4 cent a bit and disc costs between 0.05 and 0.1 cent. But he notes, too, that cores require no maintainence and offer higher reliability.

A drop in core prices to 0.25 cent a bit could come as early as next year, according to Sell. He also reports that the speed of the core replacement for disc, at 2 μs, is about three orders of magnitude better than disc.

Sell sees commercial application for core-based disc replacements in systems that require multiport accesses. In these applications—airline reservation systems, for example—several places in the memory have to be accessed at the same time. That can't be done conveniently with discs, because of the long access times.

Discs advance slowly

Activity in disc-memory technology is advancing at a much slower pace. The most advanced disc available is reported to be the IBM 3336, Model 11, which stores over 200 megabytes of data with a linear density of 4000 bits per inch. James Moreton, general manager of the Caelus Memory Div. of Electronic Memories and Magnetics, San Jose, Calif., believes that this storage density can be increased.

It should be possible to double the linear density to 8000 bits per inch, he says. To do this, the magnetic heads would have to fly closer to the surface of the disc than the current 25 μin. Moreton sees the industry producing discs with a smoother surface and better oxide coating to achieve this performance.

Commenting on the practical limitations of disc technology, the Caelus general manager says that the maximum density is probably 350 megabytes of storage.

There are other ways of increasing storage in disc systems that don't require advances in technology. Storage Technology Corp. of Louisville, Colo., has developed what it calls Super Disk. What it is is simply four disc drives bolted together. Using this technique, the manufacturer is able to produce a disc storage unit that can hold up to 400 megabytes of data.

Capable of storing up to 200-million 16-bit words, the DS330 from Texas Instruments consists of up to four disc drives and is designed for use with minicomputers. Transfer rate is 403,000 words-per-second.

Moreton foresees at least one more generation of discs from IBM—which has been the leader in rotating memories—and then the widespread use of magnetic-bubble disc-replacement memories. Since IBM, not too long ago, introduced a new disc and the company plans most of its products in five-to-seven-year cycles, Moreton doesn't see bubble memories making inroads into the rotating market until the 1980s.

Floppy discs gaining ground

One of the more recent additions to the disc technology, the floppy disc, is reported gaining acceptance and replacing cassette and cartridge tapes in many applications.

The floppy disc is 7.88 in. in diameter and is made from 3-mil thick Mylar. When used in a memory system, it rotates at 375 rpm and has a linear bit density of 3500 bits per inch.

Both the rotating speed and the storage density can be significantly increased, says Stuart Mabon, vice president of corporate planning for Pertec, Chatsworth, Calif. By using harder recording heads and coating the surface of the floppy disc with a harder material, manufacturers will probably raise the rotational speed to about 700 rpm, he reports.

But improving the rotational speed is not enough, Mabon adds. To get the full advantage of the improved rotational speed, the radial access time must also be improved, he says. At present it can take as long as 4 sec for the head to move from the outside to the inside track on the disc.

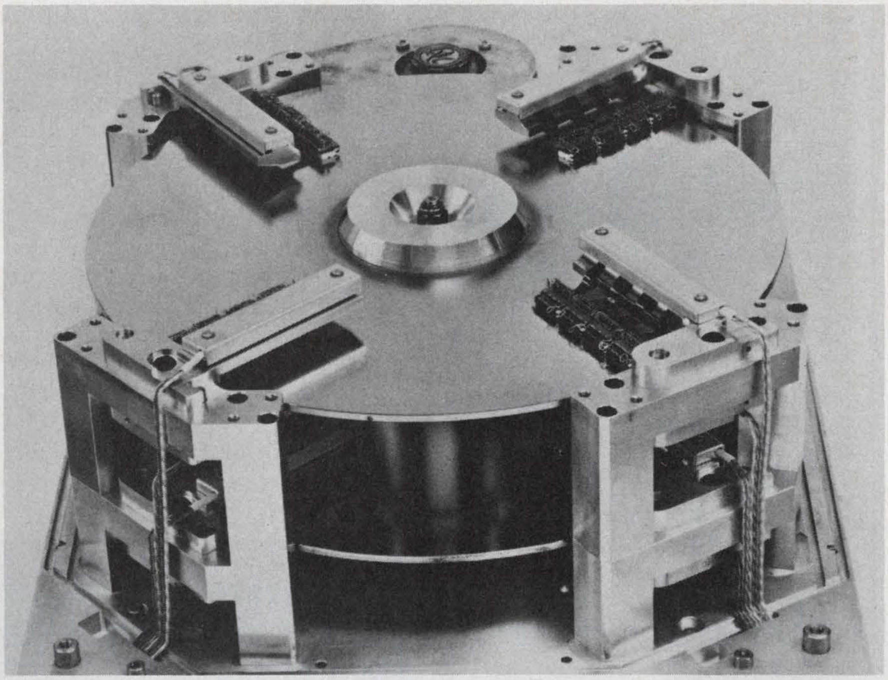
But shortening the radial access time means a significant change in the drive mechanism. There is a lot of money invested in the mechanism currently used, and manufacturers will want to get their investments back before they make any big, expensive changes, according to Mabon.

The recording density of the floppy disc can be improved in two ways, the Pertec vice-president says: First, by use of both sides of the disc to store data (present systems only use one side) and, second, by use of new coding schemes for recording data.

While floppy discs on the market are coated on both sides, only one side is used to store data. The reason? That's the way IBM does it. If both sides of the disc were used, Mabon says, disc storage could be doubled. There are problems, however.

Since the recording technique is a contact one, pressure must be applied on both sides of the disc. But the disc is very thin, and that isn't easy to do. So either the disc must be flipped over, or some way must be found to apply pressure to both sides of the disc at the same time.

Industry experts believe that within the next two to three years these advances will be incorporated into floppy discs to increase density fourfold. But most in the industry are looking to IBM and what it does. It is the leader, and if it chooses not to increase density in this way, it probably won't be done on a wide scale.



The Mididisc from SDSI is a rapid access device designed to hold 40 megabits of storage. It rotates at 3450 rpm, has an average access time of 8.5 ms and transfers data at 4.5 megabits/sec.

Bubbles will be ready soon

As for bubble technology and its potential for displacing rotating memories, several experimental systems have already been built and tested. One, a one-half megabit device, has been developed by Bell Laboratories, Murray Hill, N.J.

According to Paul C. Michaelis, a member of the technical staff who worked on the Bell project, the bubble memory contains 32,896 14-bit words. The unit, which contains all the control and detection electronics, operates at a rotating field frequency—the equivalent of the data-transfer rate—of 102 kHz. The memory, reports Michaelis, has an average access time of 2.7 ms, which is similar to that available with rotating discs. The read/write cycle time is 5 ms.

The bubble unit, Michaelis says, is constructed from 28 chips, each containing 16,448 bits.

Other companies that have advanced from the production of chips to the development of memory modules include Rockwell International and Hewlett-Packard.

Much of Rockwell's recent work has centered on a 60,000-bit bubble data recorder developed for NASA. According to a Rockwell spokesman, the 60,000-bit machine is a stepping stone to a 100-million bit unit. The larger recorder would require the development of 100,000 bubble-memory chips.

Initial plans call for the chip to measure about 225 mils on a side and have a data density of 2.5 million bits/sq. in. It is expected to take 18 months to develop and to cost about $500. Once in production, however, this could drop to $50.

Hewlett-Packard's interest in bubble memories is linked to their application in calculators, computers and instruments. The HP memory module contains conventional garnet bubble chips, wire-wound coils that produce the magnetic driving field and a permanent magnetic structure to produce the bias field. HP's bubble memory has a very good signal-to-noise ratio because of an unusual double-differential detection scheme. The scheme also results in a device that is independent of the bias field and temperature.

CCD memories emerging

Like bubble technology, charge-coupled-device technology is competing for a large slice of the disc replacement market. The thrust of the CCD activity, however, lies in nonarchival storage applications, where data are stored for relatively short periods of time.

Several CCD chips for this type of application are expected to appear before the end of the year. Companies working in this area include Bell Northern Research, RCA, Intel, Fairchild, Signetics and Texas Instruments.

Bell Northern has already built a disc equivalent device from CCDs. Using 8-k chips and a random access to a data-loop configuration, the company has constructed a device that can replace the RS 64, a disc peripheral to the

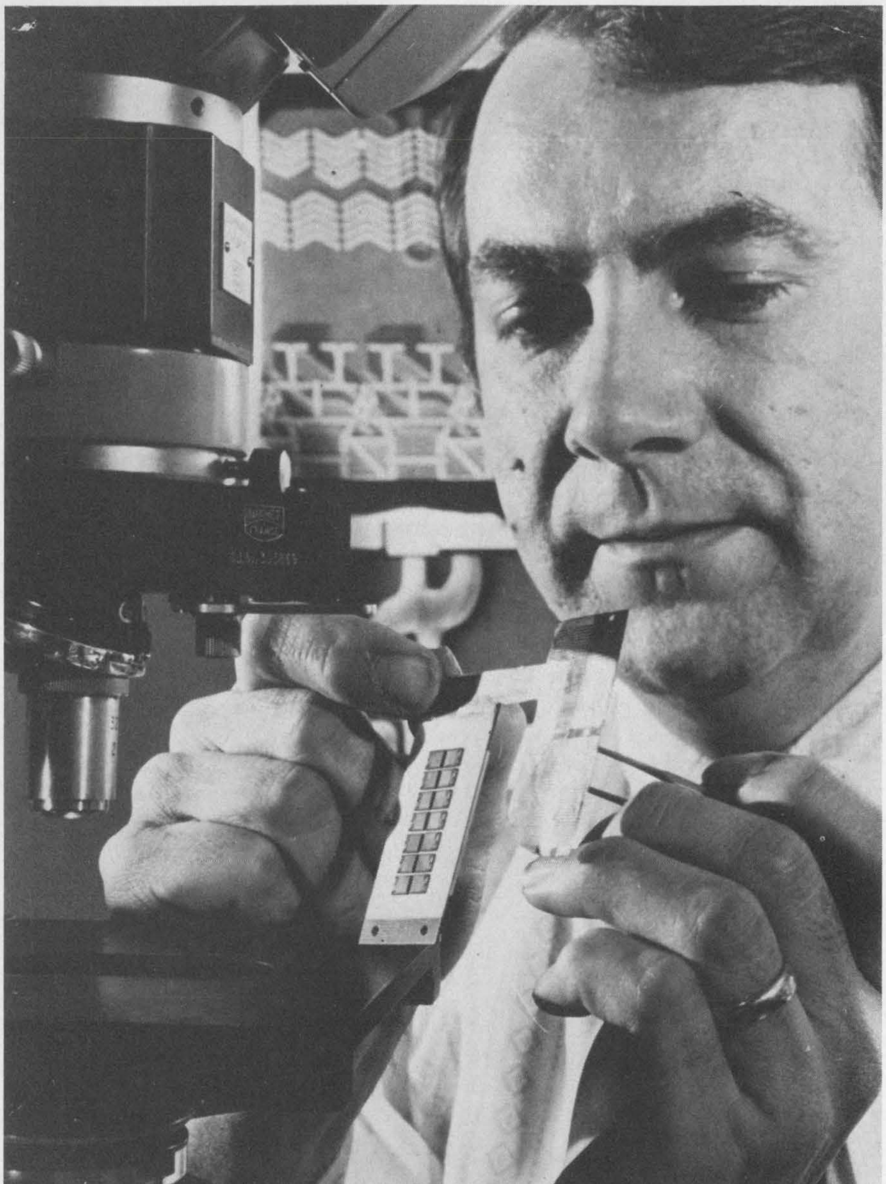
Digital Equipment Corp. PDP-11 mini.

According to Chris Robinson, manager of device applications for Bell Northern, the memory features a latency of 128 μs—two orders of magnitude better than that of a disc—a capacity of 1 megabit and a refresh rate that varies between 10 and 100 kHz.

Another CCD memory, this one designed to replace drum memories in military applications, has been designed by RCA, Van Nuys, Calif. This memory uses 16-k chips that are composed of two 8-k registers arranged in a serial-parallel-serial structure.

According to James M. Chambers, an engineer on the CCD memory project, the 16-k chip must be combined with a COS/MOS support chip to form a functional memory module. The module is the building block of the drum-replacement system, and in many respects can be equated to a track on a drum or disc, says Chambers.

He notes that data recirculate past a tap in the data loop of the module in much the same fashion that data on a rotating medium



Magnetic bubble memory chips developed by Bell Laboratories have been fabricated into a 460,544 bit bubble memory module that has a data rate of 700,000 bits/sec and an average access time of 2.7 ms.

pass the recording head. Addressing of the data is accomplished via logic on the support chip rather than through a track-selection matrix, as is the case with most drum or disc memories.

In comparing the final CCD unit with the drum it replaces, Chambers points out that the CCD unit, with an average access time of 2 ms, is five times faster than the drum. In addition it occupies about 1/10 the volume with the same capacity; at 15 lb, weighs almost 10 times less; requires a maximum of only 5 W, compared with 300 W for the drum, and has a mean time between failures of 20,000 hours, compared with 3500 for the drum.

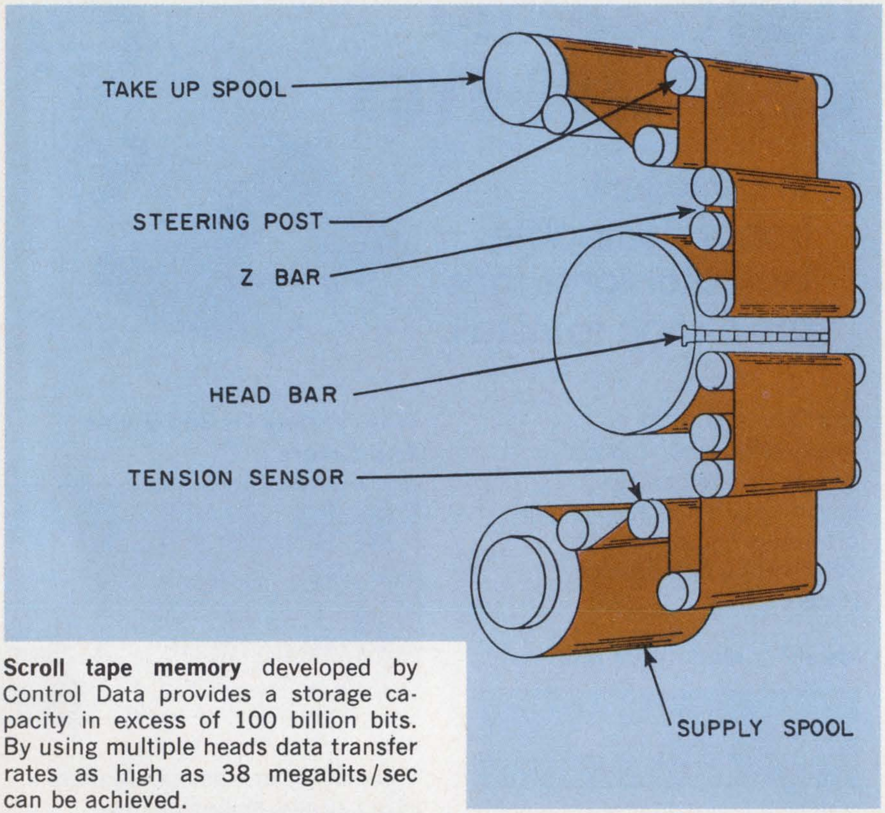
The one problem posed by the CCD version, Chambers concedes, is that its memory is volatile. This can be overcome, naturally, with a backup power source. Since only 2 W of standby power are required for this 8.4-million bit memory, a relatively small battery can be used, Chambers says. If 20-hour data retention capability is required, for example, only eight D cells are needed, he says.

Although 16-k chips have only recently begun to appear, reports from Intel indicate that 32-k CCD devices will follow shortly.

Tape memories being refined

Activity in tape memories has focused on the refinement of existing systems. The Terabit Memory system, first proposed by Ampex in 1967 and delivered in 1972, has undergone some changes. Newer versions, says Jerry Miller, a member of Ampex's research staff, include significant additions to the power and flexibility of the memory, particularly in the areas of file management and data-interface design. These advances, Miller says, make it possible to use the memory with existing computer systems without significantly changing their operating systems.

In describing the memory, Miller notes that the data rate is 6 megabits/sec, the packing density 7500 bits/in. and the over-all data density 1.42 megabits/sq. in. He points out, however, that since the same data are recorded on two tracks, to provide 100% redun-



Scroll tape memory developed by Control Data provides a storage capacity in excess of 100 billion bits. By using multiple heads data transfer rates as high as 38 megabits/sec can be achieved.

dancy, the apparent data density is only 710 kilobits/sq. in.

As with disc memories, there is still room for improvement in data rate and density. The data rate can be at least doubled, Miller contends, merely by a rise in head-to-tape speeds to those commonly used in video recorders. And further rate increases are possible, he says, with improvements in packing density.

According to Miller, the data rate may be raised in three ways: (1) The linear density can be increased to 15 kilobits/in., a figure now attainable with longitudinal recorders; (2) Improved tape guiding and head alignment tooling can make it possible to increase track density to 300 tracks/in. and (3) By use of complex error-correction techniques, it is possible to reduce the data redundancy from the present 100% to about 20%.

In combination, these changes may yield as much as four times higher density without sacrifice in reliability, Miller says. And if all that density isn't needed, he adds, an increase in data redundancy enhances data reliability.

One new development in tape memories is the Scroll Mass Storage device from Control Data Corp., Minneapolis. According to Robert A. Loenig, a designer who helped develop the memory, data are stored on a 3000-ft length of 12-in.-wide magnetic tape.

The tape is housed in an interchangeable cartridge and has a capacity of 10^{11} bits. This is about 30 times less than the storage capability of the Terabit Memory. However, the data-transfer rate for the Scroll ranges from 9.5 megabits/sec to 38 megabits/sec—much faster than the 6-megabit rate of the Ampex unit.

The increased data rate results from the fact that eight magnetic heads are used to record and read data. The Scroll memory design, Koenig says, permits the use of either bit-serial or four-head parallel recording.

In parallel recording, data received from the host CPU are dissembled and written, on an alternating basis, to the four tracks simultaneously, thereby increasing the maximum transfer rate by a factor of four. The 38-megabit rate thus attained, Koenig notes, is so high that it exceeds the transfer capability of most computer channels. ■■

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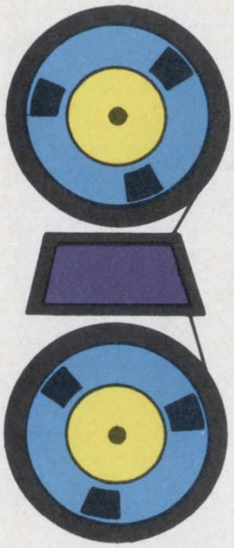


Matrix or daisy wheel? Thermal or ink jet? Serial printers offer these options and more

A revolution is beginning in the world of computer-peripheral serial printers. Many companies are choosing sides to decide upon the best technology for the widest range of applications. Here are the choices:

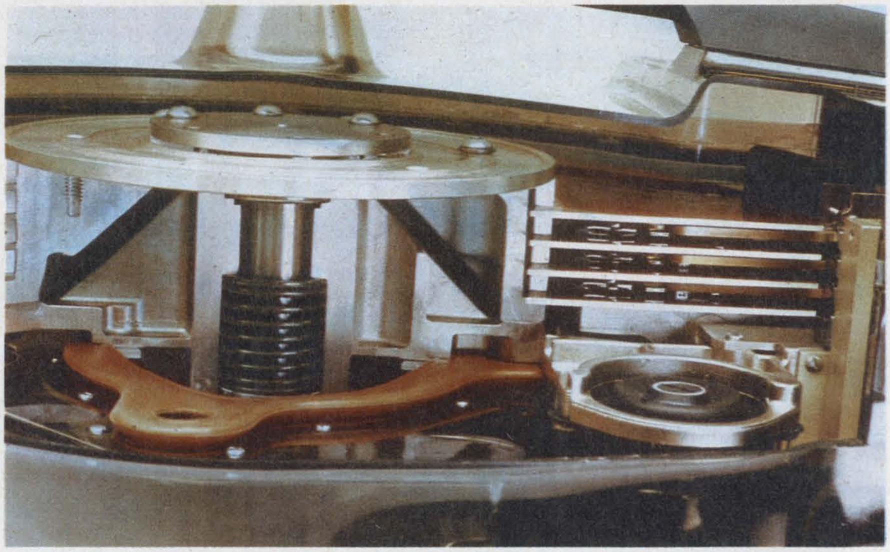
Matrix printers are fast, cheap and give multiple copies, but daisy wheels, which may not be as fast, also give full characters and have a lower parts count. Thermal printers are the most reliable and have the lowest cost. Yet quasi-line serial printers have electronic tabbing and carriage return along with full characters. And ink-jet printers are the quietest of all.

Another area of major development is that of high-density disc memories.

For minicomputers, 2200 bpi (bits per inch) has been chosen as the density standard for moving-head, disc-drive memory systems. But recent developments in larger-capacity drives have resulted in densities of up to 6060 bpi. So it looks like the move to higher densities will filter down from the large-computer systems to minicomputers. The new technology will most likely take the form of a completely new recording medium, mechanical configuration, coding scheme and controller.

When hard-copy computer printout is necessary, the main choice is between a serial (character-by-character) and a line printer. If masses of data are required, the choice is always a line printer because of its substantially higher speed. If less data are required or the application is a keyboard terminal, the choice must be a serial printer. And the serial gives a bonus: It is cheaper than a line printer.

David N. Kaye
Senior Western Editor



Incorporating the head-positioning system and the recording medium in the same module makes the IBM 3340 disc drive unique. Data density on the Winchester is 5636 bpi, and average access time is 25 ms.

For years, the most common serial printers have gone at 10 to 15 cps (characters per second). Most have been character cylinder printers, such as those made by Teletype Corp. of Skokie, Ill., or IBM Selectric mechanisms.

Where higher speeds are desirable, one of the newer technologies is necessary. The most successful of these is the wire-matrix printer. Pioneered by Centronics Data Computer Corp., Hudson, N.H., the printer uses a print head consisting of a vertical row of wires that can be pushed out against an inked ribbon to make dots on paper. The wires are moved out by individual solenoids. If consecutive rows of dots are used, a character can be formed.

Up to six copies can be made with a dot-matrix printer at speeds of up to 165 cps. With multiple print heads, they can go faster.

IBM using the matrix

To date, the most successful manufacturers of the dot-matrix printers have been Centronics and Digital Equipment Corp. of Maynard, Mass., although several others have products on the market.

Recently the dot-matrix approach was used in the new 3770 series of printer terminals offered by IBM, Raleigh, N.C. The dot-matrix printers in the terminals have speeds from 40 to 80 cps. Traditionally when IBM uses a technology, that approach becomes a de facto standard.

But dot-matrix printers do not produce a fully formed character—like those you see on this page—and the dot-matrix printer is fairly noisy. When character esthetics or silence are at a premium, a different approach is required.

Of the dot-matrix printers, the most widely used is the 101A from Centronics—or its recent 101AL, which is the same printer but with MOS/LSI circuitry inside. Both print at 165 cps in a right-to-left mode with a 132-character column width. The printer sells for just over $4000 in small quantities. For a few hundred dollars more, the 102A has two print heads, prints right to left and alternate lines left to right, and it has a throughput of 330 cps.

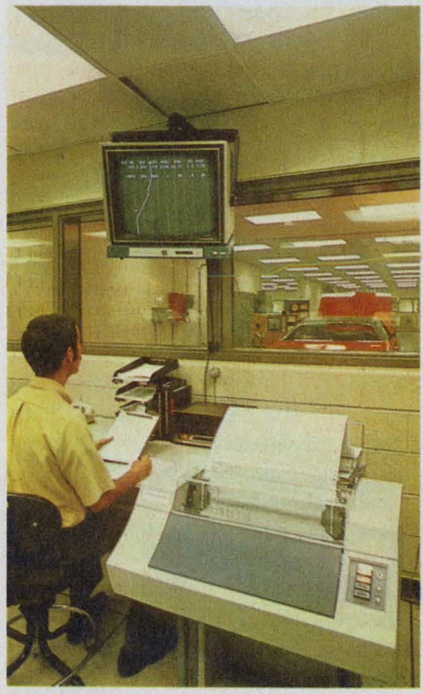
The cheapest 132-column dot-matrix printer is the LA36 from Digital Equipment Corp. It goes at only 30 cps, but it costs only $1850 in single units or $1250 for quantities of 100 and up. In addition it is a full terminal with keyboard. The Centronics printers are receive-only units, and they strike the paper without stopping the head (called printing on the fly). But Digital Equipment's LA36 stops the head before it prints each column of dots.

Digital Equipment uses a microprocessor as a controller in the LA36. Centronics has gone to MOS/LSI for most of the electronics in all of its new models. Centronics also makes a line of keyboard terminals that incorporate matrix printers, which include the 80-column Model 308 and the 132-column Model 508.

Enter the daisy wheel

Often fully formed characters are necessary, either because of the application or because the individual who reads the printing doesn't like dot matrix or segmented printing—from an esthetic standpoint. Two technologies satisfy the need for fully formed characters: the daisy-wheel and the quasi-line serial printers.

To form a daisy wheel, you do the following: Take a plastic hub and project several radial spokes from the hub. On one flat side of each spoke, place a raised piece of type. Spin the wheel parallel to the plane of a sheet of paper. When the desired type character becomes positioned in front of a hammer mechanism, stop the wheel and strike the hammer against the spoke. This drives the type character into a ribbon, and the ribbon into the paper, to make an impression. The force is great enough to make six clear copies. These plastic wheels, called daisy wheels, are readily interchangeable when different character sets are desired.



Centronics 101 dot-matrix printer records data at Chrysler's vehicle-emission center in Detroit. The 101 prints at 165 cps.

Two companies make daisy-wheel printers. The originator is Diablo Systems of Hayward, Calif. A more recent entry is Qume Corp., a spinoff from Diablo and also in Hayward. Diablo makes the Hytype I, a 30-cps receive-only printer that sells in OEM quantities for about $1000. Qume's Q30 is also at 30 cps, is receive-only, and costs about the same as the Diablo unit. Qume also has a 45-cps unit called the Q45. Diablo is expected to offer a faster model in the first quarter of 1975.

Qume and Diablo print both forwards and backwards, as desired. The printers have very low parts count and therefore high basic reliability. However, in time, the daisy wheel can wear out. David Lee, vice president of engineering at Qume remarks: "While the print wheel can wear out, it lasts a very long time and is very inexpensive to replace."

For high speed with fully formed characters, the quasi-line serial printer is the answer. They use a character chain or belt with a bank of hammers. The difference between these and regular line printers is that the electronics is designed to accept and print one character at a time. Most have been produced by General Electric, Waynesboro, Va. GE calls them Terminet printers, and uses them in keyboard, time-sharing terminals. Other major manufacturers of quasi-line serial printer terminals include Memorex, Santa Clara, Calif., and Teletype Corp.

GE and Memorex have printers that go to 120 cps, and Teletype's Model 40 can go over 400 cps. Each manufacturer also sells the printer without keyboard to OEMs, either with or without electronics. This printer has electronic tabbing and carriage return. Since there is no single print head, the position of the printed character is determined by electronic instruction to a hammer to strike at a particular time. The printers do an excellent job on multiple copies.

The quiet ones

Several technologies offer quiet printing. In serial printing the leading contenders are thermal and ink-jet printers. Thermal is more widely used. The major thermal-printer manufacturer is Texas Instruments in Houston. According to James D. Butterworth, manager of terminals and peripherals marketing: "Not only are we very quiet, but we are also the most reliable technology for serial printing. We have fewer moving parts than any other serial printer."

The TI printers use a 5 $\times$ 7 dot matrix and print at 30 cps. As receive-only printers, they sell, without case or power supply, for less than $1000 in OEM quantities. Most often these printers are incorporated in the TI Silent 700 line of terminals.

But with thermal printers, you need special paper that costs twice as much as plain paper. And you can't print more than one copy at a time.

Ink-jet printing? It's had its ups and downs. A few years ago Teletype introduced a line of ink-jet printers, but they were so expensive that sales lagged and they were discontinued. More recently, Casio Computer Co. in Tokyo introduced an ink-jet printer as both an OEM mechanism and part of a line of terminals with keyboards. This printer sells for less than $1000 in OEM quantities.

Casio's system comprises a printing head (the ink emitter), a pressure generator, a pump, a printing-head shift section, a paper-feed section and electronics for character generation, ink deflection and other peripheral control. Slight pressure is applied to an ink meniscus at the tip of the nozzle on the emitter. The meniscus is drawn forward by a strong electric field, applied between the nozzle and an accelerating electrode. The field tears off the ink to form tiny charged particles. Electrostatic deflection is applied to these particles as directed by the character generator, and the particles land on the paper in dot-matrix format. Since many dots are used, the characters appear almost solid.

This is the quietest of all the serial printers, since it is the only one that is truly noncontacting. But it has limitations. Multiple copies cannot be made, and you must contend with extraneous particles of ink sprayed at random on the paper. These spurious spots around the printed characters detract from the otherwise high quality of the printed characters.

Better and better printers

Allen G. Huefner, printer product manager for Digital Equipment, says that the prices of quality serial printers will be coming down to the $400-to-$500 range in the next couple of years. He also believes there will be more compressed printing—smaller characters spaced closer together with more lines per inch—to save paper. In addition he expects microprocessors to be used widely for logic replacement and limited user programmability in printers. Digital Equipment uses a microprocessor in the LA36 as the printer controller.

Calcomp's Trident disc drives provide from 25 to 80 Mbytes of storage, with bit densities running from 4040 to 6060 bpi and track densities of from 185 to 370 tpi.

Paul Ramsden, chief engineer at Centronics, notes that all of his company's new models use custom MOS/LSI circuitry. He expects this trend to spread and also looks for more flexible printers in the near future. For example, he cites the new Model 101S from Centronics, which has a variable-sized character set. Through special instructions, the printer can mix characters from 0.1 to 0.9 in. high in 0.1-in. increments. Ramsden calls these segmented characters, since each normal-sized matrix contains only a small segment of a larger character.

Other printers with flexible, programmable formatting will also do a reputable job as plotters.

Discs getting denser

Magnetic, rotating, movable-head disc drives are increasing capacity with more dense bit-packing. Where 2200 bpi has been common on minicomputer drives recently, densities are going as high as 6060 bpi, with products already on the market.

The drive for higher densities was started a few years ago by IBM, with its 3330 disc drive. The drive used a new recording medium and had a storage density of 4040 bpi. More recently IBM introduced the 3340 Winchester drive with 5636 bpi density. More notable than the storage density on the 3340 is the fact the disc pack, recording heads and positioning arms are contained in a single, sealed, removable module.

With the medium used in these IBM drives, densities of well over 6000 bpi can be achieved. However, with present minicomputer drives, about 3700 bpi is the maximum possible. The medium capable of 6000 bpi is known as the 3336 type.

A leader in the move to dense disc drives for minicomputers is the new Trident series from Calcomp, Anaheim, Calif. These drives use a 5-high removable disc pack and come in 25, 50 and 80-Mbyte-capacity versions. They are known as the T-25, T-50 and T-80, respectively. The disc packs are 3336-type media. Track and recording densities go from 4040 bpi and 185 tpi (tracks per inch) on the T-25 to 6060 bpi and 370 tpi on the T-80.

To achieve these bit and track densities, two major changes had to be made relative to the design of conventional minicomputer drives. First, a new recording or coding scheme had to be used. Most conventional minicomputer drives use a double frequency coding scheme that has two flux reversals for a data ONE and one flux reversal for a data ZERO. The new recording scheme is called MFM (modified frequency modulation). It is characterized by a single flux reversal for a data ONE and a single flux reversal for a data ZERO. But for a data ZERO following a data ONE, there is no flux reversal at all. MFM allows almost a doubling of the data density, compared with double frequency.

Second, a better method had to be found to position the recording head on the proper track over the operating temperature range. The technique that uses a servo surface was borrowed from the IBM 3330.

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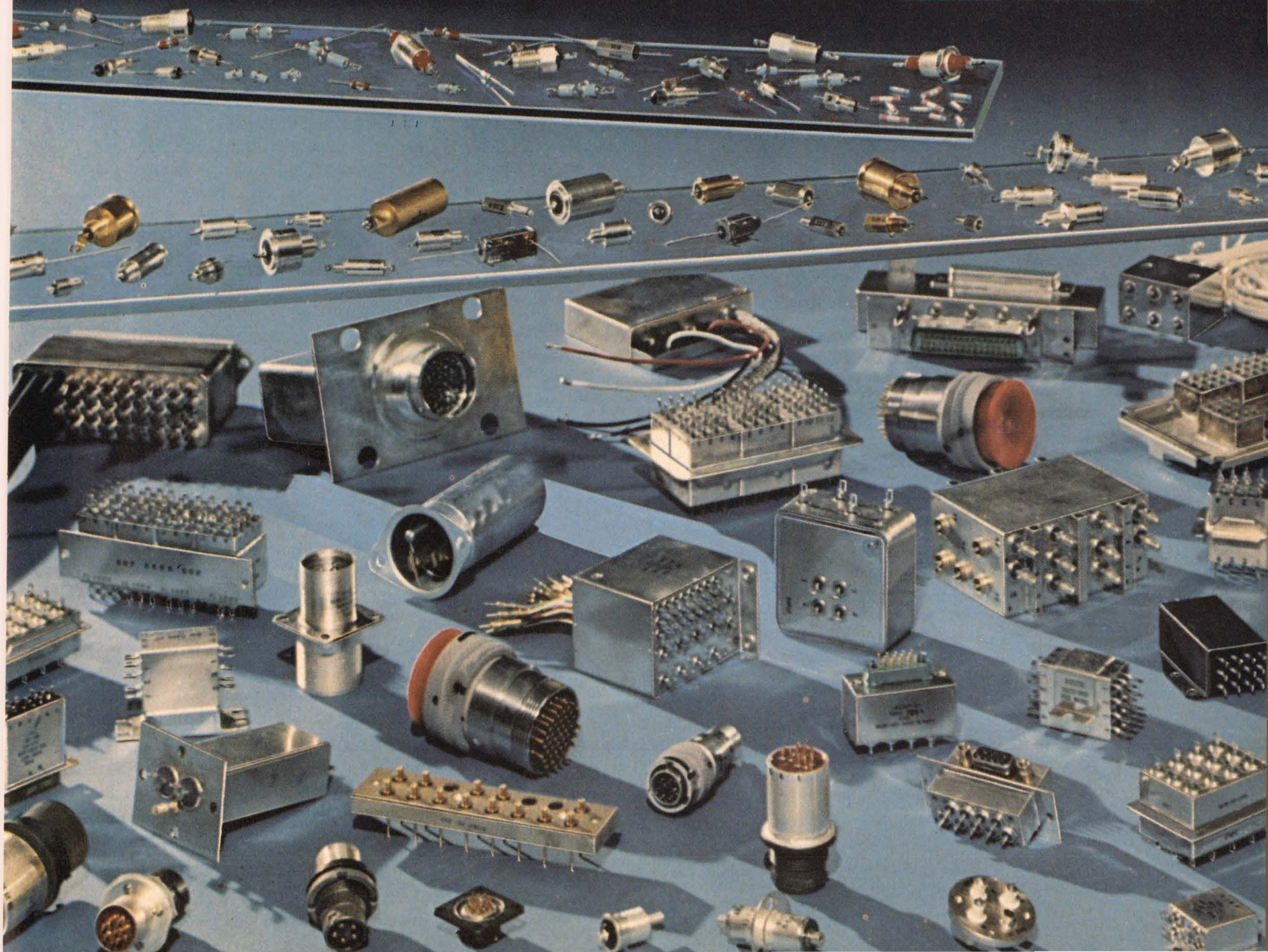


Previously an optical positioning scheme located on the drive chassis was used to locate the head on the proper track. With the higher track density, this is not accurate enough. So a servo surface is incorporated on the disc pack that contains track-location information for the data surfaces. Thus one head follows the servo surface, and the other heads are automatically located on the proper data tracks. Since the servo surface expands and contracts with temperature at the same rate as the data surfaces, positioning becomes relatively temperature independent. The Trident drives have five data surfaces and one servo surface.

The Trident rotational speed is 3600 rpm with a 2400-rpm option on the T-80. This rotational speed along with the high data density creates a unique problem for the minicomputer user. The data transfer rates get too high. Very few minis can accept data at rates faster than 2.5 MHz. The T-80, going at 3600 rpm, transfers data in excess of 9 MHz.

Paul Badum, disc product-planning manager at Digital Equipment, says that minis will ultimately accept data faster. But, he says, a solution for now is to intertwine the data on the disc such that you only accept every fourth word coming off the disc. Thus your transfer rate is cut to one fourth while the additional capacity of the disc is still used.

Walter Emery, director of engineering at Iomec, Santa Clara, Calif., is not sure that MFM recording is the answer, although he definitely agrees that a different recording scheme is needed. Iomec plans to have a minicomputer high-density drive on the market by the third quarter of 1975.

Pertec, Chatsworth, Calif., has already built a prototype drive with 3336 media and 4400-bpi data density. Don Taylor, disc product manager, says that he is not actively promoting the drive, but he will discuss price and availability with selected customers.

One thing that is not changing on the high-density drives will be access time. As Taylor notes: "We don't see a move to faster than the current 35-ms access time."

A higher-density drive is expected from Diablo Systems in the second quarter of 1975. Although the company will not comment on it, the drive is said to be similar to the one that Pertec has prototyped.

Control Data is also actively pursuing the high-density disc-drive market for minicomputers. In Minneapolis, Minn., a 40-to-80-Mbyte drive, called the Storage Module, has been developed that has a data density of 4400 bpi and a data transfer rate of 6.5 MHz. Andrew Roman, senior product specialist with Control Data in Hawthorne, Calif., notes that the Storage Module technology could be quickly adapted to a minicomputer drive. Another problem in going from the current mini drives to a high-density drive is the necessity to fly the head at about 30 μin. instead of the current 60 to 100 μin. "This even requires the design of a new air-filtration system," he says.

Daisy-wheel printers, such as this one from Qume, give high-quality, fully formed characters on six-part forms. Current daisy-wheel printers go up to 45 cps.

Imaginative mechanics

Although many in the industry hope to adapt the mechanical configuration of present minicomputer disc drives to obtain drives of higher density, some are looking for radical changes. Badum of Digital Equipment says: "It's a whole new ballgame. High-density disc drives can be built from scratch with any novel mechanical structure desired. Disc packs can be any height and diameter; new positioning schemes can be used; and any number of disc packs can be used in a single drive. Why not a minicomputer drive similar to Storage Technology's Super Disk?"

Storage Technology, Louisville, Colo., is just about to deliver its first STC 8000 Super Disk. Although designed for larger computers, the 8000 may make itself felt in the direction of new technology in minicomputer high density disc drives. Super Disk has four 15-high spindles of discs mounted in a cluster. Centered between the four spindles is a rotating member that contains four sets of recording heads. As the member rotates, the heads are positioned on all four discs simultaneously.

Each spindle contains 29 data surfaces and one servo surface. Density is 4040 bpi and 250 tpi. The speed of the discs is 3600 rpm, and the data rate is 6.4 MHz.

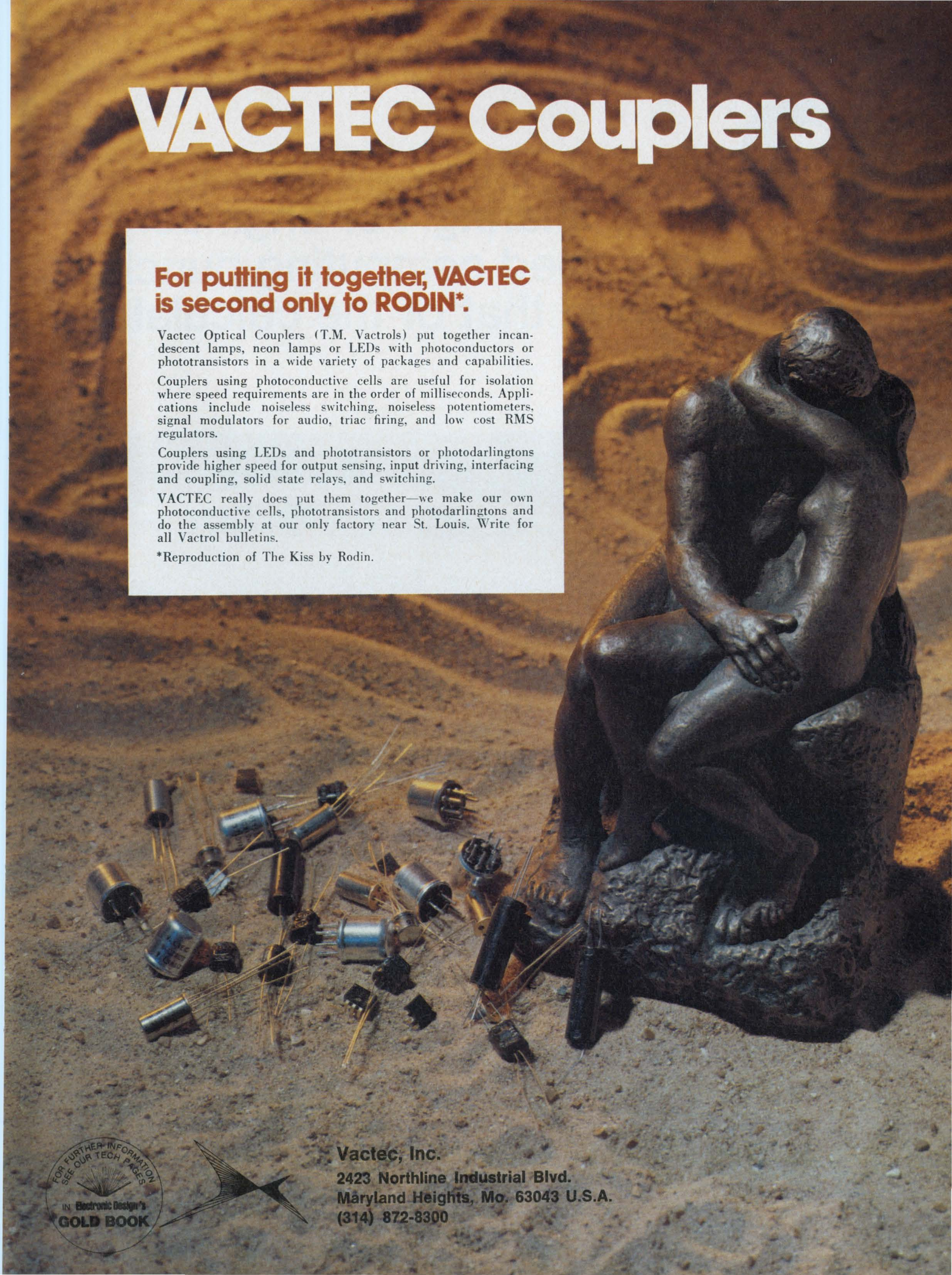
The problem of control

When data rates get high, the disc controller becomes a problem. As Taylor of Pertec notes: "Suddenly you have to handle a 50-ns pulse every 100 ns. And it's not just a question of increasing your clock rate."

Mike Brennan, president of Pico, Santa Ana, Calif., confirms the difficulties: "The key problems are data rate and data integrity. Not only must you handle extremely fast data, but you must also perform an error check on it in a very short period of time. You must manipulate a 12th-order polynomial cyclic redundancy code in 15 to 30 μs. This is twice as fast as most controller designers are used to doing it."

Ralph Tobelmann, design engineer at Pico, says that in addition most high-density disc drives are designed for microprogrammable controllers. At present things like error-retry strategy are controlled by software rather than by hardware. Other problems revolve around synchronization of data with servo information rather than just clock pulses.

The revolution in serial printers and high-density disc drives has just begun. A plethora of new products with new technologies will emerge in 1975. Versions will surface that will work with programmable calculators and even microcomputers. ■■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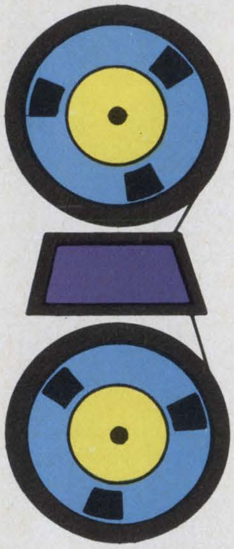

Time sharing: For engineers who need computing punch beyond that of the calculator

For engineers who need more computing power than a desktop calculator can provide or who need access to a circuit design or analysis program, time sharing is the logical choice. Even a rusty or nonexistent background in Fortran or Basic is no deterrent, since the fastest way to learn programming is with an interactive terminal that makes debugging a program much less of a chore.

Access to a large computer allows engineers to keep track of wire and parts lists and to schedule time, resources and manpower during a project. A large computer combined with specially designed programs is useful for circuit analysis and synthesis.

And many of the service-interruption and lost-data problems that plagued time sharing a few years ago are almost negligible today. This has come about through competition between the services and the realization that they must provide fast, accurate computer response to keep their business and scientific customers.

The General Electric Supercenter near Cleveland is the heart of the world's largest time-sharing computer network. It contains 15 large scale computer mainframes which comprise the bulk of the Mark III system.

Not a panacea

Time sharing is not, however, the universal solution to engineering computation. The programmable calculators developed in the last few years are simple to program and can solve many day-to-day calculations. In fact, some engineers with access to both a programmable calculator and a computer terminal solve most of their problems on the calculator.

Doug Ritchey, manager of microelectronics process development at Tektronix, Beaverton, Oreg., explains: "Most day-to-day engineering calculations can be solved with a limited number of program steps—well within the capability of a programable calculator. In addition an engineer quickly becomes familiar with the calculator's limited vocabulary of commands, and he can do a problem without having to log on a computer or remember the programming idiosyncrasies of the Fortran or Basic of the time-sharing system."

With programs that are a little more complex, however, the computer becomes attractive, because the programming is more flexible and much data can be stored. For a circuit-analysis program like Sceptre, which has about 170 subroutines, the computer is a must.

The available programs

For the circuit designer, approximately 50 different circuit design and analysis programs are available, although an individual time-sharing service may only offer a choice of one or two. Some services offer a wide selection: The General Electric Mark III information network, Rockville, Md., has about 20; University Com-

Northe K. Osbrink
Western Editor

puting, Dallas, Tex., has 15.

The programs vary widely in applications. Some are for low-frequency analysis and are designed around current and voltage nodes, while others speak the language of the microwave engineer in terms of S parameters, ports and distributed transmission-line elements. There are also programs for such diverse applications as antenna pattern plotting, frequency analysis of active and passive circuits and digital logic design.

Prefabricated programs require little or no knowledge of computer-program languages, but they do require an understanding of each program's procedures and limitations. There is also a great difference between the ease of use of programs, especially for the beginner.

Dave Goodrich, senior design engineer with the Honeywell Aerospace Div., St. Petersburg, Fla. explains: "Circuit-design programs have been designed by different people with a wide variety of backgrounds and ideas, and vary considerably. The real criterion in choosing a program is that it should provide outputs that are as accurate as the data the user puts in—with a minimum number of user decisions. For that reason, I prefer a program that automatically steps the input data between user-determined limits. Of course, the smaller the steps the program uses the longer it will take to run—but the more accurate the output resolution will be."

The biggest problem in circuit design and analysis programs is in modeling transistors and active components, according to Sergio Bernstein, president of Berne Electronics, White Plains, N.Y. The accuracy of the model determines the over-all accuracy of the program, so some programs go to rather complex models to ensure accuracy. This creates a problem for the user.

According to Bernstein, "The biggest hang-up in many otherwise excellent circuit programs is that it is practically impossible to convert the information on a manufacturer's data sheet into data that the model uses. Most of the modeling is theoretical work, done by physicists, and bears very little relation to the common data that engineers use."

As an example, one general-purpose, circuit-simulation program, known as Spice, was developed at the University of California at Berkeley and is available through a number of time-sharing services, including University Computing Co. in Dallas and Tymshare, Cupertino, Calif. Spice can provide nonlinear dc analysis, small-signal steady-state sinusoidal analysis and nonlinear time-domain transient analysis.

Models are provided for bipolar junction transistors, with a choice of either the Ebers-Moll or Gummel-Poon models, while the models for JFET and MOSFETS make use of the methods of Schichman and Hodges. A diode model is suitable for either junction or Schottky-barrier diodes. The program requests the parameters from the user, and if he does not provide some of them, the program uses "default" values.

Many of the design parameters could be hard for the engineer to determine from the manufacturer's information.

Remote batch system from Control Data can be used to support a number of engineering users by providing high speed data entry and printing capability without tying up individual terminals.

There are limitations

Spice is limited to circuits that have 400 nodes and 200 total elements, of which no more than 100 can be semiconductor devices. Circuits can consists of resistors, capacitors, inductors, independent voltage and current sources, voltage-dependent current sources and active components.

A few of the other commonly encountered programs and their developers include Circus and I/TRAC from Harry Diamond Laboratories, Washington, D.C.; Sceptre, Air Force Weapons Laboratory, Kirtland AFB, N. M.; Syscap from North American Rockwell Autonetics Div., Anaheim, Calif., and a number of recent programs from IBM. There is continual new-program development as well as updating of existing programs.

Syscap is available on the Control Data Corp. Cybernet and performs lumped-parameter, nonlinear analysis of complex electronic networks. It provides techniques to determine if components in a circuit are overstressed—an important analysis in aerospace circuit development.

Syscap is also unusual because it contains a library of transistor, diode and FET characteristics that can be entered in the program with the normal 2N number. Not only are the components modeled, but the library data contain information on maximum, minimum and typical parameters. The library is kept up to date, and most commonly used semiconductor types are in it. If the exact type is not in the library, the user can modify the parameters of a similar type that is in the library or enter data for the part himself.

Tess, another program available on Cybernet, can handle circuits of up to 601 nodes with 600 circuit elements. In addition it can be used to simulate a variety of systems, including control systems and antennas.

Tess can also be used to investigate radiation hardening, reliability, temperature effects, overload and failure, and worst-case analysis. It is a program that requires more user knowledge and interaction than Syscap and most of the others, but it is extremely flexible for both circuit and system analysis.

The circuit-analysis programs intended for microwave designers are structured somewhat differently. One example is Bamp, designed by Hewlett-Packard Data Systems Div., Cupertino, Calif. This program permits circuits to be of unlimited size, but they must be divided into a series of two-port networks. Some common two-port networks consisting of discrete components—such as resistors, capacitors and inductors and combinations of these—are predefined and require only component values from the user.

Other networks can be defined in terms of S,Y,Z,G or H parameters, which are converted within the program to S parameters. A library of the S parameters of the HP line of microwave transistors is available, and the parameters of other semiconductors can be measured with conventional or automated techniques.

After the circuit is stored

Once the circuit is defined and stored, a wide variety of parameters can be outputted. These include the S parameters of the entire circuit, which give ratios of signal reflection and transmissions as well as gain, time delay vs frequency and impedances. Outputs can be either tabular or in the form of rectangular or such polar plots as Smith charts.

Computer programs designed to interface with a remote terminal can operate either interactively or in a remote-batch mode. Generally an interactive program allows the user to input one set of variables at a time and to process them immediately and obtain an answer. In remote batch, the user inputs a list of discrete parameters or upper and lower values with orders to step between them. The computer then processes the data off-line and provides an output either when finished or when the user calls for it. Most EE programs operate in remote batch, but a few give the user an interactive option.

The KL-10 processor for the DECsystem 1080, large-scale interactive computer, uses ECL logic and cache memory for very high speed operation. The processor features a PDP-11/40 as an integral control/diagnostic console to load microcode and perform diagnostic routines.

For problems involving just a few values of inputted data, there is no significant difference in processing time between interactive and batching modes. When a problem requires much data to be processed, the batch mode offers several advantages.

Robert C. Levine, president of Information Engineering, Inc., Plainfield, N.J., notes: "Although some users like to feel they are in control and want to see their results immediately, for programs involving a lot of calculation, this is impractical. First, a time-sharing computer-operating system usually gives such a problem a low priority, since it tends to slow down the response time for all the other users. Second, running the job in the background [off line] is cheaper, both in terminal charges and because the computer time may be billed at a lower rate. If any intermediate answers are needed, many batch programs can provide them while the program is running."

Choosing a service is a problem

Choosing a time-sharing service for an engineering department can be a complex decision. The service must be able to supply the prefabricated programs that the engineers need. Among the services having the needed programs, there is a question of quality vs cost.

Datapro Research Corp., Delran, N.J., suggests a few questions to ask when remote computing services are selected:

- Are the company's services available in your area at a competitive cost—including communications and terminal costs?
- Does the company offer the programming and technical support you need?
- Does the company offer the specific programming languages and programs you need?
- Does the company support the type of terminal equipment you need or own?
- Can the company satisfy any requirements for compatibility with your existing programs and data files?
- Does the company appear able to meet your requirements for operational reliability and data security?
- Are you satisfied that the company is soundly financed and in the business to stay?

Quality of service, most users agree, varies from excellent to poor and depends on many factors. The Inertial Div. of Systron-Donner, Concord, Calif., is a user of a great deal of time-sharing computer time for both the design of inertial guidance systems and production controls.

Bud Amser, a staff engineer with Inertial, uses two time-sharing systems—General Electric and University Computing. He explains: "We are so dependent on the computer that we have to be sure that one system is available at any given time. With any system, there is the possibility that the computer will be down when you need it or that you won't be able to get connected due to phone line or other problems. It may only happen occasionally, but since we need at least 99.9% assurance of service, any down time is more than just annoying."

Today most users see the "service interrupted" message less often than they once did. This is because of greater maturity in the time-sharing industry and improvements in both hardware and software. Most customers seem quite satisfied with the reliability of time-sharing systems.

On the other hand, some areas are plagued with poor service on voice-grade telephone lines. A simple noise on the line can cause garbled data, and the user may get a "What?" message back from the computer.

A more serious problem, according to Alan Heflich, senior engineer at the Honeywell Aerospace Div., is this: "With some time-sharing networks, the noisy telephone line can cause the system to kick back to the system operating level, and all the data entered up to that time will be lost. For areas with notoriously poor telephone service, even a data-grade line has this problem sometimes."

Another telephone problem pointed out by many engineers is the company switchboard operator. Sometimes if she hears the warbling data signal, she thinks that the line is bad and disconnects the computer from the user. The solution is to install a private line for the computer terminals.

Cost is another important factor in selection of a time-sharing service. Prices between services vary greatly, and it is tempting to pick the one that charges the least. This can be a mistake.

Goodrich of Honeywell explains: "The actual cost of a time-sharing service is not just how big the bills are, but also how much time it costs the engineer to get the answer he needs. When programs are developed, some systems have error-detection routines that are fast and easy to use. On others, it is hard and time-consuming to debug programs. It seems that many of the time-sharing vendors who are not in the business of building computers give much better software support—I wish I knew why."

Engineers use simple hardware

After a decision is reached on a time-sharing service—on the basis of both cost and service—the next important decision is what terminals and other hardware will allow best use of the services. The majority of today's engineers are using the Model 33ASR terminal from Teletype Corp., Skokie, Ill. Although it has only a 10-character-per-second printing rate, it is one of the least expensive terminals to rent and has provisions for punching and reading paper tape. This permits command and data data lists to be produced off-line, so that computer-terminal time is not wasted while the inputs are typed.

The remaining engineers, by and large, use one of the many standard 80-character print-width terminals available from a variety of manufacturers. These terminals will operate at 30 characters per second, which is the maximum for voice-grade telephone transmission. Again, cost is the deciding factor in many of these choices. But the hard-copy record of both inputted data and outputted answers is an equally necessary consideration.

Barry Cohn, engineer with the applications research group at Intel Corp., Santa Clara, Calif., explains: "Most electronic-engineering problems require alphanumeric data and use tabular outputs. In the cases where a graph is necessary to display trends or crossover points, a printer can provide a perfectly usable picture, accurate enough for most applications."

Typically a desktop printer terminal will rent from $75 to more than $175 a month, and it can include a paper or magnetic tape reader for the inputting of data.

For the rf and microwave designer, graphic outputs may be a practical necessity, although many engineers plot graphs from printed data. Usually a time-sharing service has several options to provide graphics for users. Generally the least expensive is an incremental flatbed plotter, which can be interfaced to the alphanumeric terminal. The rental can add about $250 a month to the time-sharing bill. A CRT terminal, like the Tektronix 4010 or 4012, provides graphics at about the same price as a plotter and printer, but it requires at least one hard-copy option to support an engineering group.

The ideal hardware for an engineering department is usually a mix: CRTs to save paper for interactive work, printing terminals to provide permanent records and some type of graphics. It is also useful to have a high-speed printer connected to a data-grade telephone line, so long printouts can be made in-house.

How services charge

In addition to the rental of a terminal and telephone-line interface, the bill from a time-sharing service will be based on several other items. During the time that a terminal is actually on-line to the computer, there is a terminal time charge that runs from $10 to perhaps $35 an hour. The time actually used on the CPU is billed at rates ranging from about 5 cents a second, and the user is also charged for the amount of information stored on the central computer's memory for more than a few days.

Terminal users can also have a wide array of auxiliary services from time-sharing companies. For instance, Tymshare offers high-speed line printing, decollation, card reading and punching, paper and magnetic-tape I/O and other media-conversion services at its computer center. A user can request these services via his terminal, and the work is automatically performed during slow computer hours. For example, a disc file can be printed at the center and mailed to the customer to avoid use of excessive terminal time. A large program or data file may be loaded onto the computer from cards or tape at the center for access the next day. ■■

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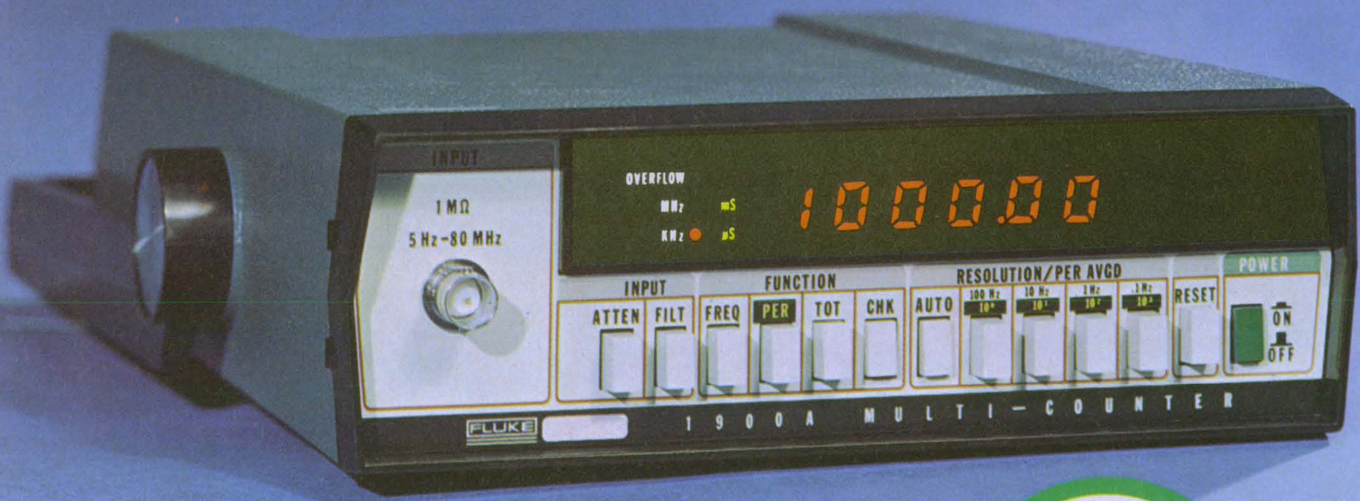

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INFORMATION RETRIEVAL NUMBER 35

washington report

Congress cuts defense budget by 5%

Despite the President's objections, Congress sliced the Dept. of Defense budget for fiscal 1975. But it wasn't with a meat axe as some lawmakers wanted. The cut was slightly over 5% of the original request.

The Administration had asked Congress to appropriate $87-billion. After a conference between the two bodies, the final figure was $82.6-billion. The reduction of actual outlays this year will amount to $2.5-billion. A total of $19.8 billion had been requested for procurement. This was reduced to $17.2-billion. Operation and maintenance funds were cut $1.72-billion. While not calamitous, $745,799,000 was sliced from the total for research, development, testing and evaluation, leaving $8,576,670,000.

Sen. John McClellan of Arkansas, chairman of the Senate Appropriation Committee, notes that while the appropriation is the biggest in history for defense, it will provide less purchasing power and requires the military services to re-evaluate and tighten their belts, particularly in the area of research and development.

Aeromagnetic survey to hunt offshore oil

Although oil men never know if there is petroleum in a spot unless they actually drill, the U.S. Geological Survey is trying airborne magnetic surveying as a source of data on the Continental Shelf off the East Coast. The survey, to be completed in a year, will take in some 300,000 square miles from the Canadian border to Florida. Sensitive detectors will be used to reveal subtle magnetic variations associated with different rocks underlying sedimentary geological structures that might contain petroleum. By analyzing these variations in magnetism, scientists expect to measure the thickness of the sedimentary deposits.

The flights will be made at 1500 feet from the coastline out to water depths of about 15,000 feet. LKB Resources, Inc., of Huntington, Valley, Pa., has received a $600,000 contract to do the work.

New contracting rules would help GSA save millions

Since 1965 the General Services Administration has had the authority to lease automatic data-processing equipment for the Executive Branch of the Federal Government. But its hands are tied, when it comes to contracting. Now the Senate has moved to untie them.

A bill introduced by Sen. Charles Percy of Illinois has been approved. It would amend the Federal Property and Administrative Services Act of 1949 to permit the GSA to enter into multi-year leases without need to spend the full amount. The maximum length of contracts would be 10 years. At present the GSA, through the Automatic Data Processing Fund, has the authority to lease computer and related equipment on a multi-year basis—the most economical lease. But the law requires that the amount payable over the entire period of the lease be spent from the fund at the time of the contract.

The GSA couldn't handle this financial load and still provide the equipment needed. So the agency resorted to one-year leases or long-term leases with termination rights, neither of which was economical.

The new bill is expected to clear the House and become law this year. The GSA estimates savings of $35-million to $75-million over a two-year period.

All-weather shipboard navigation system sought

The Maritime Administration has moved to develop an all-weather shipboard navigation system to improve shipping safety in the St. Lawrence Seaway. The system would be fully automatic and would display in real time vessel speed, position right or left of channel center line, vessel attitude or crab angle to the channel center line and distance to the next turn. A ship-mounted radar would transmit pulses to passive retro-reflectors mounted on towers along the channel. It would provide year-round precise navigation.

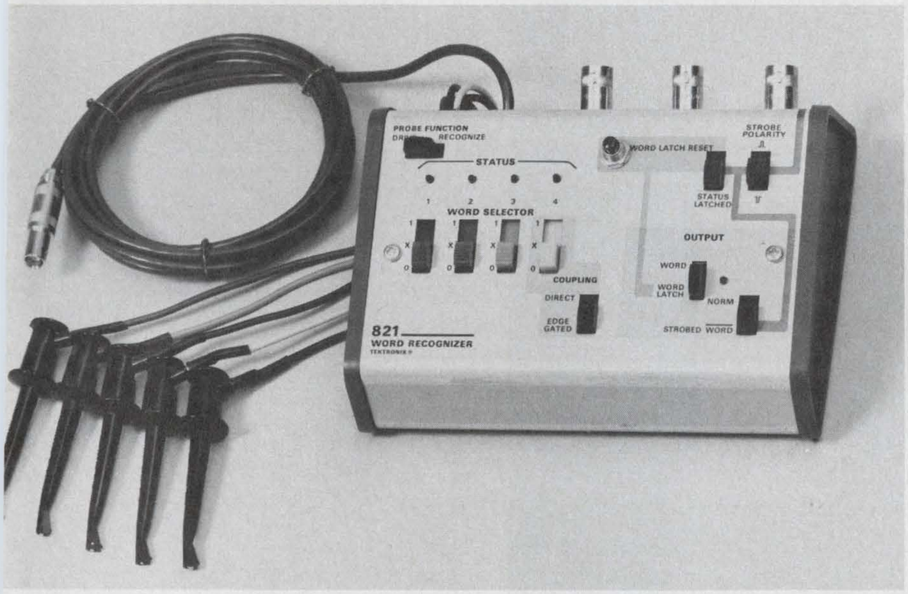
In mid-September the Office of Domestic Shipping announced that it was looking for companies with expertise in the design, development and testing of a suitable navigation system. If the Maritime Administration receives a green light, a request for proposal will be issued to companies judged best qualified.

A Commission on supplies and shortages proposed

Congress has given President Ford a suggestion to provide "economic foresight" to both the Executive and Legislative Branches of the Government: a National Commission on Supplies and Shortages. The commission would advise on possible crises in the supply of resources, materials and commodities. Congress envisions such a commission as permanent to eliminate crash planning. The group would recommend actions needed to offset or mitigate crises. The 13-member commission would be composed of five persons from the private sector, four senior officials of the Executive Branch, two House members and two Senators.

Capital Capsules: The Army Electronics Command **is acting to develop a solid-state multistage reflection amplifier, either avalanche or transferred electron diode type,** in the 60-GHz range. . . . **Microprocessor chips of various I/O word lengths are being evaluated** by the Naval Air Development Center for possible future integration into special-purpose, digital-interface designs. . . . The Air Force **is planning to establish preliminary subsystem designs for high-data-rate laser communications.** The designs would be used to link satellite to satellite, satellite to aircraft or ground, or aircraft to aircraft. The Air Force, which has designed and fabricated integrated circuits that are comparable to industrial ECL 10,000 circuits, **is seeking a semiconductor manufacturer with a suitable high-volume production line. If the circuit can be produced in quantity, the Air Force wants to use them in high-speed data processors.** It already has as ECL 10k-compatible LSI array in the design stage.

stable digital displays - two easy ways



Logic Triggered Displays

Stable oscilloscope displays of asynchronous logic sequences are easily achieved with a trigger from the 821 Word Recognizer. And the 821 will work equally well with synchronous sequences that have no single unique sync point. As a trigger generator the 821 combines your choice of input logic signals to produce a single output pulse. Appearance of a specific op code in an instruction register, a predetermined count from a digital counter, or the occurrence of a special set of logic levels at your system inputs can all be used for jitter-free oscilloscope triggering.

And the versatile 821 serves as a logic "babysitter" to indicate whether a selected combination ever occurs, as an indicator of word presence or absence at strobe time, as a strobed four channel logic probe, and as a four channel logic level driver for troubleshooting static logic. All of these valuable logic diagnostic aids are offered in one pocket-sized unit for only $200.

Delay By Events Trigger

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Easy thumbwheel selection of any delay count from 0 to 99,999 provides quick positioning of the desired data segment on the oscilloscope screen. Versatility has been assured by making the DD 501 compatible with all logic families. The DD 501 plug-in can be housed in any TM 500 Series Power Modules. It is priced at only $495 plus the Power Module ($125 for the TM 501 shown above).

For more information on stable digital triggering the easy way contact your local Tektronix Field Engineer or write: P.O. Box 500, Beaverton, Oregon 97077. In Europe write: Tektronix, Ltd., P.O. Box 36, St. Peter Port, Guernsey, C.I., U.K.

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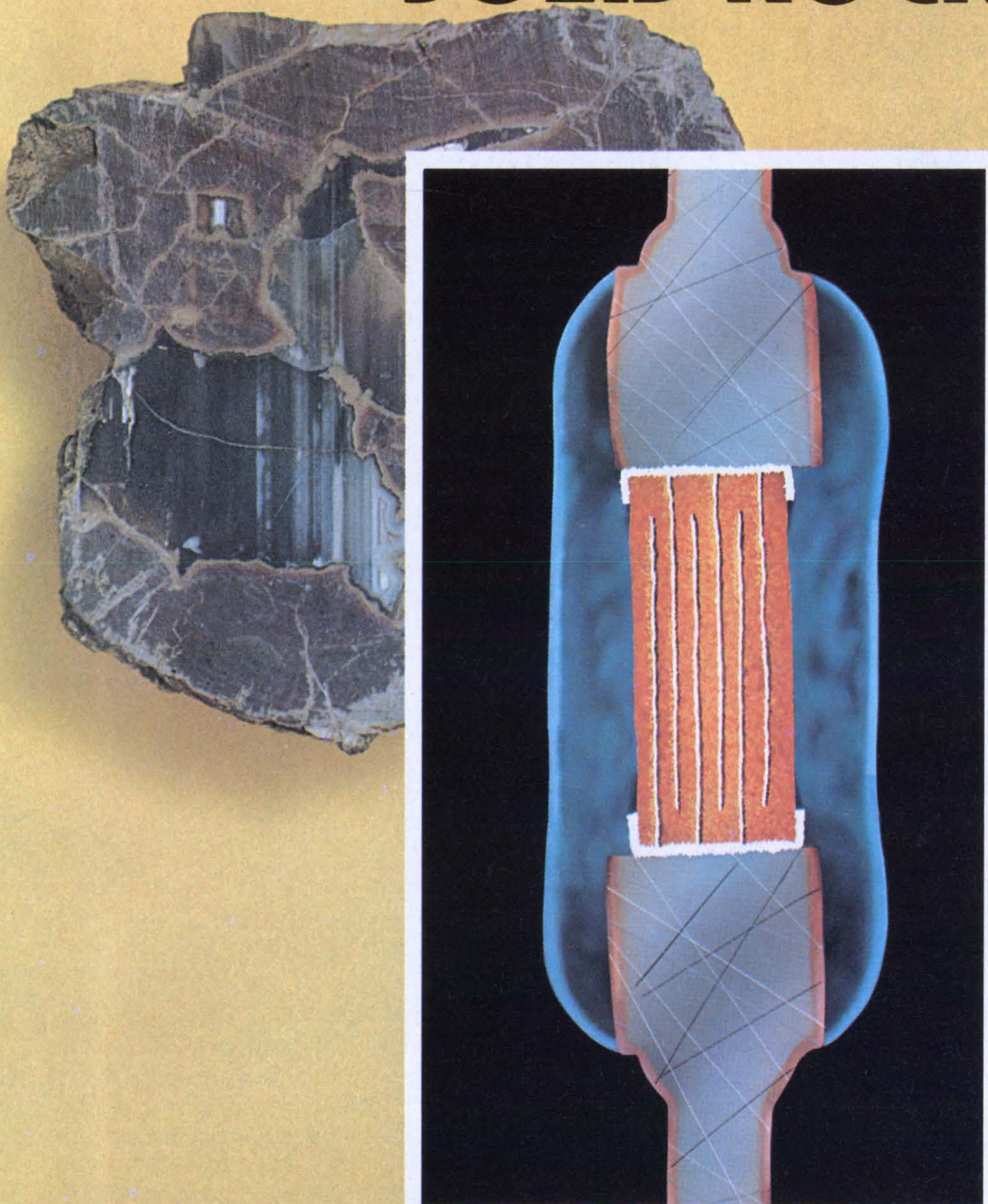
FOR DEMONSTRATION 240

SOLID ROCK



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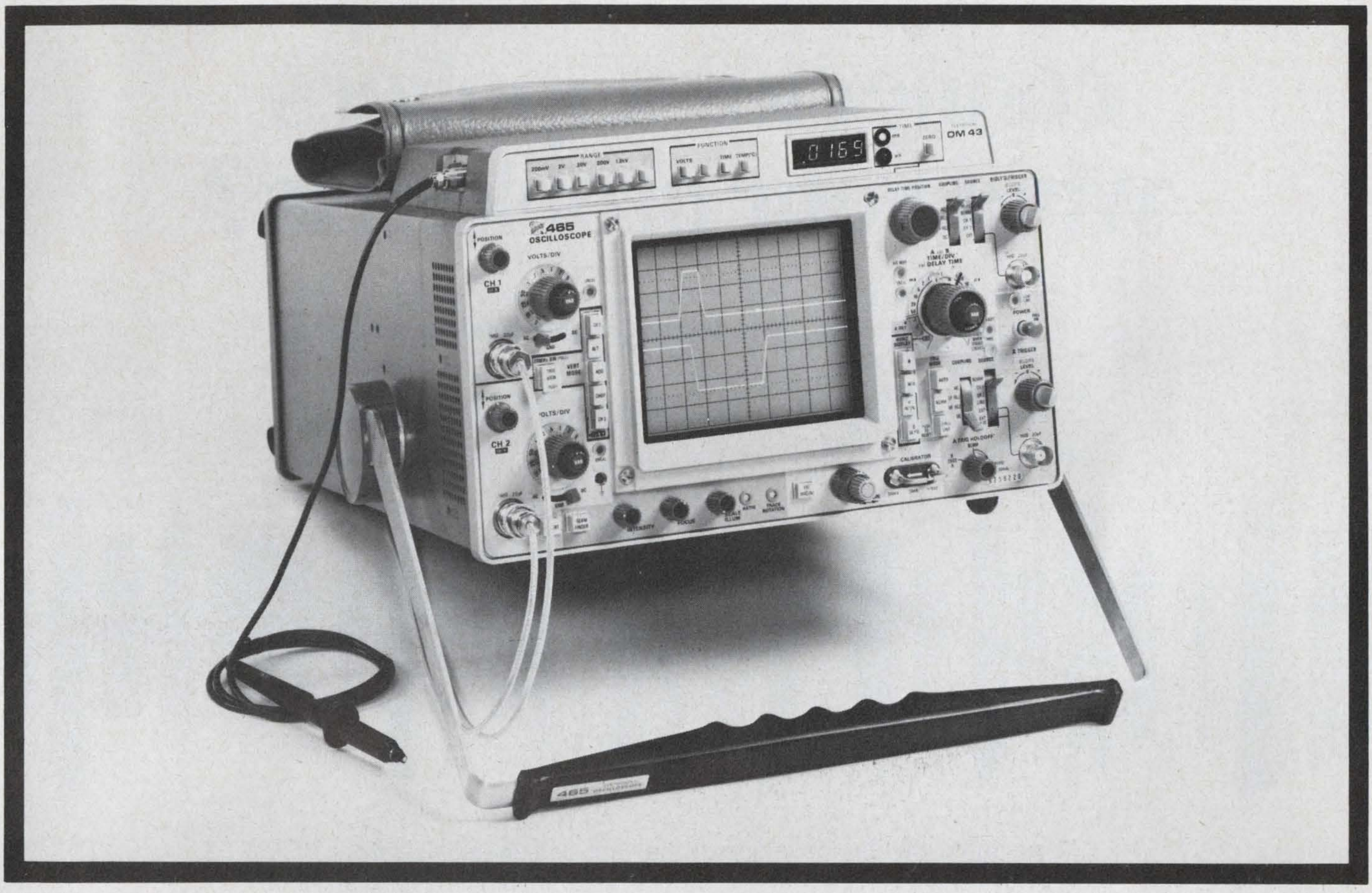
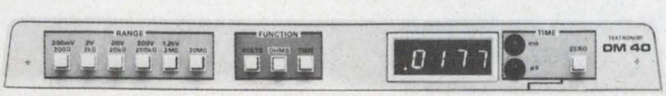
INFORMATION RETRIEVAL NUMBER 37

Digital Timing Measurements The Easy Way........



Digital timing measurement with improved resolution, 1% accuracy, increased freedom from error, faster operation, and greater operator convenience. The new TEKTRONIX DM43 with its direct numerical readout of time intervals adds all of these advantages to the field proven 465 and 475 oscilloscopes. What's more the DM43 includes precision digital meter capabilities as well. The DM43 is also available in the new 466 and 464 Fast Storage Portable Oscilloscopes.

The DM43 provides a direct numerical readout of the time between any two points on the oscilloscope screen selected by the delay time position control. 3½ digit resolution and the 1% accuracy of the DM43/oscilloscope combination provide convenient measurement of critical digital system timing in field servicing, in production, and in the design lab. Speed of measurement, freedom from error, and operator convenience are all improved since no dial readings or mental calculations are needed to arrive at a final reading.



Dc voltage measurement with an accuracy of 0.1% from 0 to 1200 V, resistance measurement within 0.75% over the range 0 to 20 MΩ, and the convenience of temperature measurement with a probe over the range −55°C to +125°C add still more to the versatility of the DM43. In field servicing, in production, and in design laboratory applications the DM43/Portable Oscilloscope combination provides the capability to meet almost any measurement need, and it's all in one compact package which can easily be carried wherever tests must be made.

With all of its added features the DM43/Oscilloscope combination is priced only $475 above the price of the oscilloscope alone. A second model, the DM40, has all of the features of the DM43 except temperature measurement for only $390.

To find out more about this innovation in portable instrumentation, contact your local Tektronix Field Engineer or write Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97077 In Europe write Tektronix, Ltd., P.O. Box 36, St. Peter Port, Guernsey, C.I., U.K.

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FOR DEMONSTRATION 241

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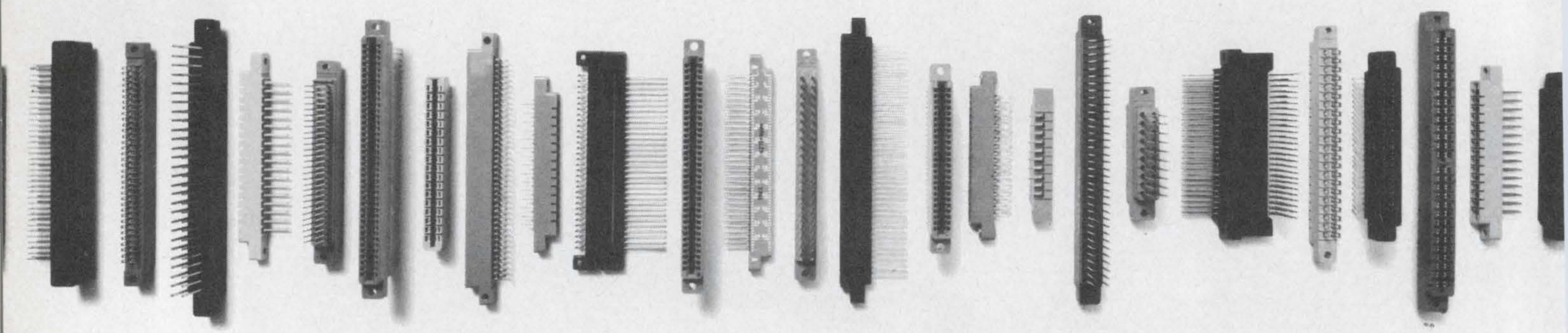

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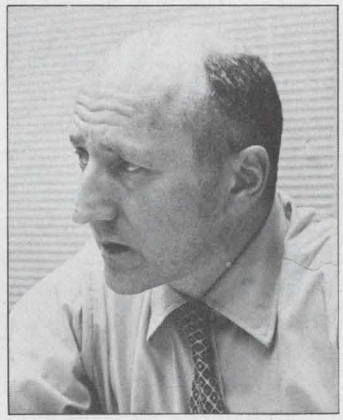
INFORMATION RETRIEVAL NUMBER 39

editorial

Gee whiz



We're getting too jaded. We take for granted the astonishing technological leaps of our industry. A mere 40 years ago, nobody had seen a scope. Now nobody's without one. A mere 22 years ago, none of us had seen a digital voltmeter. A few years later DVMs began to appear on our benches for about $4000. Today you can buy one for $200.

A mere 15 years ago nobody had heard of an integrated circuit. When Texas Instruments held a press conference in March 1959, to show a few single-chip, flip-flop "Solid Circuits," the technical world did, indeed, say "Wow." But people saw these devices as fascinating laboratory curiosities that might, one day, find a few applications where size was a paramount consideration and price was none. They cost about $1800.

Had anybody said that, in a dozen years, more complex parts would appear everywhere and would sell for as little as 30 cents, he would have been tucked away someplace for quiet and rest. A man predicting then that we'd be able to buy 4000 bits of memory on a quarter-inch square of silicon would have been classed as a nut or a dreamer. Today we greet such achievements with a yawn.

And the computer! 25 years ago almost nobody had seen one. And somebody said that the nation's computing requirements could be met by three machines—one in the east, one in the west and one in the middle. Ten years ago company presidents still included "our computer" in every tour for visiting dignitaries. Today nobody looks any more. Most of us have forgotten the days when $200,000 bought a "cheap" computer. What's our reaction today when computers are available for under $1000? Ho-hum.

And that's one of the things wrong with the engineering profession. We take our contributions for granted. We look around and see a world full of electronics. We see telephones, color television, facsimile equipment, satellite communications, electronic calculators (that sell for as little as $20), a mind-boggling array of powerful test equipment, an integrated-circuit technology with undreamed of potential. But we've lost our ability to marvel. We've lost the ability to admire our own handiwork. We don't know how to say, "Wow! I'm part of the industry that makes these things happen."

It might be a great thing for electronics engineers if we could learn from our children how to admire our achievements and say, "Gee whiz!"

GEORGE ROSTKY
Editor-in-Chief

We know you have more important things to do with your time than filling out forms. But once a year we're required to re-verify the qualifications of everyone who wants to continue his free subscription. Please take a moment now to fill out the form tucked inside the front cover. We promise we won't bother you again until next year.

FOCUS on Modems and Multiplexers

It's a rewarding challenge to join computing equipment and terminals into a distributed network. The reward is quick access to dispersed information and the kind of on-line processing that lets you put computer power where it's needed. The challenge is to select data-communications equipment that is compatible throughout the system and doesn't conspire to reduce throughput to a dribble.

If your first thought is that the EIA RS-232-C standard for data communication will help you, you're only half correct. The standard covers only the digital end of the modem—where the machines are plugged in. What goes out on the analog end—to the telephone line—is up to the modem manufacturer.

To further befuddle you, the data-communications industry has generated a collection of buzz words that is second only to that of the software industry. Not only must you decode the buzz words, you must also speak softwarese if you hope to understand what the computer is trying to do with the lines. Both hardware and software specs have to be pinned down in the selection of modems. Once you know these, you can combine modems and multiplexers to create a useful network.

The word modem is an acronym for modulator-demodulator. These send-receive sets match telephone lines, wire lines or, in a few instances, a laser beam to convert digital pulses to analog waveforms and vice versa.

The digital data are placed on a carrier by the modulator section and go over the line as ac signals. The reverse occurs at the opposite end when the demodulator recreates the original digital signals.

A modem has a transmitter (modulator) and receiver (demodulator) in the same box. Given four wires and the modulator joined to the demodulator, you get simultaneous two-way data exchange (full duplex). If the modulator and demodulator share the same line, only one machine can communicate at a time in a given direction (half duplex). A good example of the latter is conversation; one party listens while the other talks, and vice versa. The third type of communication, seldom used, is most undemocratic; one party always talks, and the other always listens. Such a communications system is called a simplex.

EIA RS-232-C establishes the standard for a

Peripheral sites can be located thousands of miles from the computer that serves them. A 4800-bit/s modem is used on Paradyne's PIX remote system.

Seymour T. Levine
Associate Editor

modem's control functions, allowable digital signal levels and the means for the initiation and termination of communications.

In a sense, the EIA standard establishes the first level of compatibility—that of the data equipment and the communications system. Manufacturers do not necessarily provide all the control and signal functions that your data equipment uses and requires, yet they will almost to a man state that they conform to RS-232-C. They do in a way. They conform to whatever portion of the spec they deem convenient! One manufacturer omits all control and detect signals. His conformance: He supplies the digital data line.

A similar standard, but not compatible with RS-232-C, has been prepared by the Consultive Committee on International Telegraphy and Telephony (CCITT) and is used abroad. And the U. S. military uses its own standard, MIL-STD-188C.

What RS-232 never tells you

The EIA standard omits other specs that can clobber your system. There is no clue to what analog signals the transmitter can send nor to how the receiver operates. Buy two modems from different manufacturers, and the result can well be like that of an AM transmitter broadcasting to an FM receiver. That guarantees you zero throughput—and quite likely a zero paycheck.

But you can find out what control signals are necessary for your device and insist on their being in the modem. Then you can buy all your modems from the same manufacturer.

Great. You've met the two conditions of compatibility—so why is your 600 line/min printer crawling like an inexperienced typist? You've overlooked another trap: Poor design of receiver and transmitter equals big error rate. Back at the office the computer sees gibberish, but it keeps trying to get the message through with reverse channel repeats and error-correction techniques.

If you build your own modem, you may be able to avoid some, but not all, of the compatibility problems. Let's see what happens if you build an integral modem wiring a commercial chip set. Your customers will love terminals and gadgets designed with these. They can relax, because you've used some of the newer modem-on-a-chip devices and they needn't fret about selection of a separate modem. Your boss loves integral modems, too, because of the value added to his product. The customer merely hooks up to the phone line, and he is on the air.

But wait till your customer tries to access the corporate computer when another manufacturer's modem is on the computer's output port. The result could be gibberish again.

Although modem vendors tend to talk around this problem, de facto standards are available. Many manufacturers base their designs on Bell's modulation techniques and provide the necessary compatibility and Bell is still the largest supplier of modems (it calls them Data Sets).

The fewest compatibility problems occur with modems designed to handle asynchronous data—data that do not use clock signals to define the bit positions. The initial transition from a One to Zero initiates the receiver's clock, so that subsequent bit times are recognized. Of course, when the sender transmits a sequence of all ONEs or all ZEROs, no transition occurs, but the receiver device recognizes a time limit for the state and can log the bits properly.

Binary frequency-shift keying (FSK) is most frequently used for asynchronous transmission. And the major specs are uniform among nearly all manufacturers. The modem's analog output is one of two frequencies—one for logic ZERO

Modems are to computers as telephones are to man. Digital techniques have shrunk the modem to a convenient size without sacrifice of performance.

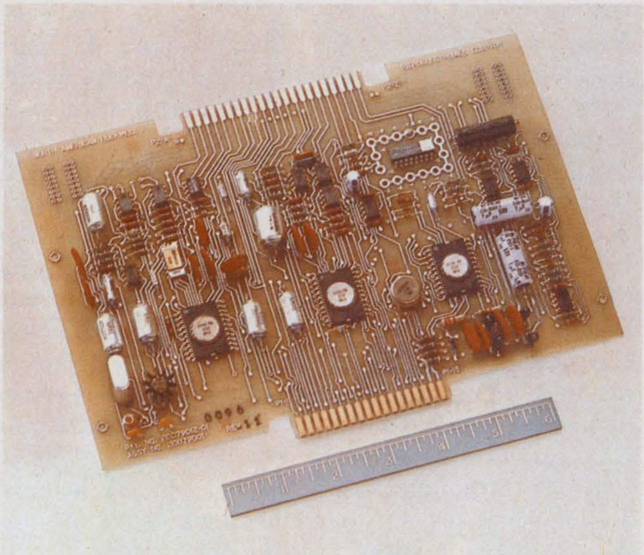
and another for logic ONE. The demodulator at the other end recognizes the tone frequency and encodes the correct binary voltage or current values.

FSK modems find most use in low-speed transmission, such as that associated with teletypewriters and a number of CRT equivalents.

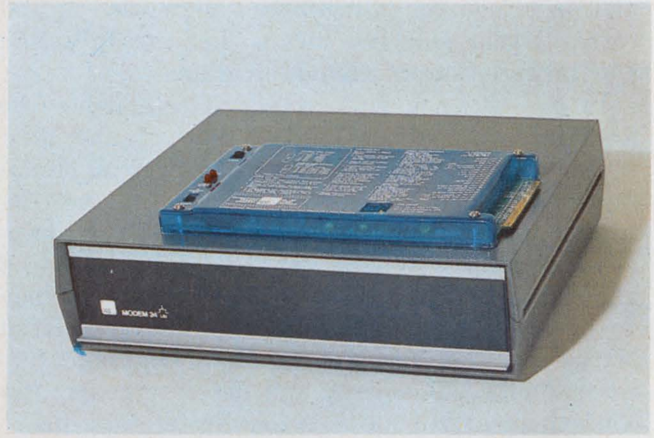
Bits, baud—what's the data rate?

Speed of data transmission is sometimes specified in baud, sometimes in bits/s. The baud rate measures the maximum number of signal elements per second. If during each element time several levels can occur—for example, amplitude levels—then baud and bit rate do not correspond. Thus 100 baud at 2 bits/baud = 200 bits/s.

The bit rate is more important, since it is the rate at which the terminal or device sends. If each signal element contains two possibilities (one bit), then bauds and bits correspond. For example, the Model 33 Teletype communicates



CMOS digital synthesis of analog functions is one of the trends in the modem industry. This board is a complete 4800 bit/s modem from Rockwell.



Large modem houses see the day when OEM modem cards become an integral part of digital design. ICC/Milgo offers its 2400-bit/s blue-chip series.

at 110 baud or 110 bit/s. For proper modem specification, you should furnish the bit rate; the manufacturer may encode the data at a lower baud rate, if necessary.

For low-speed transmission, the modems are often designed for full-duplex operation—simultaneous two-way communications on a single pair of phone lines. A two-wire line suffices, because of the separation between carrier frequencies—which is in effect, a frequency-division multiplex situation.

These low-speed modems come in four types: (1) Originate Only; (2) Answer Only; (3) Originate/Answer; (4) Automatic Originate/Answer.

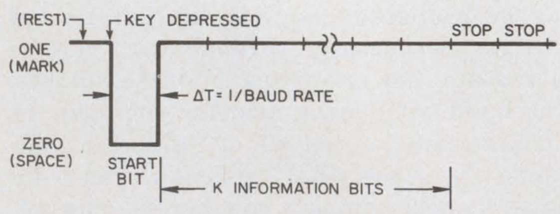
This gives you your first compatibility problem. The Originate and Answer modems must work in pairs—with an Originate unit at one end and an Answer unit at the other. If you can't find out what's on the other side of the line, you need either type 3 or the most expensive—type 4. Another way to make a mess is to put the modems in willy nilly. You'll almost certainly get zero throughput for the entire system. Beware when you read ads for asynchronous modems-on-a-card at a very low price. Such a price often delivers a card with only type 1 or type 2 operation. For type 3, you might need two cards and have to add your own switchover circuitry.

The auto-answer feature causes even further confusion. There is a type 2 unit called Answer-

Asynchronous Code—A start-stop affair

Press a button on a simple asynchronous terminal and out pours a prescribed fixed-length sequence of logic ONEs and logic ZEROs. Then the signal line remains set at a logic ONE until another key is pressed. By previous arrangement, the receiver at the opposite end recognizes the start of a message. How? By convention, the line rests at logic ONE; the first bit is a ZERO, then the code bits come, which are followed by one or two stop bits (both logic ONE). The first transition trips the receive controller, and additional circuitry allows examination of line state at the proper bit time. The receive terminal also knows the number of information bits. The Stop bits frame the end-of-character, and are compatible with the idle or wait state.

Baudot code uses five information bits; ASCII, eight. The total bits sent per character also depend on the necessary stop time (number of Stop bits).



Model 33 Teletype terminals use two Stop bits and ASCII code—that is, 11 bits per character. This is the code used on Western Union's TWX Network at 110 baud. Telex uses the five-bit Baudot code with a rest period of 1.5 baud times, and operates at a 50-baud rate.

In communications circles, the number of message bits equals the level. By definition ASCII is an eight-level code. Another feature of ASCII is the check bit: The first seven bits define the 2^7 characters—the eighth is available for parity-check purposes.

Only, Automatic-Answer, which is used for unattended terminal devices.

Asynchronous data carry no reference clock, so the receiver must rely on $0 \rightarrow 1$ and $1 \rightarrow 0$ transitions to decide between ZERO and ONEs. But telephone lines introduce noise and delay distortion that produce time displacements of the transitions. You can't control the phone lines, but you can try to avoid additional distortion from the modem.

The modem distortion spec is often omitted, or if given, it can be quite misleading. With full-duplex operation on a single line, the transmit channel interacts with the receive channel. But you want minimal interaction. At worst-case conditions—0 dBm transmit, 40 dBm receive—about 7.7% is a good value.

If given, the distortion values are often not specified for the associated transmitter output. With some FSK modems, the user can trim out the bias. A small voltage fed to the comparator or slicer circuit compensates for lack of symmetry in the discriminator output. Once adjusted, the remainder of the distortion is random jitter. But what about tempco and other drift factors that are almost always omitted in the spec sheet?

Although most designers supply clean digital pulses to the modem's modulator, you can still make a mistake and supply signals with slow rise times—more than 1% of the baud time. What happens is this: Because the modem doesn't use a precision comparator to dictate frequency transitions, the change from Mark to Space or vice versa doesn't slew at the signal rate. So distortion is introduced. The modulator chatters between the two allowable frequency states. Sloppy pulses can result inadvertently if the cable capacitance is too large. The EIA spec recommends that cable lengths be less than 50 ft.

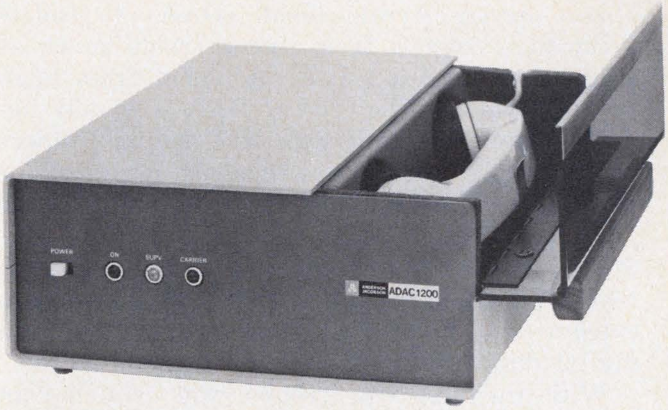
Choose the right features

The basic RS-232 spec delineates 25 lines for control and data signals for interface with digital machines. But in commercial modems, the availability of each pin can become a special feature at extra cost.

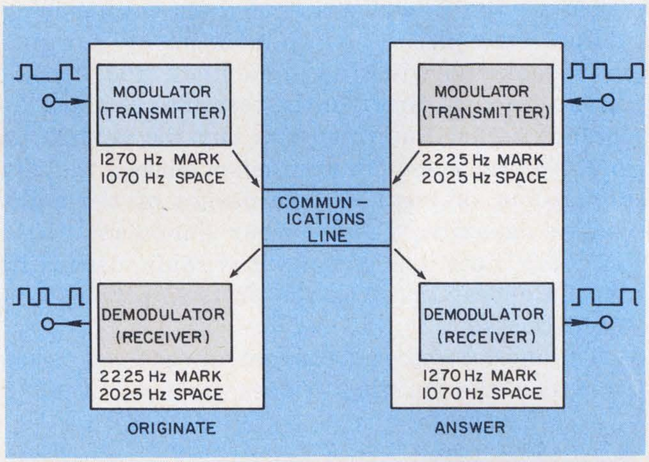
Ask yourself two basic questions: Will the modem operate on the direct-distance dialing (DDD) network or on a leased line? And will the modem be from an independent manufacturer or from the Bell system?

In the Bell system, you tell the representative what you are trying to do; he recommends the Data Sets, and Bell takes the end-to-end responsibility for data integrity. If you select and specify modems, you must tell the vendor whether you are on leased or dial-up facilities.

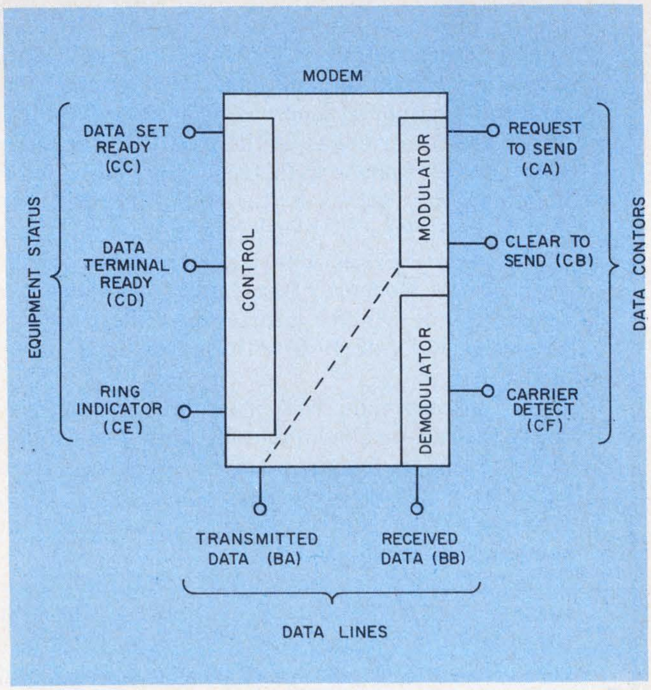
With dial-up facilities, you have to use a Bell



The acoustic coupler gives quick access to a line. Data rates up to 1200 baud are possible with the ADAC 1200 from Anderson Jacobson.



Originate and Answer modems must operate in pairs so that receiver and transmitter frequencies match.



Summary of signal types, designated by EIA RS-232-C, for use with modem control.

Direct Access Arrangement (DAA) to isolate the modem signals from line currents (such as ring) and to protect Bell equipment from inadvertent damage. The type of DAA is equally important. Some provide logic-level signals; others use contact closures. Also, modems designed for private-line use are often incompatible with the DDD network.

The signals that modems work with, regardless of modulation form, fall into three main categories: equipment status, control lines and digital data lines.

With the first two groups, you establish an acceptable sequence for initiation of channel communication and obtain feedback that the channel is operating. Actual transmission or reception of data occurs over the data-line group. The subset of signals required depends very much on the intended use of your equipment.

For example, a bargain-basement terminal could make do with just data lines, and it could use an integral timer in the terminal to allow for channel setup. But when you buy the modem, allow for future system expansion. Should the vendor go out of business, the design of the added control capability falls on your shoulders.

Status lines are almost inevitably used with dial-up operations. And the protocol can be quite sophisticated.

The most common data-control sequence is one in which the terminal raises Request to Send, and the modem responds (after an appropriate delay) with Clear to Send. But with a dial network one must also have a ring indicator to show when the equipment is to operate. On private lines (dedicated lines furnished by the phone company) you can often dispense with the status signals.

Unfortunately, the RS-232-C spec does not indicate the exact logic relationship between the carrier turn-on time and the conditions under which combinations of status, data controls, and received-carrier result in a Clear-to-Send signal. Rather, a de-facto standard—based on how Bell uses available control lines—governs. Not all manufacturers adhere to that standard, but the vast majority do.

Present regulations require the use of a DAA device, if your modem operates on the direct-dial system. Bell supplies the DAA in three basic models, all of which provide a 600 Ω audio circuit, transformer coupled to the line. But that's where the similarity in models ends.

Model CDT provides the audio circuit only; calls are made and answered manually. Models CBS and CBT provide for automatic call-and-answer capabilities under electrical control. The CBT unit provides contact closures to your circuit and requires contact closures from the circuit. CBS communicates with RS-232-C voltage levels.

As part of the modem spec, you must tell the

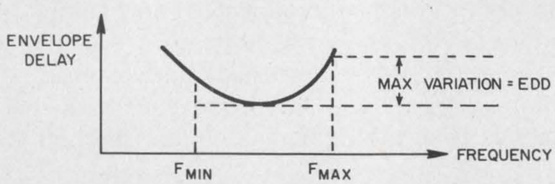
Line specifications and Bell services

An ideal channel—one that can support the Nyquist rate—should have flat amplitude and linear phase as function frequency. Instead, among other things, telephone lines introduce amplitude variation and phase variations. The amplitude response tends to drop sharply at the upper and lower edges of the band and the delay (derivative of phase with frequency) has a parabolic shape as shown in the illustration.

For data rates of 2000 bit/s and above, these linear network characteristics require correction, or the modems often cannot overcome the resultant intersymbol interference—that is, successive pulses interfere with one another at the sample times.

At the maximum rate, 9600-bits/s, nonlinear distortions—harmonic and signal-dependent noise—subvert communications. Phone lines often show an increase in ambient noise when a signal is present because of the action of compandors on the line.

Bell provides several types of conditioning for private lines, called C1, C2, C4 and D1. The first three afford additional equalization for the line's frequency characteristics of envelope delay and amplitude response (see table).



DEFINITION OF DELAY DISTORTION

D1 conditioning deals only with harmonic distortion and ambient noise. A 1004-Hz test tone is sent, then notched out at the receiver. The noise must be at least 28 dB below the test-tone power. Harmonic distortion levels in terms of fundamental to harmonic are

- Second harmonic—35 dB (min).
- Third harmonic—42 dB (min).

Incidentally, Bell is replacing the single-tone tester with a new four-tone unit; the third harmonic will be specified as 40 dB if the four-tone unit is used.

The D1 spec is entirely independent of the other conditioning specs; in fact, the customer can specify any C conditioning along with D1. To attain D1, Bell reroutes the line to facilities that are capable of D1-level operation.

vendor which type of DAA you will use and which DAA lines will be handled by the modem. The DAA control signals include ringing signal, off-hook circuit, request-for-data mode, and DAA coupler response.

But without a clear understanding of the DAA and modem characteristics, the designer cannot allocate logic functions such as answer, autocall and line disconnect, between computer or device, modem and DAA.

One popular device that avoids DAAs, yet affords asynchronous communications on the dial network, is the acoustic coupler. With this device, the telephone handset is placed inside form-fitted cups and signals are coupled acoustically to the modem signal circuits.

As a general rule, these devices can suffer from stray audible noise, vibration and limitations on the frequency response of the handset microphone and earpiece. More often than not, specs for acoustic couplers do not include bias-distortion figures.

Look for a carrier-detect lamp or indicator. Since the user must go through the motions of inserting the handset, such an indicator will show whether the connection is adequate for data transmission. Otherwise the appropriate handshake fails to occur—while the user ponders whether to wait or hang up and try again.

Also the manufacturer should derate acoustic sensitivity. The sensitivities for an acoustic coupler that can also operate with a DAA are

Summary of Bell System private-line specification options

Parameter	Linear conditioning spec				Nonlinear conditioning spec
	Basic leased line	C1	C2	C4	D1
Envelope delay distortion (EDD)	800 to 2600 Hz 1750 μs	1000 to 2400 Hz 1000 μs	1000 to 2600 Hz 500 μs	1000 to 2600 Hz 300 μs	Does not apply
		800 to 2600 Hz 1750 μs	600 to 2600 Hz 1500 μs	800 to 2800 Hz 500 μs	
			500 to 2800 Hz 3000 μs	600 to 3000 Hz 1500 μs	
				500 to 3000 Hz 3000 μs	
Frequency response relative to 1004 Hz	500 to 2500 Hz −2 to +8 dB	1000 to 2400 Hz −1 to +3 dB	500 to 2800 Hz −1 to +3 dB	500 to 3000 Hz −2 to +3 dB	Does not apply
	300 to 3000 Hz −3 to +12 dB	300 to 2700 Hz −2 to +6 dB	300 to 3000 Hz −2 to +6 dB	300 to 3200 Hz −2 to +6 dB	
		300 to 3000 Hz −3 to +12 dB			
Harmonic distortion	NOT APPLICABLE				Fundamental to second harmonic: 35 dB minimum; to third harmonic 42 dB* minimum
C-Notched Noise with 1004 Hz tone	NOT APPLICABLE				Noise at least 28 dB below received 1004-Hz test tone

* Revised to 40 dB if measured with newer four-tone test set.

Slow-speed asynchronous

Characteristics	103A	113A	113B
Speed	0-300 baud	0-300 baud	0-300 baud
Modulation	FSK	FSK	FSK
Operation	H/FDX 2W	H/FDX 2W	H/FDX 2W
Line type (s)	DDD Priv.	DDD	DDD
Reverse channel	—	—	—
Comments	—	Originate only	Answer only
	All units compatible		

Medium-speed synchronous

Characteristics	201A	201B	201C
Speed	2000 bit/s	2400-bit/s C2	2400 bit/s
Modulation	PSK	PSK	PSK
Operation	H/FDX 2W/4W	H/FDX 2W/4W	H/FDX 2W/4W
Line type (s)	DDD Private	Private	DDD Private
Modem equalization	—	—	Compromise
Comment	No diagnostic indicators	No diagnostic indicators	Full diagnostic complement

High-speed asynchronous

Characteristics	202C	202D	202 R	202S	202T
Speed	0-1200 DDD 0-1400 C1 0-1800 C2	0-1200 DDD 0-1400 C1 0-1800 C2	0-1200 DDD 0-1400 C1 0-1800 C2	0-1200	0-1200 0-1800 C2
Modulation	FSK	FSK	FSK	FSK	FSK
Operation	H/FDX 2W/4W	H/FDX 2W/4W	H/FDX 2W/4W	HDX/ SMPX	H/FDX 2W/4W
Line type(s)	DDD Private	DDD Private	DDD Private	DDD	Private
Reverse channel	5 baud	5 baud	None	5 baud	5 baud
Comments				small size 2.2 × 5.8 × 10.8-in. Local and remote test; diagnostic lights	Small size; full diagnostics; fast turn-around

High-speed synchronous

Characteristics	208A	208B	209A
Speed	4800 bit/s	4800 bit/s	9600 bit/s D1
Modulation	PSK	PSK	Quadrature amplitude modulation
Operation	H/FDX 2W/4W	HDX	H/FDX 2W/4W
Line type (s)	Private line	DDD	Private line
Modem equalization	Auto	Auto	Auto
Comments	Fast-line turn-around	Fast line turn-around	Split stream Full diagnostic complement

Most manufacturers compare their product, or make the product compatible, with Bell modems. The four categories describe Bell's current offerings.

about 10 to 13 dB less in the acoustic mode. Note also that the spec refers to line signal strength, not acoustic energy in microbars (as measured for microphones).

Modulation quickens the pace

Data speed (bit/s), line condition and type of modulation pose a triple threat at signal speeds of more than 1800 bit/s. Modulation chews up bandwidth—and some forms use more than others. In fact, the bandwidth of the typical voice channel is 2400 Hz, which places the Nyquist rate of (2 × bandwidth) at 4800 baud. Some of today's modems run at 9600 bit/s. But to do so, the signal elements must have multiple levels to represent groups of message bits.

Modems that use frequency modulation (and almost all do use FSK) usually operate asynchronously. The demodulator doesn't sample at prescribed bit intervals, so Start-Stop signals, such as those used in TTYs, can be transmitted at any time.

FSK devices use a lot of bandwidth relative to the digital signal rate. At rates up to 1200 bit/s, dial-up lines suffice. Near the practical FSK limit of 1800 bit/s, leased lines become necessary to avoid distortion.

Timeplex's Model 202 is an exception to the 1200-bit rule. This FSK unit allows 1800 bit/s on direct-dial lines, and does 2000 bit/s on private lines with C2 conditioning.

When specifying FSK modems, therefore, note whether direct-dial operation is possible at the chosen speed; and if the manufacturer requires a private line, see what level of conditioning is needed. Most units require none. In effect, you must compensate for lack of filter design in the modem by paying for better line conditioning from the common carrier—sometimes even at

1200-bit/s speed.

At any speed, check that your FSK transmitter uses phase-coherent transitions between mark and space. With such a scheme, the mark and space oscillators, if separate, are phased to switch at zero output levels. And the modems can hold switchover distortion to 2 or 3%. With single oscillators, no phase jumps occur at the mark/space transitions.

Synchronous transmission eliminates the Start-Stop bits on every character to gain increased throughput. A clock source, internal to the modem, marks the sample points on the digital waveform for the transmitter. The receiving modem reconstructs the clock signal, and supplies it to the digital machine. The terminal or machine at the receiver interprets the modem's digital output in time to the clock beat. Of course, time must be allowed for the sender and receiver to get into step prior to data initiation. With synchronous transmission, data bits are continuous until the complete block of data has been sent.

Modulation format is one spec that modem manufacturers do not emphasize. But a poor choice can hurt your throughput or make you overpay for a given data rate. Also certain modulation types are unusually vulnerable to line problems.

The possible formats have the following characteristics:

- AM occupies double the baseband bandwidth, so the theoretical baud rate is halved, and the technique requires very accurate AGC.
- VSB or vestigial sideband, uses a sharp filter to cut off all but 7 to 10% of the redundant sideband found in AM. Detection is difficult, and modems that use this technique, although efficient, are expensive and vulnerable to channel perturbations.
- PM, or phase modulation, has a double sideband like double-sideband AM. If four or more phase angles are used, bandwidth efficiency exceeds that of AM.
- QUAM, or quadrature AM, makes efficient use of bandwidth. Two AM systems are combined. Each uses the same carrier frequency, but the carrier phase difference is 90° between the channels.

More phases of amplitude levels permit transmission of more bit/s with a given internal baud rate. An increase in the number of allowable levels does not increase the requisite bandwidth. Each allowable phase or amplitude can represent a combination of two or three successive message bits. Thus a unit that operates at 1200 baud can handle a 3600-bit/s message rate. In fact, the bit clock is often derived through a circuit that upscales the baud clock of the modem.

Four to eight phase-step modems are popular at speeds up to 4800 bit/s. Most use a differentially coherent phase detector rather than a coherent reference. The scheme, referred to as DPSK, has a 2 or 3-dB lower noise margin than coherent phase operation. And when an error does occur, it can double, since the second symbol uses the first as the phase reference. But cost of the modem is moderate, and start-up is rapid. Also pulse-to-pulse coherence allows the unit to ride with channel phase jitter. And the unit has faster acquisition time than the VSB type.

However, with eight-phase modulation (three bits encoded at a time), such units become very vulnerable to line phase jitter. QUAM is a better choice than eight-phase DPSK when error rate is critical. With its double baud-rate capacity, fewer levels need to be encoded. The jitter immunity of the modem should approach that of a four-phase differential PSK unit.

A notable combination of modulation techniques enables Vadic's VA3400 to supply 1200 bit/s, full duplex on two-wire lines. Each transmitter channel uses QUAM modulation. The QUAM modulation conserves enough bandwidth for the FDM techniques of the 300-baud modems to be usable.

The invisible throughput specs

Throughput is perhaps the most important measure of performance as far as the modem user is concerned. However no manufacturer guarantees throughput.

The modem speed in bit per sec is only one factor that affects throughput. Lots of speed with many errors still gives low throughput. In addition the way the lines are handled comes into play. A steady rate of 4800 bit/s without gaps cannot be attained on the dial-up network. Techniques like polling add system delays to be accounted for.

The manufacturer's literature often states that his modem provides lower error rates than comparable Bell units. But Bell does not publish a separate error rate for its modem. However, for a complete Bell system—modems and lines—the company can maintain an error rate of one bit per 100,000 bits transmitted for all but the 9600 bits/s rate (where no error rate has been established). One Bell study shows that 77% of long-haul connections had an error rate of 1×10^{-5} or better.

Another misleading, or even irrelevant, spec is modem error rate as a function of signal-to-noise ratio (SNR)—a rating suitable for gaussian noise. But gaussian noise is not what messes up phone-line data transmission.

Phone lines achieve typical SNRs of 30 dB. The chief causes of error are phase hits (sudden uncontrolled phase jumps of over 20°), gain hits

Laser trimmer sets FSK frequencies precisely for Cermetek's hybrid modem modules. The unit trims the frequency determining resistors for the 300-baud set.

(sudden changes of gain or loss) and phase jitter. Phase hits average 2.5/hr at 2-ms duration. Gain hits last between 5 to 20 ms and occur at about 2.7/hr, with a step change of at least 3 dB. Only at 9600 bits/s does random noise begin to have a bearing on feasible error rate.

Where the manufacturer does quote an error rate, ask whether the reference is to bit or block and how large the block is. At slow speeds or with asynchronous transmission, data are sent character by character, and bit error rate is the appropriate measurement.

Synchronous systems, usually 2000 bits/s and above, transmit data blocks. And the system usually retransmits the same block if errors are detected at the receiver.

Block error rate performance is the key to synchronous throughput. Bell specifies such performance in terms of a 1000-bit block—that is, the number of 1000-bit blocks that contain one or more bit errors, divided by the total number transmitted. A system that offers a 10^{-2} error rate averages one block error per 100 and provides throughput of 99%, calculated from 100 $(1-10^{-2})$. Block error rates for 500 to 10-kbit blocks can be established by linear interpolation with good accuracy. For example, a 3000-bit block would show an error rate of 3×10^{-2} if a 1000-bit block has a 1×10^{-2} rate.

Amplitude and delay distortion decrease the available baud rate of the phone channel. Past signal elements smear into the current element and generate confusion called intersymbol interference (ISI) at the decoder.

At slow rates of 1200 baud or less, there is sufficient time for previous signal elements to die before the next element is sent, but not with 1800 baud.

To conquer the problem, the manufacturer can include equalizers in the modem—at extra charge, of course. Or you can get the line conditioned by Bell at a monthly charge: for C 1, $5 to $10; for C 2, $19 to $28; for C 4, $30. If your cheap modem has no equalizer, the bill can go as high as $3600 a year for a 2400-bits/s rate.

Above 2000 bits/s, some companies offer adjustable equalizers, and either you or your customer does the adjustment. Typical set-up times are 10 to 15 s.

Ironically self-adjusting or auto-equalizers are less costly than the manual ones. One reason for this is that the error control loop continuously resets gain and eliminates the need to hold adjustments with great precision over long periods. The circuit measures the over-all transient response of the channel by cross-correlation and directs the gain-control units to set up a flat response. Ideally a pre-arranged signal sequence should be used. But with the high SNR of the line, the received data can be used instead.

Dial-up facilities do not have pre-determined phase and gain characteristics: the actual values depend on how the call is routed. Therefore before the auto equalizers can operate, a set-up time is needed for the first gross adjustment with each call. With private lines this is only necessary before the first call. During this period the transmitter applies a predetermined data sequence—usually a 512-to-1000-bit pseudorandom signal. Once the first adjustment is completed, two units can track on received data. Both set-up and track response times are often omitted by the spec makers. For its 4800 Multipoint Modem, Codex quotes 140 ms to set-up and 50 ms to track—both examples of fast operation.

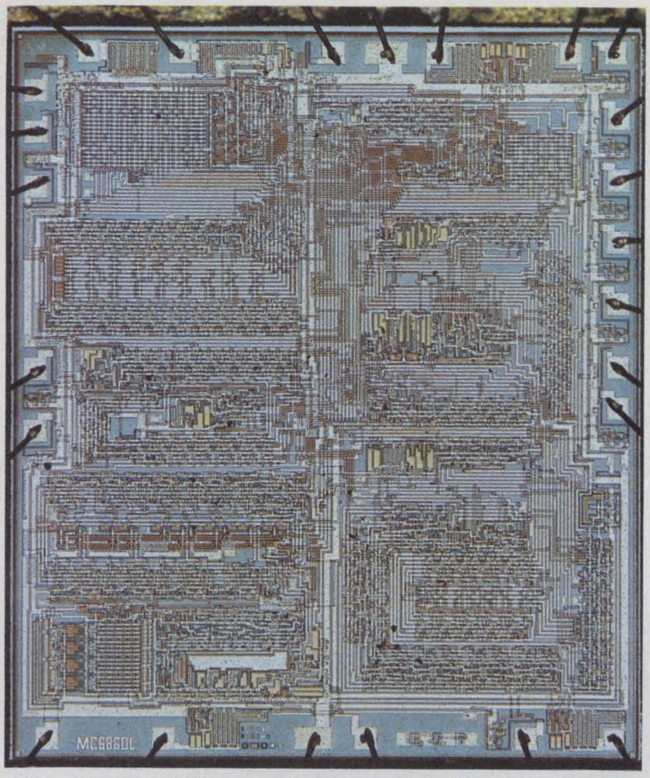
Note that auto-equalizing also makes units from different manufacturers incompatible; First, pseudorandom sequences often differ. Second, the units use bit-randomizing schemes to ensure stable equalizer operation.

And there's one more missing spec—the number of delay sections used. A good number lies between 16 and 30. Remember that too few taps cannot compensate sufficiently for ISI, and ISI degrades error rate just as surely as the familiar white noise.

Fast devices that go slow?

Clear-to-send delays become important on the DDD network, especially when a sophisticated terminal is in contact with an intelligent device or computer port. The DDD network provides two wires; so if two transmitters try to send deliver carriers simultaneously, they will interfere with one another. Exceptions are slow-speed FSK units that use separate frequency bands.

Echo suppressors used on the DDD network require about 100 to 150 ms before traffic can be



Add external filters and Motorola's NMOS chip, the MC6860, becomes a full-fledged 300-baud modem with all control lines.

reversed. So when machines want to carry on back-and-forth conversations, messages wait 300 ms for echo-suppressor cutout—the first 150 ms before the data block is sent and another 150 ms for the acknowledge back.

A 960-bit block thus takes 400 ms to transmit at 2400 bits/s, plus a wait time of 300 ms, so the idle time is 300/(300 + 900) or 43%. A solution to the problem is use of one of the newer modems that can provide one-way turnaround times of 8 ms at 2400 bits/s; so the total time wasted is 16 ms, not 300. This type of modem, which emits a tone in the 2010-to-2240-Hz region for 400 ms, disables the suppressors. Then it provides sufficient energy outside the band to keep them off. But, in practice, you can't get 8 ms turnaround time. Don't blame the modem manufacturer for this; talk to Bell. On terrestial private channels for example, Bell promises a maximum of 50-ms delay, so each side may wait up to 50 ms before it hears from the other.

If satellite communication is involved, delays of 300 ms or more are common. And the only solution to throughput becomes longer block lengths, with error-correcting codes that minimize the repetition of previous data.

The 4800-bit/s high-speed units with auto-equalization add some more message dead time for the unwary user. After dial-up, the modems train for 260 ms or so before transmission begins. But each time you turn the line around, 40 to 50 ms is needed to update the equalizer. Result: RTS-CTS delay equals 40 to 50 ms each way, not 8 to 10 ms.

Then there is modem propagation delay—a hush-hush spec. That delay amounts to some 15 to 25 ms and represents delay through the very long equalizers used in fast modems.

So if your system uses short data blocks that are exchanged often between machines, a 2400-bit/s unit can sometimes allow greater throughput than the speedsters. Of course, the 4800 bit/s units really show their mettle on long messages, where block time is much longer than accumulated dead time.

The number of 4800-bit/s units has proliferated since Codex and International Communications Corp. (ICC/Milgo) introduced the first versions. The most recent additions come from IBM (Model 3874), Bell (208B) and Rixon (T208B). All have the fast turnaround feature and 40 to 50 ms RTS-CTS delay. The newest, Intertel's MCS 4800, features the fastest training time—50 ms.

Manufacturers intending to pursue higher speeds include Tele-Dynamics Ambac (now working on 4800 bit/s for DDD use), and Intertel.

Private two-wire lines can afford greater 4800-bits/s throughput than DDD operation. Since private lines have stable delay and amplitude characteristics, manually adjusted equalizers eliminate the 40 to 50 ms for update of the adaptive equalizer. In fact, the RTS-CTS delay need only be long enough to synchronize and recover the clock—8.5 to 12 ms.

Private-line, four-wire facilities (full duplex) simplify things further. Each pair forms an independent channel, so that both transmitters can send carrier continuously, and all receivers remain active and synchronized. Therefore RTS-CTS delay from zero to any convenient figure is available even with automatic equalization. And the adaptive equalization, if used, eliminates the need for line conditioning.

Is anyone listening?

A single computer port can communicate with and control 10 to 50 terminals, especially with communication that is best described as inquiry-response. Users request information via keyboard entry and receive it from the computer after a brief pause. To control the situation, the computer polls (addresses) each terminal, one at a time, waits for a reply and sends information back at its convenience. This sequence repeats in round-robin fashion.

The modem at the CPU is always in a transmit condition—that is, the carrier is constantly on. But the modems at the remote sites transmit one at a time, although all listen for the address. Each time a terminal sends, it must raise RTS and wait for CTS. All carriers cannot be on at once, because of mutual interference. The computer's modem transmits on one pair of wires but receives, in party-line fashion, on the other pair. Since the sites can be far apart, line characteristics differ, so that different equalizer settings are necessary.

Use of adaptive equalizers in the fast units automatically incurs the 50-to-60-ms RTS-CTS delay plus the modem-to-modem propagation time. Sometimes a 2400-bit/s modem gives equal throughput to the 4800-bit/s unit where brief messages (one or two lines) are exchanged.

More than a double feature

Modem manufacturers offer many options. If you want low price, some of the 300-baud chips leave you with the design of active filters.

Selectable time delay for RTS-CTS is a very important option if your equipment must be compatible with a variety of devices. Also check into delays already built into the terminal's reaction times and data-signal controls. Sometimes the terminal can drop RTS too soon for the modem to complete the transmission.

Look for soft-carrier turnoff—usually built into stand-alone units, but an option for boards —if you operate in a polled situation; otherwise line transients may cause the modem at the computer end to add spurious data to the received signal.

Try to avoid units that have too many preset controls that must be tweaked. Since most modems operate in commercial environments, your customer won't appreciate drifting performance. Good technology and increased use of LSI should obviate many adjustments.

Visual status displays often help you to isolate faults rapidly between terminal, line, modem and CPU. For the computer site, where racks of modems often reside, status lights on key control lines give the operator quick clues for trouble.

With a series of send-receive tests and status lights, the flick of a switch lets you loop digitally with the terminal. Then you can go through the modem's analog sections, continue on through the wire to the remote site, and finally loop through to the remote modem.

If modems contend for lines or are polled, modem sharing can reduce costs. One modem supplies the received signals in RS-232-C format for up to four terminals, but only one terminal gains control of the transmitter at a given interval. Normally each terminal would use a separate modem, each of the same speed and cost as the one at the CPU site.

Built-in mux capability, available from Bell and independents, can help reduce line costs. Such modems let you split a fast stream into several slower ones, rather than use a separate line for each.

Infrared light beams form an invisible highway for computer data. The Optran system moves data with an error rate of 10^{-10}. The maximum speed is 1 Mbit/s; the range is up to one mile.

A number of high-speed units also offer dial-backup if down time is extremely critical. On one 9600-bit/s unit, you set the units for 4800 bit/s, then dial one circuit for half-duplex or two circuits for full duplex. Often the speed of operation is transparent to the computer software. And sometimes the auto-equalized units can continue at 9600 bit/s or 7200 bit/s on the DDD network.

But don't ignore Bell's charges when you reach for 9600 bit/s. The 9600-bit/s units may require D1 conditioning on a particular line. The cost means $100 installation and $100/mo. thereafter. So be sure the benefits match or exceed this value.

In the area of human factors, you might check into a voice-adapter feature, which allows communication with remote sites when data are not being transmitted.

Shave line charges with mux

Both time-division multiplexers (TDM) or frequency-division multiplexers (FDM) help to stuff slow-speed data from several sources onto a single voice-grade line.

FDM units are the least efficient. They subdivide the available bandwidth into separate frequency bands. Each data channel occupies a frequency slot. All channels can operate concurrently, because of guard bands between channels. Inefficiency occurs because the guard bands waste frequency space. And the less-than-ideal frequency characteristics near the voice-band edges prevent usage near 300 and 3000 Hz.

Most FDMs consist of precise filters and a multiplicity of FSK modems, each tuned to a particular frequency. FDMs are used primarily with multiple asynchronous terminals or devices, all connected to the same point-to-point line. Total capacities achieved on voice-grade lines range from 1200 bits/s for two 600-baud subchannels to 1800 bits/s for 24, 75-baud channels.

With multiple modems tuned to separate frequencies, both drift of the center frequency, FSK limits and harmonic distortion become important to ensure that one channel does not crowd out others. Specs don't try to deceive on these figures: They hardly ever exist. Other specs give the number of channels allowed at a particular baud rate, but almost never discuss the total number allowed with mixed baud rates, because faster baud rates require larger guard bands.

These units often operate on unconditioned 3002 lines; C4 conditioning can sometimes add another 150-baud channel.

A change in receiver and transmitter cards simplifies channel addition or speed change. But the user has to juggle individual output signal levels at the mux, since the total output to the line may not exceed 0 dBm.

Time-division multiplexers allocate repetitive time slots to each channel. The combined bit streams are sent back and forth along the line through high-speed synchronous modems. The units decommutate the stream and reconstitute the original data channels.

The TDM achieves practically full-line efficiency, minus a certain overhead time for buffering. As a digital device, it contributes little error of its own—a virtue that manufacturers often tout to the hilt.

A basic pitfall not mentioned in TDM specs is modem error. For modems that operate at 4800-to-9600-bit/s speed, bit error rate often exceeds that of the slow units. And every bit that travels on the line experiences that error rate. Instead of 1×10^{-6} on the bits of your 30-char/sec printer, you get 1×10^{-5} or worse. At a print width of 132 characters, that's one character error for every 76 lines of copy on 11-bit ASCII code. But when you total traffic amounts to 2400 bit/s, synchronous modems give a comfortable 1×10^{-6} error rate, which isn't so bad.

On the other hand, some of those bits aren't data, but mux-to-mux control. Between that and the digital operations performed by channel combination, the unwary designer can pay as much as 30 to 40% throughput penalties on dial-up synchronous operation.

TDM suppliers often provide dazzling arrays of speed specs, and have lately conquered many of the inflexibilities of the earlier models. The timing specs—especially character delay value—are what you must get from the manufacturer. To use the spec, calculate the delay time through the system and add the character delay to find the round-trip delay. The delay, as a percentage of total transmit time, gives you the system's inefficiency.

The ingenious user often gets the impression that he can sum up the bit rates of all the inputs to obtain the output rate. Sometimes the calculation works—with these muxes that accommodate terminal mixtures. The newer units strip Start and Stop bits off the asynchronous data. The time gained is applied to the synchronous inputs. But if you want to take two 4800-bit/s streams and connect the mux to 9600 bit/s-modem, you can't.

Bit-interleaved TDMs combine digital data into frames, each with sync bits followed by data bits, one from each channel. Character-interleaved muxes send sync plus all characters from one channel. On the next frame, the next channel character is sent on, etc. Bit-oriented units synchronize faster than character-interleaved ones, and have shorter delay. But they do not use the channel rate as efficiently. Character-interleaved units assemble bits, and the process introduced delays of at least two character periods.

Regardless of which mux you use, recognize that a communications network often supports more than one terminal type. So different rates and codes must be accommodated. And operation of the device should be transparent; that is, any code should pass through the units without modification.

The modem shopping list

Modems fall into five natural groupings:

- Slow-Speed asynchronous—to 300 baud.
- High-Speed asynchronous—to 1800 baud.
- Medium-Speed synchronous—2000 to 2400 bits/s.
- High-Speed synchronous—3400 to 9600 bits/s.
- Local-Link devices—rates to 1 Mbits/s.

The bit and baud rates are rough subdivisions; the major categories are asynchronous and synchronous. However, units that do more than 3400 bit/s almost always use advanced circuit techniques, such as programmable digital filters. So they deserve a special category. For those who need their own local system, manufacturers offer units linked by twisted-wire pairs, IR laser beams or microwaves, instead of phone lines. Some of the technical and performance differentials can be seen in the tables of Bell specs included in this article—most independent manufacturers follow these trends at speeds to 2400 bit/s. But they can often work with less line conditioning.

For slow speeds, units range from desk-top equipment to a single chip from Motorola. Other types include acoustic-coupler versions and plug-in PC boards.

Practically all claim Bell-103 or 113 compatibility. The chief feature is the ability to give simple full-duplex operation on two-wire pairs.

DataServ's Series 1300 units ($350; 1 to 9 quan.) generate step-like approximations of sine waves digitally, and feature a digital discriminator for detection. Originate-and-Answer modes are selected automatically. An analog filter converts the step approximation to continuous sine wave. The unit is also available as an OEM card, Model 1310, or as a desk-top set, Model 1340. Sanders also offers crystal-controlled digital units for DDD or private-line use.

Pulsecom offers a full line of Bell compatibles, including the newer 103 and 113A models in card or desk-top form. They feature less than 3% distortion (back-to-back) and provide three types of interface: RS-232, TTY current loop (up to 20 mA) and party-line or hubbed operation.

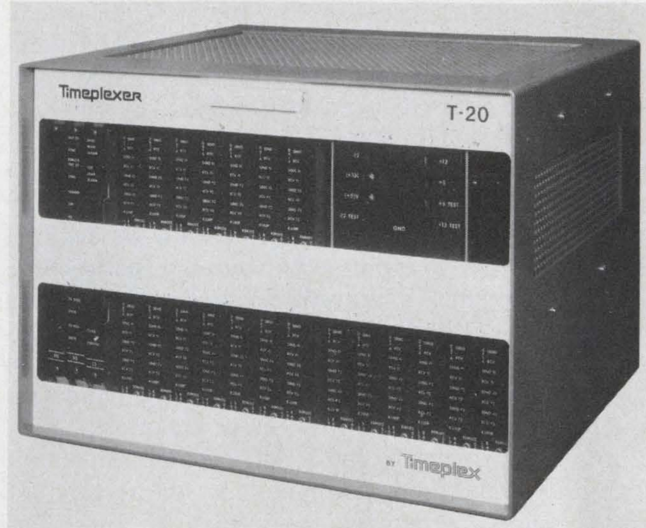
ComData provides a basic rack ($465) and auto-answer modems for $170, the Model 330 D2-42. Each modem contains its own dc supply, including four diagnostic lamps: Ring, Data Set Ready, Carrier Detect and Data Terminal Ready. A four-stage receive filter provides 50-dB discrimination to the adjacent channel.

Model 300 A from Penril replaces Bell 103A2 Data Sets and offers auto-answer capability with CBS or CBT coupler. A rear panel switch establishes digital loopback. And the unit can be arranged for use with an Auto-Call card. Either tone or impulse dialing is available with automatic transfer of control from modem to terminal.

Check into ATS DM-2103F, G sets for self-contained local and remote tests, plus compatibility with Bell 103 and 113 units. The specs are clear and the units deliver less than 8% bias distortion under worst-case conditions. No adjustments are required for line signal ranges from 0 to −50 dBm.

RFL, Prentice and Singer Tele-Signal also offer 103 and 113-compatible modems. And Prentice offers IBM-compatible low-speed modems.

There are many PC-board bargains at 300 baud. The Tycom 900, and Originate-only modem, sells for only $69, and it claims 103 compatibility. Of course, the control lines are limited to Carrier Detect and Data Set Ready. RFL's Model 5105 is smaller than the 900, offers plug-in filters for FDM, and has more control lines, including Request to Send.



In addition to combining data from multiple channels, a TDM serves as a test center. Switches and lamps help pinpoint problems among modems, lines, other multiplexers, terminals or computers.

At prices from $95 to $195 (depending on quantity), the M-2103F from Advanced Terminal Systems features remote switchover from Answer to Originate. The digital modulators and demodulators are all crystal-controlled, and the modulator is phase coherent.

Anderson Jacobson's AJ Series 12 includes Bell or IBM compatibility, plus the ability to operate in FDM situations.

For low jitter plus bias (under 8%), Tele-Dynamics offers the 7113A and 7113B. The FSK is phase-coherent, but there are just the data lines (no control lines). Opt Industries offers 300-baud modems for FDM, and Series 4200 Automatic Dialers.

Cermetek offers a set of four thick-film hybrids that handles most 103/113 functions, and the parts cost under $60 (100 quan.). The price of the miniModem includes the critical component for two-wire operation, the 30-dB transmit filter ($12.70). Each package measures a mere 0.6 × 0.9 × 0.2-in. in the form of 16-pin DIPs. And you can configure for electronically switched Answer or Originate operation.

In November Motorola will announce the MC-6860, and NMOS LSI chip that includes all major control lines. This complete modem, used with a 1-MHz external crystal, outputs sine waves from an integral DAC. The output has eight discrete amplitude steps per cycle. Jitter is specified at 7% at 300 baud, and the unit can provide Originate or Answer operation. But for full-duplex operation on two-wire phone lines, you must design a six-pole Chebyshev bandpass filter for the receiver. The filter is fairly critical: 450 Hz, 3 dB bandwidth with 0.7-dB ripple.

The digital approach is similar to that of Data-Serv's Series 300, but the MC-6860 is designed for use with Motorola's M6800 series microcomputers.

Exar Integrated Systems (P. O. Box 4455, Irvine, Calif. 92664) offers some general-purpose ICs for FSK modem construction. The XR-210 is a general PLL chip with RS-232-C drive compatibility. Without the bipolar RS-232-C drive spec, PLLs, such as Signetics' 565 or Harris' 2820, function just as well. But they require additional comparators to meet the RS-232-C spec. According to the manufacturer, only the XR-2206C (that has sine wave) or the 2207 VCO function generators meet the stringent Bell-compatible transmit frequency stability, namely, 0.2%.

Warning:

Be aware of these constraints

Whether you use desk-top modems, cards or chips, bear in mind that:

- FCC Tariff 260 does not allow mixed use of Bell and foreign modems on private lines. Check before you install.
- The telephone company tells the customer what output power to supply for DDD use. The range is from −1 dB to −10 dB in 1-dB steps.
- The maximum power loss on the DDD network is 37 dB; make sure your modem can handle this.

Acoustic couplers for data on the move

Acoustic couplers let you converse with terminals or computers through your telephone's handset, wherever there is one.

Top speed on these devices is 1200 baud—half duplex, of course. Anderson Jacobson was the first, with ADAC 1200. There are at least two other manufacturers of fast units. The Design 1200 from MI 2 uses both inductive and acoustic links with the handset, and Omnitec recently announced its Model 1200A.

Most acoustic couplers operate at 300 baud. Prices range from $99.50 (Tycom Model 920) to $360 for Livermore's Model C, and even higher. The Model C includes an acoustically shielded walnut case, EIA interface, 20-mA TTY current drives, and a choice of Originate or Answer operation.

Omnitec's Model 703A, costing $489.50 (1 to 4 units) automatically answers your phone and puts the terminal on-line. A separate electromechanical device rests on the base of the phone and "lifts the hook" when a ring is detected.

To get 450 baud, check into Omnitec's Model 701B ($341; 1 to 4 qty). The unit offers both acoustic or DAA operation and Bell compatibility.

ComData Series 150 couplers provide four types of digital interface: EIA RS-232, MIL-E-188B, TTY and DTL/TTL. There are stripped versions for OEMs as well as desk-top units.

For TTY-oriented users, Digital Techniques Corp. offers an acoustic unit that you install instead of the face plate on Teletype's Model 33 and 35. The DTC 3300 provides 20-mA current loops and uses acoustic/magnetic coupling. The price is $289.75. For TTY-leasing, RCA Service Co. provides originate/answer couplers with inductive/acoustic coupling. Teletype Corp., Skokie, Ill., also offers an RS-232-C interface for use with external modems.

Usually 1800 bit/s represents the upper limit on asynchronous operation. With the exception of Vadic's full-duplex, two-wire unit, FSK modulation dominates. The Timeplex 202 attains 2000 baud rate with C2 conditioning, and does 1800 baud in DDD use. The Timeplex modem generates out-of-band FSK signals, then translates them into the phone line's frequency range. And the technique avoids adverse beat frequencies.

The 1800-bit limit is due to the large spectral width of the FSK signal and spurious in-band signals. Practically all stand-alone units have soft-carrier turnoff as standard. A 900-Hz tone, transmitted for 30 ms, clamps the receiver data line to prevent spurious signals during carrier switchoff.

Check out the type of line conditioning required. Often levels lower than the Bell equivalent are specified. For example, the 7202 D/E from Tele-Dynamics doesn't require conditioning at 1800 baud. Bell specifies C2 for its 202D.

Both cards and at least one MOS chip serve the OEM user in the medium-speed area. The electrical levels at the interface span the range from EIA to CMOS. For example, RFL's 6835 Series offers TTL, CCITT, HTL and CMOS. An optional feature is a soft-carrier turnoff.

In addition to Tele-Dynamics, Sanders offers a synchronous unit, the 12SC. Neither is Bell-compatible.

Rockwell's 10371 chip provides a carrier detector, transmitter, receiver and control circuits. To build a complete modem, you'll have to add external circuits such as a resistive summing network (to produce the step-like sine wave) and active filters to limit bandwidths. A 10-ms delay is available, but the user must also supply logic to implement RTS-CTS protocol.

And don't forget to check the FCC and common-carrier rules before you attempt to use chips or cards as integral units in your designs.

A middle ground: 1800 to 2400 bit/s

The majority of self-contained units operates synchronously on DDD or unconditioned lines. Many manufacturers, such as ICC/Milgo and

Intertel, include digital pattern generators for full checkout. The 2400-bit/s speed is quite popular for order-entry or remote-inquiry terminals that operate in a polled environment. Auxiliary modem-contention units help reduce costs because four to six terminals can contend for a single modem. Such devices are offered by ICC, Intertel, Penril, Codex and Rixon.

Intertel, Penril and General DataComm offer special diagnostics for polled systems. Intertel uses a 75-baud module that allows the central site to address each remote modem via a 75-baud (out-of-band) test channel. An automatic tester isolates faults.

Rixon offers tests via the DDD network from its Data Service Center. These tests are available on many products like the CS 2401, OEM 2400-bit modem (Bell 201B-compatible).

ICC's Modem 24 LSI disables the echo suppressors. Others like GTE Lenkurt's T61A offer 75 to 150 baud reverse channels for data acknowledgement. But your computer and equipment must have provisions for such use. The T61A also features the shortest RTS-CTS delay—3.5 ms; the normal range is 8.5 to 10 ms. However, the GTE units use duo-binary transmission: a three-level technique that is incompatible with Bell or other units. The 2400-B modem from Penril uses AM-VSB and requires C2 conditioning. The result is said to be lowered purchase cost and small size. The OEM card measures 4.75 × 7.75 in.

If you find your system's requirements shift frequently between synchronous or asynchronous operation, Livermore's 412/424 might offer some economic advantages. Plug-in cards convert operation from 1200 bit/s asyn to 2400 bit/s synchronous. Either mode is Bell-compatible or can meet CCITT (European standards). The basic modem costs $510 (single quantity); the conversion card to 2400 bit/s is $285.

Technologically, there has been some digital encroachment on certain analog functions, particularly the filters and detectors. Universal Data Systems' UDS-201B, based on off-the-shelf CMOS, uses digital frequency synthesizers (for all waveforms), digital line compensator and

Representative 4800-bits/s modems for DDD use

Manufacturer Model	Modulation	Digital Interface	Bell Compatibility	Configuration	Comments
ICC/Milgo 4700/48*	Three-level VSB	RS-232-C Mil. Std-188	None	Desk-top	40 ms turn-around Auto call
Livermore Data Systems 440/48*	QUAM modulated by coded AM	RS-232-C CCITT	None	Desk-top Single card 6 × 9 in.	1.1 s training time
Bell 208B	Refer to Bell Data Set listing				
Codex 4800	QUAM	RS-232-C CCITT V.24	None	Desk-top	40 ms turn-around; auto answer optional 150-baud reverse channel
IBM 3874	8-phase	RS-232-C	None	Desk-top	Fast turn-around Auto call, three-port contention
Singer Tele-signal 4832D	QUAM	RS-232-C CCITT	None	Desk-top	Optional reverse 150 baud channel Can mpx in 1200 baud units
Rixon T208B*	8-phase PSK	RS-232-C	208B	Desk-top	First Bell-compatible unit
Intertel MCS 4800*	QUAM	RS-232-C	None	Stand-alone or rack-mount	Trains in 50 ms; has modem sharing

*Also operates on unconditioned private lines digital filters. The synthesizer's accuracy is such that the first undesired product term is the 15th harmonic, which is easily filtered out. The UDS-201B is also available as a three-card OEM set. Prentice mentions that its P-201B uses digital synthesis.

For volume OEM applications, ICC's CM 244A offers the works—equalizer, carrier detector and RS-232-C protocol at TTL signal levels. The unit even includes a 511-bit, test-pattern generator and an error detector. The modem operates at 2400 bit/s on unconditioned or DDD network and measures 10.05 × 5.93 in. The blue-chip series features a protective cover with clear instructions for users. Slide switches select test/normal and ac loop-back.

Sanders' two-card set, the 24SC, features practically complete digital implementation on this Bell 201B-compatible device. Like ICC, most of the RS-232-C controls are implemented. How-

A sampling of modems for high-speed operation on private lines

Manufacturer model	Rate (bit/s)	Modulation	Minimum line Conditioning	Operation	Digital Interface	Bell Compatibility	Comments
IIC Model 208A	4800	PSK	U	FDX/4W	RS-232-C	208A	50 ms RTS-CTS delay; Identical to Bell 208A; mfd. under direct license from Western Electric
Penril 4800B-1	4800	8-phase	U	HDX/FDX 2W/4W	RS-232-C	None	Manual equalization RTS-CTS 8.5 ms
Bell 208A	4800	Refer to Bell Data Set Listing					
ICC/Milgo Modem 4600/48	4800	QUAM	U	HDX/FDX 4W	RS-232-C Mil-Std 188 C	None	Manual equalization; Modem sharing: 4 terminals; Split-stream: two, 2400 bps
Codex 4800	4800	QUAM	C1	FDX 4W	RS-232-C CCITT V.24 Mil 188C	None	50 ms RTS-CTS Delay
GTE Information Systems IS/2481	4800	Duobinary SSB	C2	HDX/FDX 2W/4W	RS-232-C Mil 188B	None	150 bit/s reverse channel; Manual equalization; RTS-CTS 21.6 ms
Paradyne M-48	4800	VSB	U	HDX/FDX 2W/4W	RS-232-C	None	
IBM 4872	4800	SSB	C2	FDX/4W	RS-232-C	None	Manual equalization
Codex 7200	7200/4800	QUAM	C2	FDX/4W	RS-232-C CCITT V.24	None	Data multiplexer, No fast equalization for polling. Setup is 275 ms Modem sharing.
IBM 3875	7200/3600	QUAM	C2	FDX/FDX 2W/4W	RS-232-C	None	Modem sharing: 3 machines
Codex 9600	9600/7200/4800	QUAM	C2	FDX 4W	RS-232-C	None	Modem sharing; Four port mux; 275 ms set-up time
ICC/Milgo Modem 5500/96	9600	QUAM	C2	FDX 4W	RS-232-C	None	Four-port mux; modem sharing DDD at 4800 bit/s
Paradyne M-96	9600	VSB	D1 recommended	FDX 4W	RS-232-C	None	PMOS digital implementation
Bell 209	9600	Refer to Bell Data Set Listing					

ever, C2 conditioning is recommended, whereas the ICC/Milgo unit has a strappable built-in equalizer to permit operation on DDD or unconditioned lines.

Meet the speedsters: 4800 to 9600 bits/s

Of all situations, the DDD network offers the greatest challenge. To date, the highest speed attained is 4800 bit/s.

A variety of modulation techniques is used, and all units have automatic equalizers. ICC/Milgo, Bell, Codex, IBM and Rixon provide fast turnaround through echo-suppressor disablement. Only Rixon's is Bell-compatible. Prices vary considerably. Livermore's 440/48 sells for $2950; IBM's price ranges from $4650 to $7200. Livermore includes a line quality indicator at no extra charge. The two-digit readout is based on the average activity of the auto-equalizer. High activity correlates with poor lines and vice versa.

Most manufacturers who build 4800-bit/s DDD units make similar units for private-line use—type 3002 voice-grade lines. Also the degree of required conditioning ranges from none to C2. And some units use manually adjusted equalizers. A number of these modems also offer built in muxes.

Hycom produces 4800-bit/s OEM modems for dial-up or private use. A special-purpose processor, made up of three MOS/LSI circuits, performs all modem functions. These include: detection, filtering, equalization, phase-lock-loop tracking and modulation. A change of the program ROM alters the entire modem.

Paradyne's M-96 operates on a similar all-digital basis. Analog signals are converted immediately to digital form, then operated on in arithmetic fashion to synthesize modem functions.

The Hycom unit, Model 502, is contained on five PC cards, each 5.38 × 5.08 in. Features include test patterns and echo-suppressor disablement for rapid turnaround. Modulation used is QUAM.

Rockwell Microelectronics offers a half-duplex, 4800-bit/s modem on a 6 × 10-in. board, the M-48, which is also based on digital synthesis. In quantities of 1000, the unit price is under $1000. The unit features QUAM modulation and

Representative FDM units

Manufacturer and model	Special features	Capacity			Maximum channel speeds available (baud)	System interface	Remarks
		Speed	No.	Total Baud			
ComData Series 200	Access to tones loop-back test Data regenerator to remove bias Voice channel available	75 300	22 5	1650 1500	75, 110,135, 150, 300, 600 intermixed	Contention and multidrop	Limits shown for C2 conditioning
RFL 5150 Multiplex Modem system	Plug-in filters for channel assignment Strappable for EIA, CCITT TTL or TTY	75 300	24 4	1850 1200	75, 110,150 200, 300,600 1200	Multidrop	C1 conditioning required for 1200 baud, no conditioning on other speeds
Singer Tele-Signal 2503H	Only 2 adjustments on receivers bias and clamp. One level control on transmitter	150 150	12 11	1800 1650	150 only	Multidrop	Twelve channels with C4 conditioning, 11 unconditioned
Tele-Dynamics Ambac 7260 Series	Pluggable filter modules for data rate selection loopback tests	75	22	1650	75, 110, 150, 300, 600 intermixed	Multidrop	Six-channel building-block assembly. Rate shown for C2 conditioning
DataStat 1100, 1500, 3000 and 600	Modular mix of modules for variety of speeds	110 300	16 6	1760 1800	110, 150, 300, 600 intermixed	Multidrop	Data shown for C2 conditioning
GTE Information Systems IS/8800	Party-line adapter for terminals Voice channel available	75 300	25 6	1875 1800	75, 110, 150 300 bit/s.	Contention and multidrop	Line conditioning not stated for given capacity

adaptive equalization. A phase-locked loop counteracts low-frequency phase jitter. According to the manufacturer, a 9600-bit/s unit is under development.

Uncommon carriers for shorthauls

To transmit computer data over short distances with RS-232-C protocol, and with no phone charges, there are local distribution units that use infrared beams, twisted-wire pairs or even simple microwave transceivers. The latter require FCC licensing, of course.

At least two manufacturers supply optical links capable of full-duplex transmission; each unit has a receiver and transmitter.

Computer Transmission Corp.'s (Tran) Optran units provide full-duplex operation—up to one mile in favorable weather—with speeds of 2400 to 250 kbit/s. Transmission can be synchronous or asynchronous, with strappable turnarounds from 0 to 250 ms.

The OpCom Div. of International Laser Systems (2111 W. Central Blvd., Orlando, Fla. 32805) provides LDL Series with data rates up to 1.544 Mbit/s. The company claims one mile for most weather conditions, and eight miles in clear weather. Model LDL provides RS-232-C (20 kbit/s max); or MIL-188C at 10 kbit/s maximum. Range of Model LDL is 3000 ft. The LDL, complete with two transceiver terminals, costs $9350.

Companies such as Tran, ICC/Milgo, Prentice and DataStat offers units that operate over wire pairs. DataStat's SLD-4 will do 50 kbit/s at distances up to 10 miles. ICC's Com-Link II can op-

Sample selection of TDM units

Manufacturer and model	Interleaving Technique	Channel speed mix	Max output (bit/s)	Throughput	Code-handling capability	Comments	Port convention available
Infotron Timeline 240	Character	To 162 ch. A/S	12 k to 240 k A or S	To 120% on Asyn.	5 to 8 info bits asyn; auto-speed detection	Sync to 4800 baud	Yes
Codex 900 Series	Character	To 64 Ch. A/S 7200 bit/s max on S	9600	100%	5 to 8 info bits asyn; auto-speed detection	Configuration remotely programmable; port contention by subgroup assignment	Yes
Timeplex Timeplexer T-96	Character	To 96 50-1200A 2400-4800 S	9600	97%; 100% at 2000 bit/s	Code mix built in 5 to 7 info bits; 8-bit is an option	Isochronous data card available. Synchronous drop-off lines. Hub and Star capability	Yes
GTE Information Systems IS/8500	Character	To 116 @ 110 baud A	9600	Specified by number and ts. of asyn.	Up to 116 ch. at 110 baud each, intermix four speeds	Allows mixture of four asyn. speeds	No
Singer 2533-Series	Character	To 76 A	4800	Specified by bit/frame and ms per char	Divide bits trans into frame size; 12, 110-baud ch. for 1200 bit/s output	Good for bulk encryption. Accepts all speed and code mixtures	No
Computer Transmission Corp. Multitran 1215	Bit and Character	To 115 A	to 50 kbit/S	Depends on speed mix	Up to four syn at 2 speeds and 12 asyn. Expanders available; has auto-speed detection	Complete speed and format intermix	Yes
Livermore Data Systems Data Distribution System 670	Character	To 128 A	70 kbit/s	Handles 34,300-baud channels with 9600 bit/s modem.	Intermix of seven baud rates. Auto speed detection	Hub and Star capability. Replaces ADS 660.	Can provide parallel output to 16-bit mini (interrupt driven)

Putting the facts at your fingertips

Data-communications literature covers such a broad area that the designer often can't spot the trees from the forest. However, a number of courses and some of the manufacturer's literature can help you.

The following is a sampling of literature at various levels:

For a very fast but thorough systems orientation to TC consult Control Data Corp.'s Institute for Advanced Technology, 6003 Executive Blvd., Rockville, Md. 20852, (301) 770-8566 on their three-day seminars. The course, "Design of a Data Communication System," ($395), is particularly rewarding for newcomer and veteran alike. For greater technical detail check out "Practical Engineering of a Data Communications Network" ($395).

Microdata, 17481 Red Hill Ave., Irvine, Calif. 92705, offers "The Communications Handbook," ($2.50), which can provide good systems orientation along with a gentle pitch for their Model 1600 minicomputer.

To dig deeper into the modem's innards get on the list for GTE Lenkurt's "Demodulator" booklets, which cover a variety of topics from modulation to phone-line characteristics in easy-to-read style.

Further basic information appears in two useful little books: "Introduction to Data Communications" by D. E. Murphy and S. A. Kallis, Jr. (ICC/Milgo) and "Data Modem Selection and Evaluation Guide" by V. Vilips, Artech House, an affiliate of Horizon House Microwave, Dedham, Mass., 1972. Both books are written by staff members of ICC/Milgo and emphasize the product line—especially the selection guide. But the information helps you see the interrelation between type of transmission, phone-line characteristics and modem operation.

Your final plunge into data communications should include Computer-Communication Networks, N. Abramson and F. Kuo, Editors, Prentice-Hall, July, 1973, and some Bell System publications; in particular: "Data Communications Using Voiceband Private Line Channels," Bell System Technical Reference Pub. 41004 October, 1973 and "1969-70 Switched Telecommunications Network Survey," Bell System Technical Reference Pub. 41007.

Before you initiate that design or configuration, get some straight facts on RS-232-C and its applications. Write to Engineering Dept. Electronic Industries Association; 2001 Eye St., N.W., Washington, D.C. 20006 for EIA Standard RS-232-C "Interface Between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange," August, 1969 ($5.10) and "Application Notes for EIA Standard RS-232-C," Industrial Bulletin No. 9, May, 1971 ($2.60).

erate at 19.2 kbit/s at distances up to three miles over a 22-gauge wire pair.

Spectron Corp. (Church Rd. and Roland Ave., Moorestown, N.J. 08057) eliminates back-to-back modems entirely. Its unit simply transposes send-and-receive data signals. The range is 50 ft., point-to-point, at speeds up to 20 kbit/s.

Finally, Norden Div. of United Aircraft (Helen Street, Norwalk, Conn. 06856) offers millimeter wave units designed for very high speeds, such as computer-to-computer exchanges. A TDM mux lets you mix up to 23 data streams to one 1.544-Mbit/s stream. The unit operates under a pending FCC developmental license. Each full-duplex radio weighs about 30 lbs.

A sampling of TDM and FDM

Muxes offer three basic types of operation: asynchronous, synchronous and high-speed (50 kbit/s). The asynchronous units handle ASCII or other asynchronous terminals (mostly TTYs) and merge them into a synchronous bit stream. The medium-speed units handle block-oriented transfers, and combine them to form 9600-bit/s streams for 3002-type channels. The faster units can continue the combination with rates up to 50 kbit/s, and are designed for Bell's 8000 Series lines or equivalent.

TDMs differ greatly in their ability to mix channel speeds and types (synchronous or asynchronous). Many units offer computer-port contention; that is, the mux seeks out an available CPU port. Others map data input to a port in a fixed manner so that your call does not go through even if other ports are free. Be sure to check that the software can manage random port selection and to what degree—speed, terminal type and terminal signal protocol. Several manufacturers including Codex and Timeplex, accept isochronous (self-clocking) data. These data are frequently generated by encryption devices used with TTYs or similar asynchronous devices. The bit pattern produced has no Start-Stop units. And the mux must generate and time a clock signal to the bit stream to transmit it. The same is true of the decrypter or receiver device when the information is recovered.

Channel capabilities of muxes differ considerably. Some work with asynchronous terminals others have programmable channel capabilities as with the Codex unit. However, most require card changes to accommodate different terminals. A few have automatic speed detection so that terminal speed changes are handled without user intervention. Of course, you should check how much software intervention is needed to complete the change.

Special multiplexers, such as the Timeplex T-96, have a hubbing feature. The central mux can interface with two to three high-speed lines (such as those from distant muxes) to aggregate or combine data channels in a star-like pattern at the central site. With full hubbing capacity, the central mux at location X can bypass data from City A to City B or from City B to City C. Yet A, B and C can have channels to X. And X can have channels to A, B and C. The first unit to have this feature was the American Data Systems 670, and the unit is available from Livermore Data Systems (ADS merged into Livermore Data Systems).

For the most part, FDM manufacturers allow free intermix of speed and provide features found in 103-style modems. A few force single-speed operation. Sinces muxes are asynchronous, you can operate from zero to the maximum baud limit. But the channel bandwidth is wasted if you have slower devices. Practically all manufacturers provide the necessary adjustment for dynamic range. Be sure to consult them about mixed speeds and channel frequency assignments. As a rule of thumb, try to place the fastest channels near the line's center frequency, since the response there is reasonably flat. Locate the lower-speed channels symmetrically about the center. You'll find ComData's Series-200 brochure particularly lucid on this subject. ■■

Need more information?

We wish to thank the many companies that provided information used in this report. The companies and products cited in this report were selected for their illustrative, or in some cases, unique qualities. However, manufacturers not mentioned in the report may offer similar products. Readers may wish to consult manufacturers listed here for further details. Coding: (A)—acoustic couplers; (B)—asynchronous modems; (C)—synchronous modems; (D)—time-division multiplexers and (E)—frequency-division multiplexers.

AT&T, 195 Broadway, New York, N.Y. 10007. (212) 393-9800. (K.J. Whalen). (B, C) **Circle No. 401**

Advanced Terminal Systems, Inc., P.O. Box 90121, Los Angeles, Calif. 90009. (213) 644-5321. (T. Pine). (B, D) **Circle No. 402**

Anderson Jacobson, Inc., 1065 Morse Ave., Sunnyvale, Calif. 94086. (408) 734-4030. (R.B. Tabke). (A, B, E) **Circle No. 403**

Astrocom Corp., 15012 Minnetonka Industrial Rd., Minnetonka, Minn. 55343. (612) 933-2208. (T.H. Frahm). (A, B, C) **Circle No. 404**

Bendix Corp., 1400 Taykir Avenue, Baltimore, Md. 21204. (301) 825-5200. (D) **Circle No. 405**

Bowmar Instrument Corp., 8000 Bluffton Rd., Fort Wayne, Ind. 46807. (219) 747-3121. (R. A. Ionni). (B) **Circle No. 406**

Bunker Ramo Corp., Information Systems Group, Trumbull Industrial Park, Trumbull, Conn. 06609. (203) 377-4141. (P.F. Burke) (B) **Circle No. 407**

Burroughs Corp., Business Machines Group, 6071 2 Ave., Detroit, Mich. 48232. (313) 972-7000. (B, C) **Circle No. 408**

Carterfone Communications, 2639 Walnut Hill Lane, Dallas, Tex. 75229. (214) 350-7011. (D. Connolly). (B) **Circle No. 409**

Cermetek, 600 National Ave., Mountain View, Calif. 95040. (415) 969-9433. (R.S. Smith). (B) **Circle No. 410**

Codex Corp., 15 Riverdale Ave., Newton, Mass. 02195. (617) 969-0600. (R.W. Lowry). (C, D) **Circle No. 411**

Coherent Communications Systems, 85D Hoffman Lane S., Central Islip, Long Island, N.Y. 11722. (516) 582-4044. (M.F. Feinberg) (B, E) **Circle No. 412**

Collins Radio Co., 4311 Jamboree, Newport Beach, Calif. 92663. (714) 833-4723. (R.L. German). (B, C, E) **Circle No. 414**

ComData Corp., 8115 Monticello, Skokie, Ill. 60076. (312) 677-3900. (W.L. Manning). (A, B, C, D, E) **Circle No. 413**

Computer Transmission Corp. (Tran), 2352 Utah Ave., El Segundo, Calif. 90245. (213) 973-2222. (D.A. Barr). (B, C, D) **Circle No. 415**

Control Data Corp., 8100 34 Ave., S. Minneapolis, Minn. 55440. (612) 888-5555. (B, C) **Circle No. 416**

Counterscan Systems, P.O. Box 536, E. Highway 6, Sutton, Neb. 68979. (402) 773-3875. (E. Wach, A.D. Spangler). (Contention Mux; 512 channels) **Circle No. 417**

Credex Corp., 7920 Charlotte Dr., S.W., Huntsville, Ala. 35802. (205) 883-0710. (B) **Circle No. 418**

Datapoint Corp., 9725 Datapoint Dr., San Antonio, Tex. 78284. (512) 696-4520. (E. Gistaro). (A, B) **Circle No. 419**

Data Products Corp., Stelma Telecommunications Div., 17 Amelia Pl., Stamford, Conn. 06904. (203) 325-4161. (J.J. Corless). (A, B, C, E) **Circle No. 420**

DataServ, 770 Airport Blvd., Burlingame, Calif. 94010. (415) 342-0877. (J.H. Pinzone). (B) **Circle No. 421**

DataStat Inc., 246 Sobrante Way, Sunnyvale, Calif. 94086. (408) 732-7618. (B, C, E) **Circle No. 422**

Da-Tel Research Co., P.O. Box 1206, N. Park Ave., Montrose, Colo. 81401. (303) 249-6129. (E.A. Gilbert). (B, D, E) **Circle No. 423**

Digital Communications Associates, Inc., 2801 Clearview Pl., Atlanta, Ga. 30340. (404) 458-6215. (J. Spencer). (D) **Circle No. 424**

Digital Techniques Corp., 4248 Delmere Ct., Royal Oaks, Mich. 48073. (313) 549-8663. (R. Sniatkowski). (A, B) **Circle No. 425**

Duracom Corp., 7300 N. Crescent Blvd., Pennsauken, N.J. 08110. (609) 662-7272. (D) **Circle No. 426**

Econolite, P.O. Box 6150, Anaheim, Calif. 92806. (714) 630-3700. (J.T. Gillis). (B) **Circle No. 427**

Electro General Corp., 128 E. Jackson Ave., North Hopkins, Minn. 55343 (612) 935-7704. (R. Dossett). (B) **Circle No. 428**

Fujitsu Ltd., 680 Fifth Ave., New York, N.Y. 10019. (212) 265-5360. (B, C, D, E) **Circle No. 429**

Gandalf Data Communications Ltd., 15 Grenfell Crescent, Ottawa K2G 0G3 (613) 825-4526. U. S. Distributors: Penril Data Communications Inc. (D. Cunningham). (B, C, Contention-type TDM) **Circle No. 430**

General Atronics Corp., 1200 E. Mermaid La., Philadelphia, Pa. 19118. (215) 248-3700. (W.L. Lutz). (B, C, D, E) **Circle No. 431**

GTE Information Systems, Inc., One Stamford Forum, Stamford, Conn. 06904. (203) 357-3035. (A. Jernee) (A, B, C. D, E) **Circle No. 432**

GTE Lenkurt Inc., 1105 Country Rd., San Carlos, Calif. 94070. (415) 591-8461. (T.F. Curry). (B, C, E) **Circle No. 433**

General DataComm Industries, 131 Danbury Rd., Wilton, Conn. 06897. (203) 762-0711. (M.J. Levesgue). (A, B, C, D, E) **Circle No. 434**

General Dynamics Corp., Electro Dynamic Div., P.O. Box 2566, Orlando, Fla. 32802. (305) 834-1000. (B, C) **Circle No. 435**

General Electric Co., Data Communication Products Dept., Waynesboro, Va. 22980. (804) 942-8161. (C.F. Rockwell). (A, B, C, E) **Circle No. 436**

Hallicrafters Co., 600 Hicks Rd., Rolling Meadows, Ill. 60008. (312) 259-9600. (C) **Circle No. 437**

Hughes Aircraft Co., Microelectronics Div., 500 Superior Ave., Newport Beach, Calif. 92663. (714) 548-0671 (B) **Circle No. 438**

Hycom Inc., 16841 Armstrong Ave., Irvine, Calif. 92705. (714) 557-5252. (B. Cook). (C) **Circle No. 439**

International Business Machines Corp., Data Processing Div., 1133 Westchester Ave., White Plains, N.Y. 10604. (914) 696-1900. (R.A. Pfeiffer Jr). (B, C, E) **Circle No. 440**

I. I. Communications Corp., 250 Welsh Pool Rd., Lionville, Pa. 19353. (215) 363-9800. (C.H. Haggerty). (B, C) **Circle No. 441**

Infotron Systems Corp., 7300 N. Crescent Blvd., Pennsauken, N.J. 08110. (609) 665-3864. (D) **Circle No. 442**

Integrated Electronics, P.O. Box 213, Dover, N.J. 07801. (201) 366-9009. (A) **Circle No. 443**

Integrated Micro Systems, 1215 Terra Belta Ave., Mountain View, Calif. 94040. (415) 965-3900. (P.R. Kemp Jr.). (B) **Circle No. 444**

Interface Engineering Inc., 386 Lindelof Ave., Stoughton, Mass. 02072. (617) 344-7383. (T. Scanlon). (D) **Circle No. 445**

International Communications Corp., 8600 N.W. 41 St., Miami, Fla. 33166. (305) 691-1220. (M.A. Kenny). (B, C); Asyn. modem for export only. **Circle No. 446**

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Intertel Inc., 6 Vine Brook Park, Burlington, Mass. 01803. (617) 273-0950. (B, C) **Circle No. 447**

Lear Siegler Inc., 714 N. Brookhurst St., Anaheim, Calif. 92803. (714) 774-1010. (L.R. Couts). (E) **Circle No. 448**

Livermore Data Systems, 2050 Research Dr., Livermore, Calif. 94550. (415) 447-2252. (J.G. Nugen). (A, B, C, D) **Circle No. 449**

MI 2 Data Systems, Inc., 1356 Norton Ave., Columbus, Ohio 43212. (614) 294-2694. (G. Gerhard). (A, B, D) **Circle No. 450**

Mohawk Data Sciences, 791 3 Ave., King of Prussia, Pa. 19406. (215) 337-1910. (S. Keane). (C) **Circle No. 451**

Motorola Semiconductor Products, Inc., 5005 E. McDowell Rd., Phoenix, Ariz. 85008. (602) 244-6900. (B. Drew) (B) **Circle No. 452**

NCR Corp., Main and K Streets, Dayton, Ohio 45479. (513) 449-2000. (K. Turner). (B, C). **Circle No. 453**

Northern Radio Co., 325 W. Hibiscus, Melbourne, Fla. 32901. (305) 727-6700. (E) **Circle No. 454**

Novation Inc., 18664 Oxnard St., Tarzana, Calif. 91356. (213) 344-7191. (A, B, C) **Circle No. 455**

Omnitec Corp., 2405 S. 20 St., Phoenix, Ariz. 85034. (602) 258-8246. (F. Willes). (A, B) **Circle No. 456**

Paradyne Corp., 8550 Ulmerton Rd., Largo, Fla. 33540. (813) 536-4771. (K. Nordling). (C) **Circle No. 457**

Penril Data Communications Inc., 5520 Randolph Rd., Rockville, Md. 20852. (301) 881-8151. (B, C, D) **Circle No. 458**

Prentice Electronics Corp., 795 San Antonio Rd., Palo Alto, Calif. 94303. (413) 327-0490. (A, B, E) **Circle No. 459**

Pulsecom Div., Harvey Hubbell Inc., 5714 Columbia Pike, Falls Church, Va. 22041. (703) 820-0652. (C.M. Gray). (B, E) **Circle No. 460**

Quindar Electronics Inc., 60 Fadem Rd., Springfield, N.J. 07081. (201) 379-7400. (J.S. Tennant). (B, D, E) **Circle No. 461**

RCA Service Co., Technical Services Bldg., 204-2, Camden, N.J. 08101. (609) 779-5087. (V.A. Littlefield). (A, B) **Circle No. 464**

RFL Industries, Powerville Rd., Boonton, N.J. 07005. (201) 334-3100. (J. Simon). (A, B, C, E) **Circle No. 463**

Randtech Corp., 88 Church St., Amsterdam. N.Y. 12010. (518) 843-3060. (J. Havlicek). (E) **Circle No. 462**

Receptors, 4203 Spencer St., Torrance, Calif. 90503. (213) 373-6951. (J. McCullar). (B, C, D, E) **Circle No. 466**

Rixon Inc., 2120 Industrial Parkway, Silver Spring, Md. 20904. (301) 622-2121. (J. Stahl). (B, C) **Circle No. 467**

Rockwell International, Microelectronics Div., P.O. Box 3669, Anaheim, Calif. 92803. (714) 632-8111. (S. Maxwell). (B, C) **Circle No. 465**

Sanders Data Systems, Daniel Webster Highway S., Nashua, N.H. 03060. (603) 885-3727. (J.J. Egan Jr.). (B, C) **Circle No. 468**

Sidreal Corp., P.O. Box 1042, Portland, Ore. 97207. (503) 223-0863. (R. Taylor). (B) **Circle No. 469**

Singer Co., Kearfott Tele-Signal Operation, 250 Crossways Park Dr., Woodbury, N.Y. 11797. (516) 921-9400. (E. Bohnslav). (A, B, C, D, E) **Circle No. 470**

Sola Basic Industries, Electric Div., 1717 Busse Rd., Elk Grove Village, Ill. 60007. (312) 439-2800. (J.D. Kimball). (B) **Circle No. 471**

Solid State Electronics, 15321 Rayen St., Sepulveda, Calif. 91343. (213) 894-2271. (E.Y. Politi). (E) **Circle No. 472**

Sonex Inc., 2339 Philmont Ave., Huntington Valley, Pa. 19006. (215) 947-6100. (R.E. Donaghy). (B, D) **Circle No. 473**

Syntech Corp., 11810 Parklawn Dr., Rockville, Md. 20852. (301) 770-0550. (G. Fritkin). (B, C, D) **Circle No. 474**

Tele-Dynamics, Div. of Ambac, 525 Virginia Dr., Fort Washington, Pa. 19034. (215) 643-3900. (J. Jurenko). (A, B, C, E) **Circle No. 475**

Telefile Computer Products, Inc., 17785 Sky Park Circle, Irvine, Calif. 92664. (714) 557-6660. (D) **Circle No. 477**

Teleprocessing Industries, Inc., 82 McKee Dr., Mahwah, N.J. 07430. (201) 529-4600. (E) **Circle No. 476**

Timeplex Inc., 100 Commerce Way, Hackensack, N.J. 07601. (201) 646-1155. (M.L. Bond). (B, C, D) **Circle No. 478**

Tuck Electronics, 4409 Carlisle Pike, Camp Hill, Pa. 17011. (717) 761-4354. (B.C. Hill Jr.). (A, B, C, D, E) **Circle No. 479**

Tycom Systems Corp., 26 Just Rd., Fairfield, N.J. 07006. (201) 227-4141. (Lynn Leone). (A, B) **Circle No. 480**

Tymshare Inc., 10340 Bubb Rd., Cupertino, Calif. 95014. (408) 257-6550. (A) **Circle No. 481**

Univac Communications & Terminals Div., 322 N. 22 W, Salt Lake City, Utah 84116. (801) 328-8066. (c/o A. Fera V.P. Marketing, P.O. Box 500, Blue Bell, Pa.) (B, C) **Circle No. 482**

Universal Data Systems, 2611 Leeman Ferry Rd., Huntsville, Ala. 35805. (205) 533-4500. (G. Grumbles). (B, C, E) **Circle No. 483**

Vadic Corp., 505 E. Middlefield Rd., Mountain View, Calif. 94043. (415) 965-1620. (T. McShane). (B, C) **Circle No. 484**

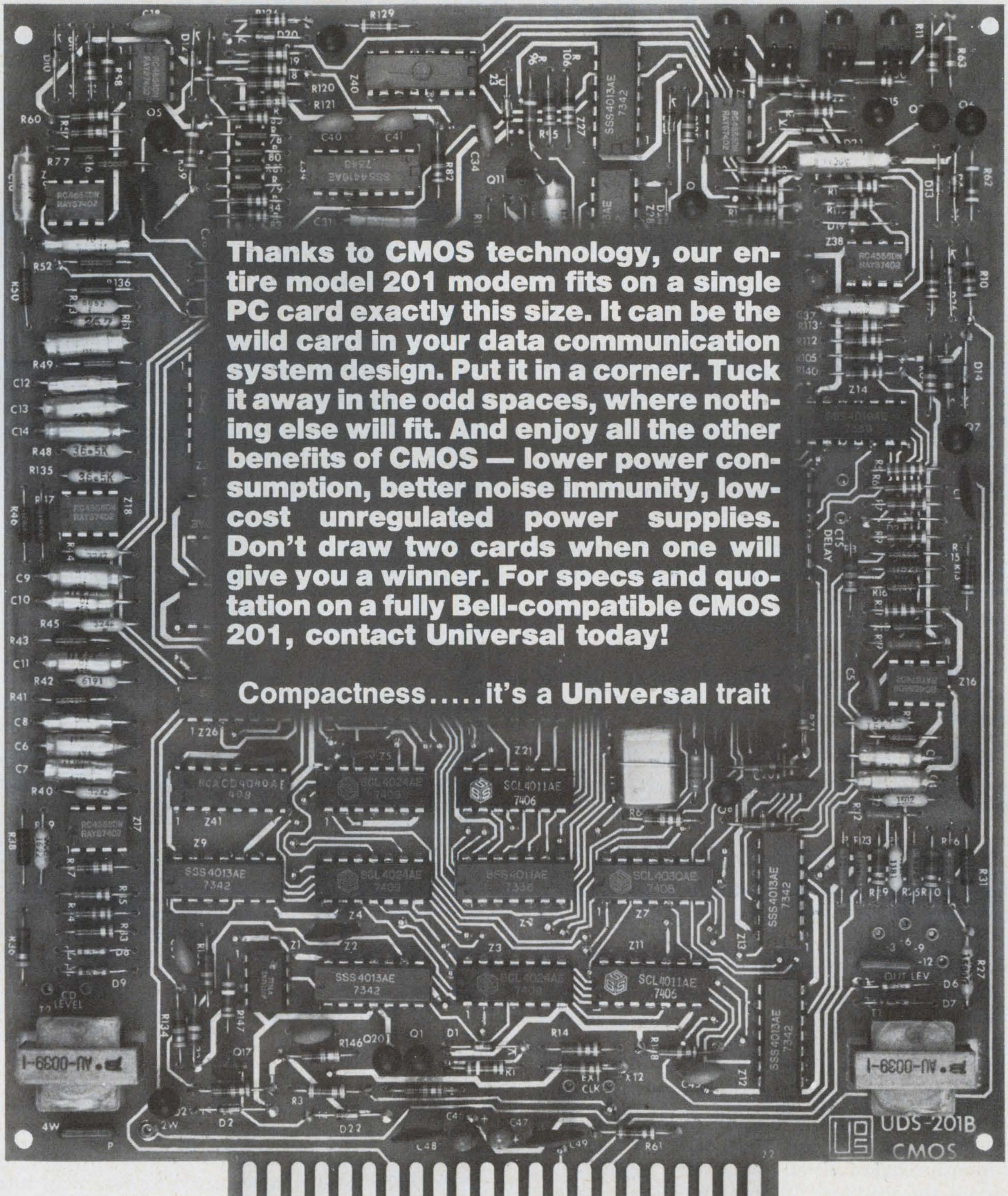
Victor Graphic Systems, Inc., 95F Hoffman Lane S., Central Islip, N.Y. 11722. (516) 582-3500. (R. Grimshaw). (B) **Circle No. 485**

Webb, Jervis B. Co., Ann Arbor Computer Corp., 415 W. Huron St., Ann Arbor, Mich. 48103. (313) 761-2151. (B, C) **Circle No. 486**

Western Digital Corp., 3128 Red Hill Ave., Box 2180, Newport Beach, Calif. 92663. (714) 557-3550. (S. Stuart). (B, C) **Circle No. 487**

Wiltek Inc., Glover Ave., Norwalk, Conn. 06852. (203) 853-7400. (J. English). (D) **Circle No. 488**

OUR CMOS 201 MODEM IS A CARD!



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Extend LSI-processor capabilities with microprogramming. Increasingly, vendors are offering this feature to minimize hardware for a wide range of systems.

Microprogramming techniques offer designers many advantages: They allow an LSI-microprocessor system to be tailored to a specific application. They also permit the same hardware to be optimized for two dissimilar applications, such as text manipulation and process control.

Any microprocessor has advantages over hard-wired logic. For example, a microprocessor-controlled benchtop tester might be programmed to test a family of MSI integrated circuits. Then by a change of programs, the same hardware could be used to test a different class of circuits, such as memories.

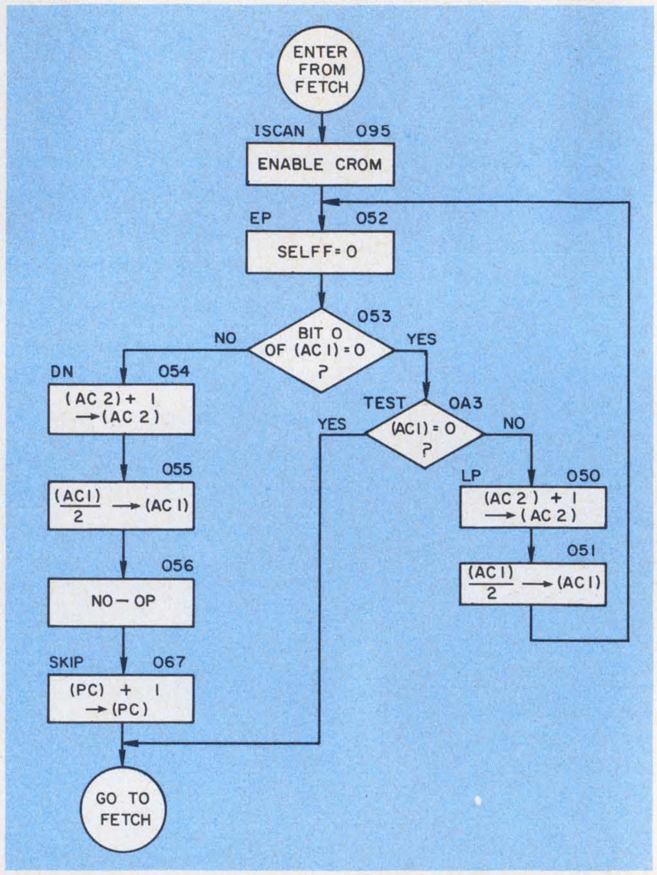
But microprogramming extends the programmable characteristic one level further (see box). It represents one of several large-computer features that have been incorporated into current or planned LSI processors. Others include large register arrays, multiprocessing and virtual memory. However, of all the new capabilities, microprogramming appears to have the most universal application.

Some of the benefits

Increased execution speed represents one of the major benefits of microprogramming. Designers can achieve a more efficient or more extensive instruction set. Other benefits include a proprietary design that cannot be duplicated easily, an instruction set tailored to reduce system memory requirements, and possible emulation of other computers.

In addition, basic features of the system architecture can be modified. These include data length, register allocation, interrupt structure and data input-output operations. And sometimes the entire application program can be written at the microprogram level. Thus it's possible to eliminate the memory required to store machine instructions, the time needed to access and decode them, and the registers required to address and store them.

George Reyling, Jr., Project Manager, National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, Calif. 95051.



1. **The flow chart outlines an interrupt-scan routine** (ISCAN) that can be microcoded into a single machine instruction. A series of test and skip operations follow a clearing of the select flag (SELFF = 0). Register AC1 should be loaded with the interrupt-select status word, and AC2, with the base address of a pointer array for the service routines. PC refers to the program counter.

Increased speed leads directly to improved system throughput, or system response time. An important response-time parameter in many systems is the total time required to detect an interrupt, to identify the interrupting device and to branch to the device's service routine. Without microprogramming, this time can become excessive when polling techniques are used, and when the system employs a large number of interrupting devices.

For example, the following interrupt scheme prevails in some applications that use a 16-bit

```
000  000000  *ISCAN   INTERRUPT SCAN INSTRUCTION
000  000000  *
000  000000  *        AC1 = INT STATUS WORD
000  000000  *        AC2 = STARTING ADDRESS OF INTERRUPT TABLE MINUS ONE
000  000000  *                (OR CURRENT INTERRUPT SCAN ADDRESS).
000  000000  *        IF AC1 = 0 THERE IS NO CHANGE IN AC1 OR AC2 AND THE NEXT INST
000  000000  *                IS EXECUTED.
000  000000  *        IF AC1 .NE. 0 THEN AC1 IS SHIFTED RIGHT UNTIL A 1 IS SHIFTED
000  000000  *                OUT OF BIT 0. THE SHIFT COUNT IS ADDED TO AC2 AND THE
000  000000  *                NEXT INSTRUCTION IS SKIPPED.
000  000000  *
095  000000           ORG X'95
095  000000  *        ASSEMBLER DIRECTIVE SETS MICROPROGRAM COUNTER TO HEX ADDRESS 95.
095  229405  ISCAN    B       EP,RE
096  000000  *        LOC X'95 IS THE ENTRY POINT FOR ISCAN.
096  000000  *        BRANCH TO THE LOCATION LABELLED EP. ENABLE CROM FOR EXECUTION.
050  000000           ORG X'50
050  00DB40  LP       ADD,AC2,,AC2   CIN
051  000000  *        INCREMENT THE CONTENTS OF AC2 (REGISTER 6)
051  351610           OR,,AC1,AC1   SHR
052  000000  *        SHIFT THE CONTENTS OF AC1 (REGISTER 5) RIGHT ONE BIT.
052  00A290  EP       RFLG,SELFF,AC1    OR,CMPA     DC WITH 46(ALSO 42,56)
053  000000  *        CLEAR THE SELECT CONTROL FLAG (SO THE LINK IS NOT INCLUDED
053  000000  *            IN SHIFTS). PLACE THE COMPLEMENTED CONTENTS OF AC1 ON THE
053  000000  *            RESULT BUS SO BIT ZERO MAY BE TESTED.
053  2518C4           B,BIT0          TEST          AC1 ON R BUS
054  000000  *        IF BIT ZERO OF THE RESULT OF THE PREVIOUS MICROINSTRUCTION
054  000000  *            IS TRUE, BRANCH TO THE LOCATION LABELLED TEST (OTHERWISE
054  000000  *            NEXT ADDRESS). PLACE THE CONTENTS OF AC1 ON THE R BUS.
054  00DB40  DN       ADD,AC2,,AC2    CIN         DC WITH 50                         DC
055  000000  *        INCREMENT THE CONTENTS OF AC2.
055  351610           OR,,AC1,AC1    SHR                                           DC
056  000000  *        SHIFT THE CONTENTS OF AC1 RIGHT ONE BIT.
056  00A290           RFLG,SELFF,AC1    OR,CMPA    REQD FOR DC AT 52                DC
057  000000  *        CAUSES THE SAME FUNCTION AS THE INSTRUCTION AT LOCATION 52, BUT
057  000000  *            IS INCLUDED AS AN EFFECTIVE NO-OP TO ALLOW PHYSICAL
057  000000  *            MINIMIZATION OF THE MICROPROGRAM STORAGE PLA.
057  002748  SKIP     ADD,PC,,PC    CIN,IF                                          DC
058  000000  *        INCREMENT THE CONTENTS OF THE PROGRAM COUNTER AND BRANCH
058  000000  *            TO THE INSTRUCTION FETCH ROUTINE.
0A3  000000           ORG X'A3
0A3  22814C  TEST     B,NREQ0   LP,IF
0A4  000000  *        BRANCH TO LOCATION 50 (LABELLED LP) IF THE RESULT OF THE
0A4  000000  *            PREVIOUS MICROINSTRUCTION WAS ZERO. OTHERWISE BRANCH TO
0A4  000000  *            THE INSTRUCTION FETCH ROUTINE.
```

2. **The assembly-language listing** details the microcoded scan instruction outlined in Fig. 1.

What is microprogramming?

In a microprogrammed processor, operations on the fundamental register-transfer level can be programmed. These basic operations are the elements of conventional machine instructions.

With minicomputers or large-scale computers, microprogramming employs a single high-speed memory whose outputs control the data paths in the systems either directly or through decoding logic. This memory is then programmed—in a manner analogous to conventional machine or assembly-language coding—to provide the functions needed for the processor's instruction set.

The microprogram provides a "fetch" phase to form an address, to access the machine instruction from the system memory (external to the CPU) and store it in the CPU instruction register. Also the microprogram has an "interpret" or "execute" phase to carry out the operations specified by the instruction. Microprogramming techniques can be extended to other programmable storage means besides conventional memories and to systems that include a number of programmable control sections operating in parallel or in a hierarchy.

In the case of microprocessors, microprogrammable units probably have evolved as much from programmable logic arrays for the control section of calculators as it has from an extension of conventional microprogramming techniques. In fact two current microprogrammable microprocessors use programmable arrays, rather than conventional ROMs for microprogram storage.

microprocessor (the IMP-16) from National Semiconductor, Santa Clara, Calif.: An interrupt causes the processor to issue a command to all devices to supply simultaneously their interrupt-request status over an assigned bit on the system data bus. The microprocessor scans the resulting 16-bit data word (if you assume 16 or fewer devices can interrupt) to determine which devices are interrupting and then services them. To perform this operation, a routine, consisting of shift and test instructions, requires 32 memory locations and takes 530 μs to scan all 16 bits.

But with a microcoded version of a single machine instruction, the same operation occurs in 112 μs. A flow chart of the microprogram appears in Fig. 1, and the listing is shown in Fig. 2. (The microcoded instruction, along with a variety of others, comes in an optional chip for the IMP-16.)

Another example occurs with the multiply function. The machine-instruction version of this routine requires 11 memory locations and executes in 678 μs (not including system memory-access delays or subroutine call and return delays). However, the microcoded version executes in 171 μs, for a 4:1 speed improvement. The ratio approaches 6:1 in a system with a 1-μs memory when the multiply routine is used as a subroutine and memory-cycle delays are included.

Typically, microprograms provide direct improvements in microprocessor performance. However, the technique can be employed indirectly to monitor system operation. Information obtained from the monitor microprogram can then be used to improve processor efficiency.

For example, a microprogram might be written to count the number of executions of each instruction in an application. The resulting information forms the basis for improvements in system throughput. Changes in the microcode for each instruction can be evaluated, and the effects of new instructions can be estimated.

Some of the problems

The heightened development costs and increased development times represent the major disadvantages of microprogramming. Development times increase because two program levels are encountered—one at the micro-instruction level and one at the machine-instruction level.

Furthermore the microprogram development is more complex. It requires a very detailed knowledge of the internal logic and timing of the microprocessor. And when machine instructions are changed from the standard set, software development aids offered by the manufacturer can no longer be used.

One way to cut down on some of these costs is to obtain an initial design that uses the manufacturer's fixed instruction set. Then an additional control chip can be microcoded to provide tailored instructions. This method also allows use of available software development aids.

The cost of a custom-masked control chip is considerably higher than that for a read-only memory, primarily because of the increased complexity. As a result, total over-all costs tend to discourage use of microprogramming in low-volume applications or experimental system designs. However, microprogram development systems are being offered for these applications.

Which micros are microprogrammable?

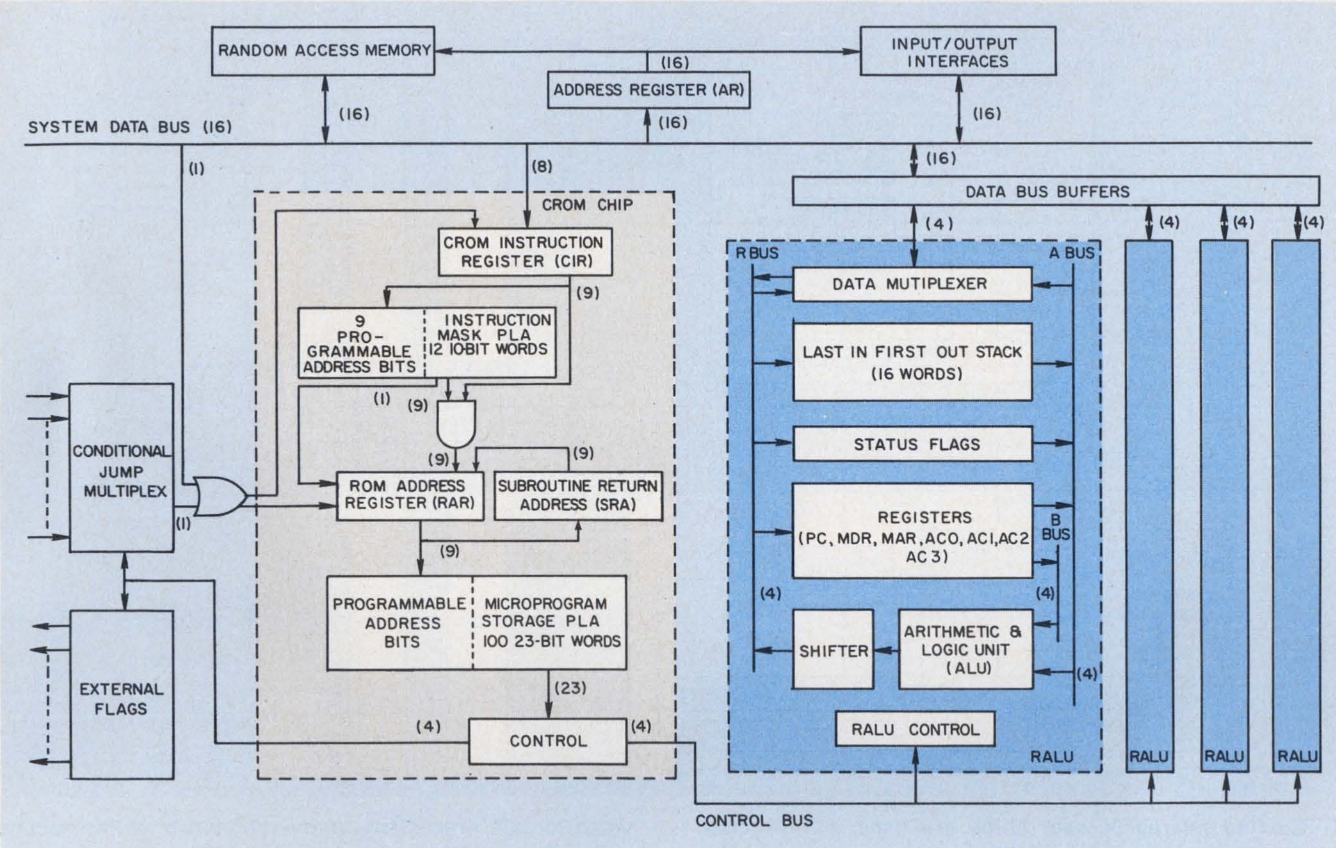
LSI microprocessors that are microprogrammable have been developed by American Microsystems of Santa Clara, Calif., and Computer Automation of Newport Beach, Calif., in addition to National Semiconductor. Other current microprocessors could undoubtedly be considered microprogrammable, but they have not been so promoted. And still other LSI processors expected shortly are described as microprogrammable.

Microprogrammable processors generally employ two basic LSI chips. A complete central-processing unit is formed by the addition of standard ICs for clock generation, data buffering and control.

One of the two chips, dedicated to system control, contains the microprogram storage and control logic. Generally called a CROM (control read-only memory), it accesses the correct microcoded routine for each machine instruction fetched, sequences through the microroutine, and provides the data-manipulation control signals to the second basic chip. This second chip, sometimes called an RALU (register and arithmetic logic unit), provides data storage and processing. It comes in a bit-slice configuration, so that several can be combined to form processors with word lengths that are multiples of the basic bit-slice length.

A block diagram of a 16-bit system using National Semiconductor's IMP chips appears in Fig. 3. The RALU provides a 4-bit slice of each of the following functions: seven data registers, a four-function ALU with complementing input, a data shifter, a status register, a 16-word last-in first-out stack and an input-output register. Up to eight of these chips can be used to build processors whose word lengths are multiples of four bits. All RALUs operate in parallel under control of the CROM to form a synchronous parallel processor.

The operational characteristics of the processor are primarily determined by a microprogram stored in the CROM. The microprogram specifies the assignment of the seven RALU registers, the instruction set used by the processor, and the



3. **A 16-bit LSI microprocessor** employs two basic building-block chips. The control read-only memory (CROM) contains the microprogram and control logic for the second chip, a register and arithmetic-logic unit (RALU) that processes data. From National Semiconductor, the unit also uses PLAs in the CROM.

timing and function of the control signals in the processor interface. It also makes possible the different word lengths that can be built with the RALU.

The CROM contains an instruction register that holds the current machine instruction to be executed. Also a programmable logic array (PLA) generates an instruction mask that is logically ANDed with the instruction microprogram address. The address provides the correct sequence of microcode for the current machine instruction.

Another PLA, with a capacity of 100 micro-instructions, stores the microcode. The use of PLAs simplifies the translation of machine instructions to starting addresses, and it provides increased efficiency in the encoding and higher speed execution of some micro-instruction sequences.

Computer Automation's microprocessor chips, custom ICs contained in the company's Naked Mini product, resemble the IMP chips (Fig. 4). The 4-bit data-processing chip contains an arithmetic and logic unit, a file of seven data registers, status flags and an input-output interface. The control chip provides an instruction register, a sequence register and control logic plus a PLA for microprogram storage.

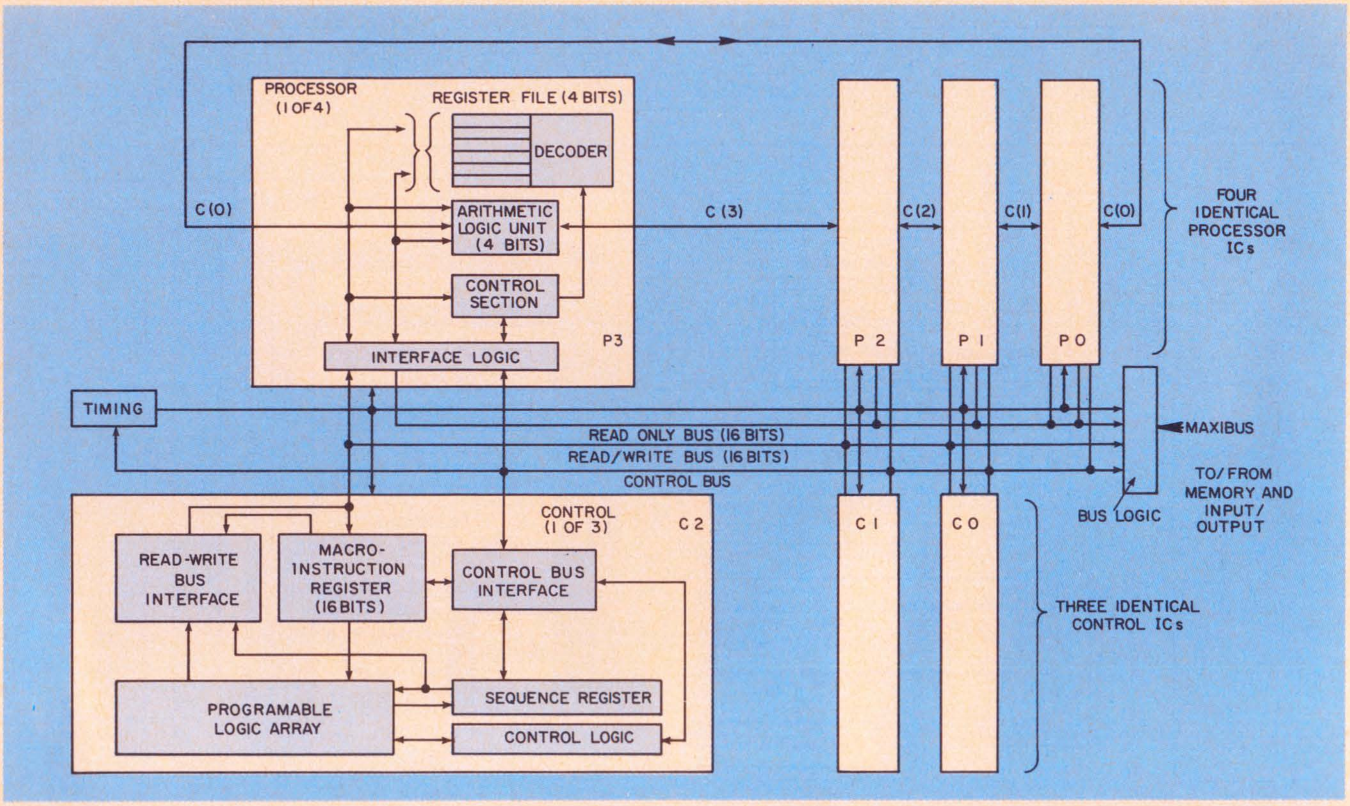
A significant architectural difference from the IMP control chip exists in the microprogram PLA addressing. In the Computer Automation chip, the PLA controls these functions: translation of instruction op codes to micro-routine addresses, testing of branch conditions and sequencing of micro-instructions. This provides higher-speed microprogram execution in some instances. However, a large PLA address decoding section is required.

The chip set proposed by American Microsystems differs somewhat from the other two (Fig. 5). Specifically the data-processing chip is an 8-bit slice and the control chip uses a read-only memory, rather than a PLA, for program storage. Also the microprogram capability appears to be intended primarily for the application program. However, the capability can also be used for machine instructions.

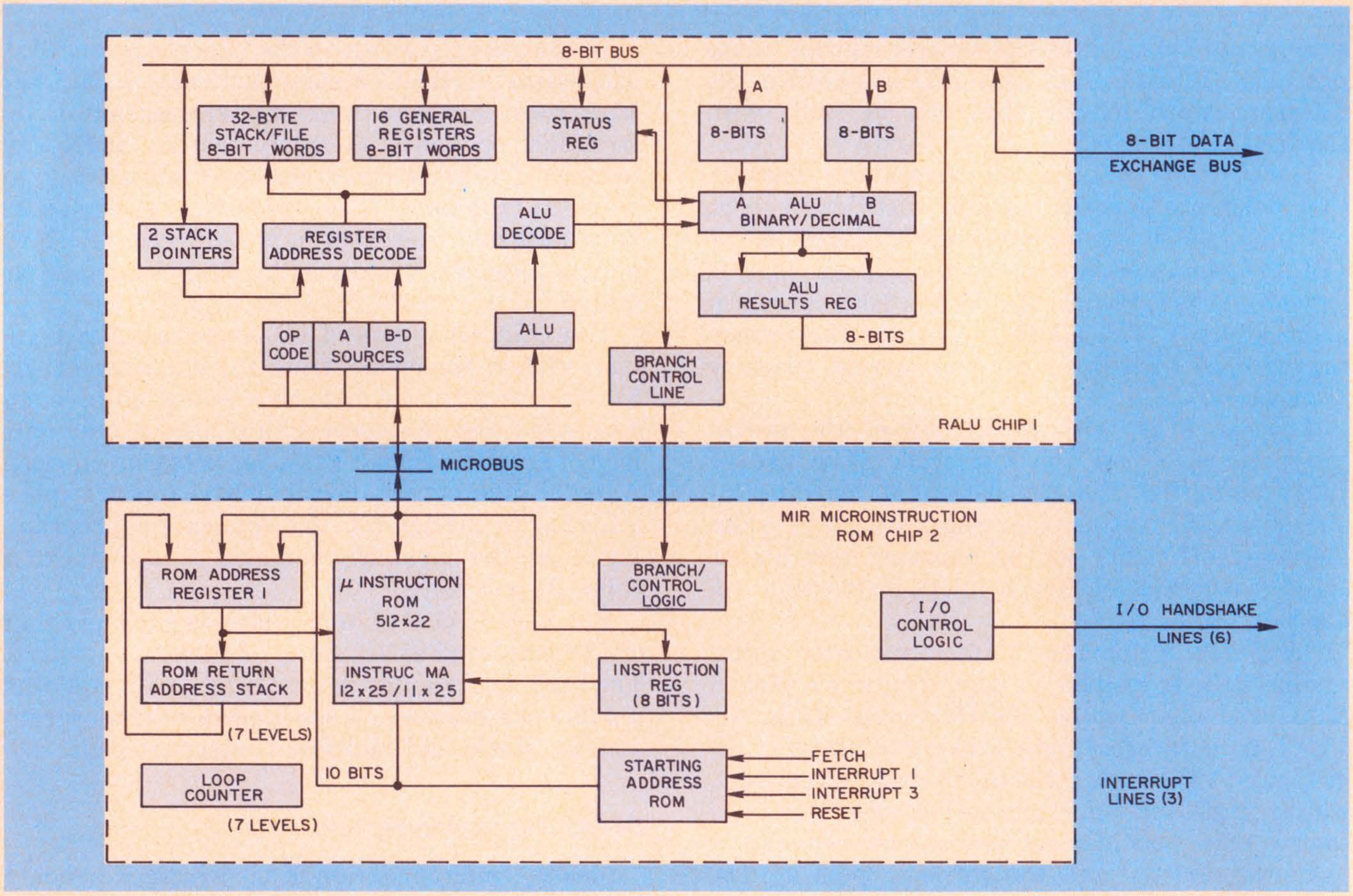
The 8-bit RALU chip provides 48 registers that can be employed as stacks or as general registers. The MIR (micro-instruction ROM) chip contains a 512-word memory, a seven-level microprogram address stack, and multilevel interrupt logic.

Developing microprograms

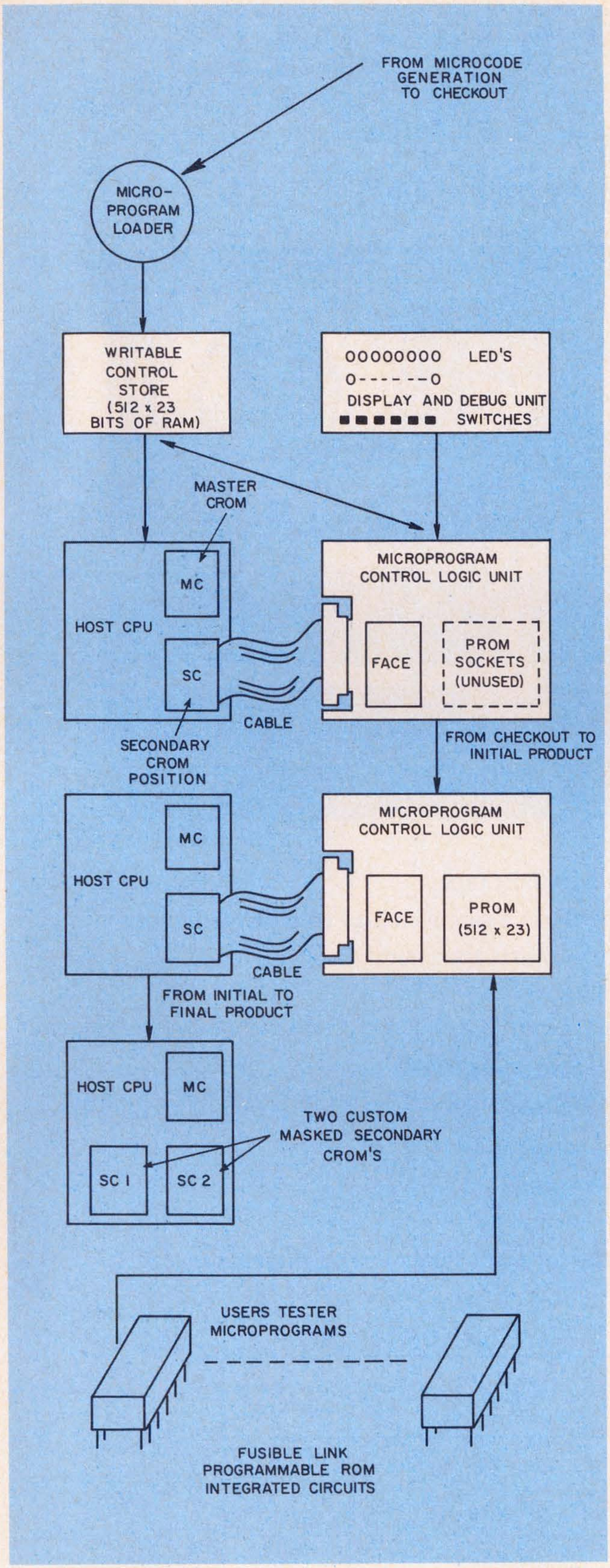
Ideally microprogram-level changes should have a short turn-around. This rules out mask-programmed control chips. Instead the functions



4. **Custom microprocessor chips** are used in Computer Automation's Naked Mini/LSI. The chips resemble the National Semiconductor's IMP series, in that one IC is devoted to data processing under the control of the second chip. However, the control chip has been organized for higher speed at a sacrifice in chip area.



5. **Another microprogrammable unit** has been proposed by American Microsystems. Unlike the other units, this one employs an 8-bit slice, rather than 4 bits, and the control chip uses a ROM instead of a PLA.



6. **One development system for field microprogramming** can be used in low-volume applications. The system employs a writable-control store, control-logic unit and display and debug unit. The FACE (field-alterable control element) chip in the control-logic unit constitutes the heart of the system. Functionally similar to a CROM, the FACE chip uses external memory for the microprogram store.

of the control chip ought to be obtained with other forms of logic, or the system ought to be simulated on a computer. However, both approaches suffer from simulation inaccuracies and high cost.

An alternative approach, presently available only from National Semiconductor, uses a modified CROM. Functionally identical to a CROM, the modified version is called a field-alterable control element (FACE). The chip differs from a CROM in that it doesn't contain the microprogram store. Rather, external RAMs, ROMs or pROMs are employed.

FACE represents the key element of a microprogram development system that can be applied economically to low-volume applications or for program development prior to specification of a custom CROM for high-volume applications. The complete development system consists of a microprogram control-logic unit, a writable control store and a display and debug unit (Fig. 6).

The control-logic unit contains the FACE chip and directly replaces a CROM. Optional programmable ROMs can be obtained to store the designer's microprogram. Also ROM inhibit logic permits memory bank switching, if needed. Other facilities simplify the mapping or transformation of instruction operation codes into microprogram addresses.

The writable-control store (WCS) consists of 512-words by 23-bits of high-speed, bipolar read/write memory. A serial "handshaking" interface for the WCS provides a universal I/O scheme that doesn't depend on the host system. Hence microprograms can be modified more quickly than when pROMS are used.

The display and bebug unit (DDU) traps, latches and displays the control signals of the user's microprogram. Through switches and LEDs on the board, errors in the microcode can be detected and corrected readily.

The development system can operate with the host processor either as a secondary control element, a master controller, or as a noncontrolling element. In this manner, the host system may employ a standard CROM as the basis to load the writable-control store.

The development steps begin with the writing of a microprogram in a symbolic language, then its assembly on a time-sharing facility. The resulting object microcode must be loaded into main memory, then into the WCS via a microprogram loader. The DDU is used for testing and debugging.

The tested microprogram can be stored more permanently in pROMs for test or pre-production systems. In the final product, the object microcode generates a custom mask-programmed CROM. The end result is a system that employs only one or more additional CROMs to achieve the custom instruction set. ■■

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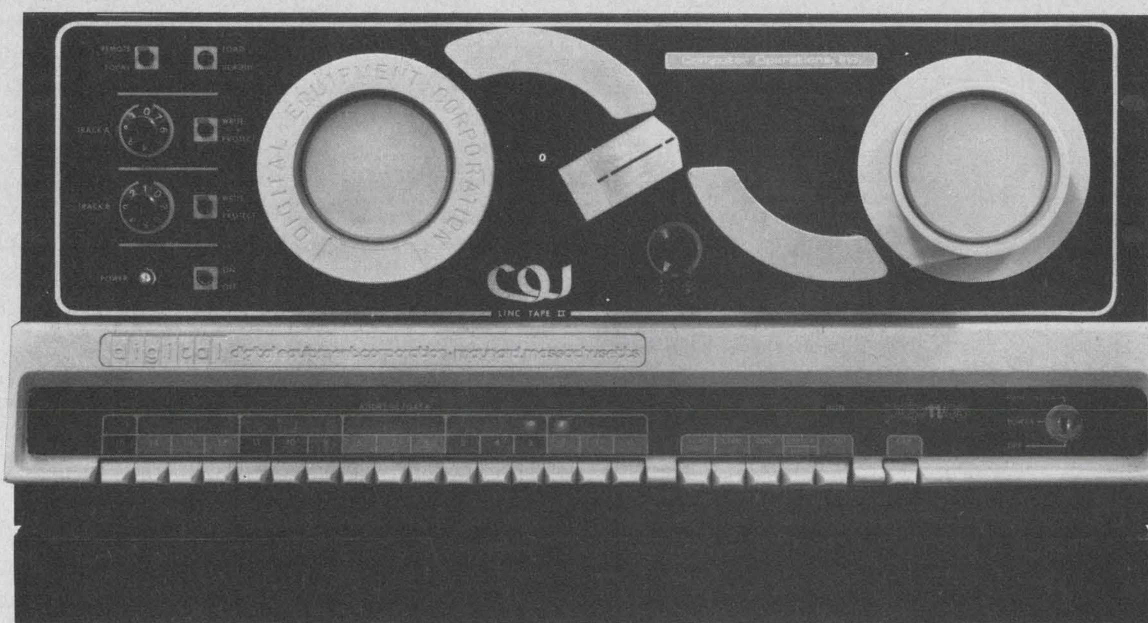

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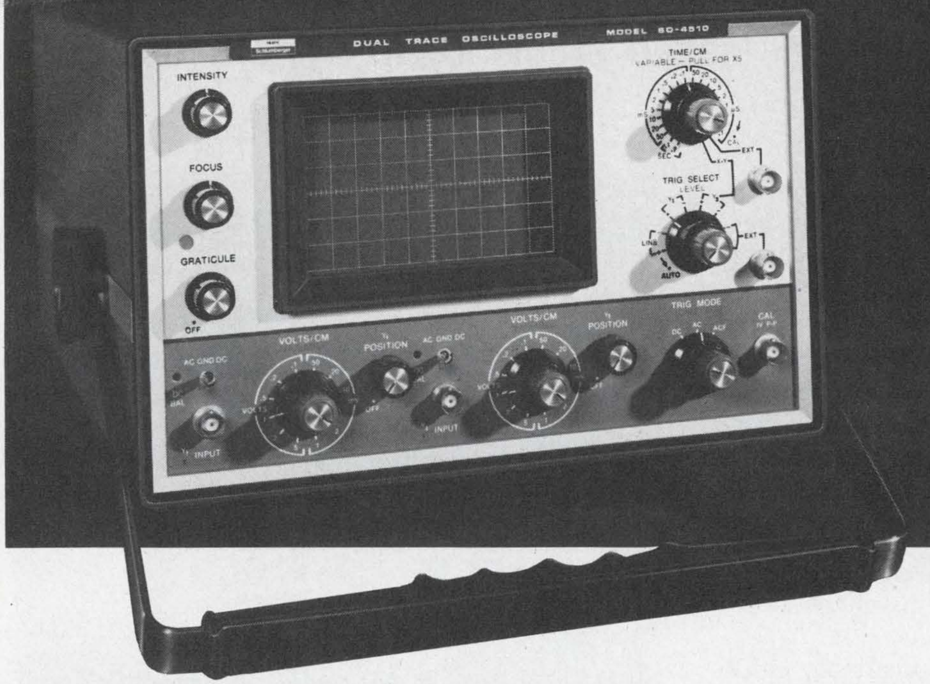

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Improve memory systems with 4-k RAMs.

These ICs combine large storage densities with other features that allow increased efficiency in system designs.

Memory-system designers are turning increasingly to 4096-bit dynamic RAMs as a cheaper, higher-speed alternative to core in add-on and mainframe computer applications. The new IC memories are also being used to reduce the number of packages and power dissipation in smaller semiconductor systems for minicomputers.

Moreover a growing number of IC manufacturers are entering the field either with proprietary 4-k RAMs or as alternate sources.[1] Memory costs, now 0.4 cent per bit, should drop to 0.15 to 0.1 cent within four years (Fig. 1). And current speeds of about 300-ns access should be improved even more with the 150-ns versions expected within a year.

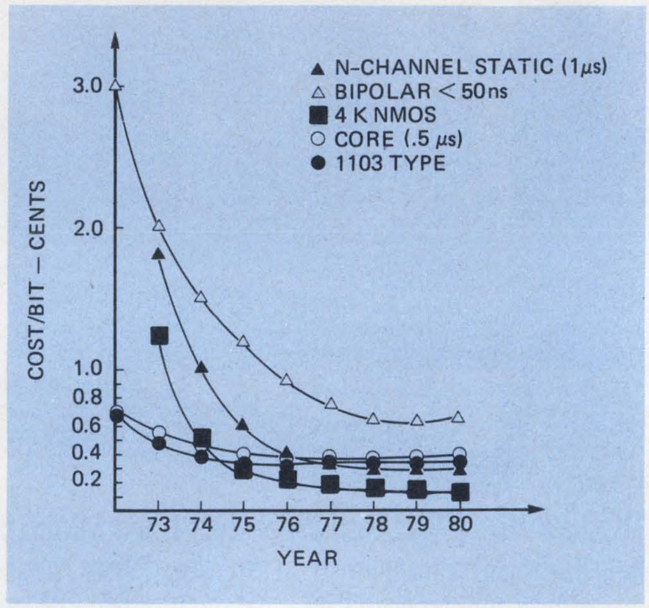
Additional features built into available chips allow increased efficiency in memory systems, but not without the need for careful attention to various design facets. These include PC-board layouts, which bear the brunt of the packaging demands. And key internal circuitry should be examined to determine the complete characteristics of the memory.

4-k RAM replaces core: an example

One example of the replacement of core with semiconductor memories is from Cincinnati Milacron, Lebanon, Ohio. In a minicomputer used by the manufacturer, a 32-k word × 9-bit (8 bits plus an optional parity bit) memory system employs 4-k dynamic RAMs to upgrade an existing core system (Fig. 2).

Compared with core, the semiconductor plug-in replacement memory offers much lower power consumption (14 to 1 reduction), takes up much less chassis space (4 to 1 reduction), and costs slightly less per bit. The semiconductor memories have an operating power dissipation of about 3 W, and standby power with refresh is only 0.25 W.

Raju Shah, Product Manager, Marketing, **T. C. Lo,** Senior Engineer, **Jeff Linden,** Staff Engineer, American Microsystems, Inc., 3800 Homestead Rd., Santa Clara, Calif. 95051.



1. **The low cost per bit of today's 4-k dynamic NMOS RAMs** is expected to drop even further in the years ahead. Access times are also expected to drop.

Data refresh for the dynamic memories uses the DMA (direct-memory access) channel on a cycle "steal" basis. After every 256 machine cycles, the refresh control circuitry steals one memory cycle to refresh the memories.

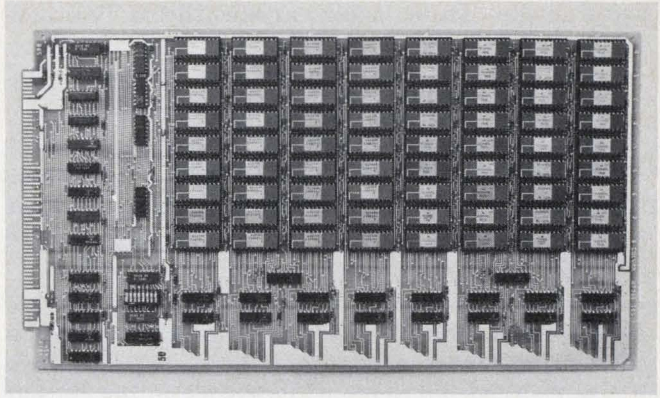
The memory system contains 4-k RAMs (AMI/Motorola 6605), co-developed by American Microsystems, Santa Clara, Calif., and Motorola Semiconductor, Phoenix, Ariz.[2] IC memories from either manufacturer can be used interchangeably on the board because of identical fabrication methods.

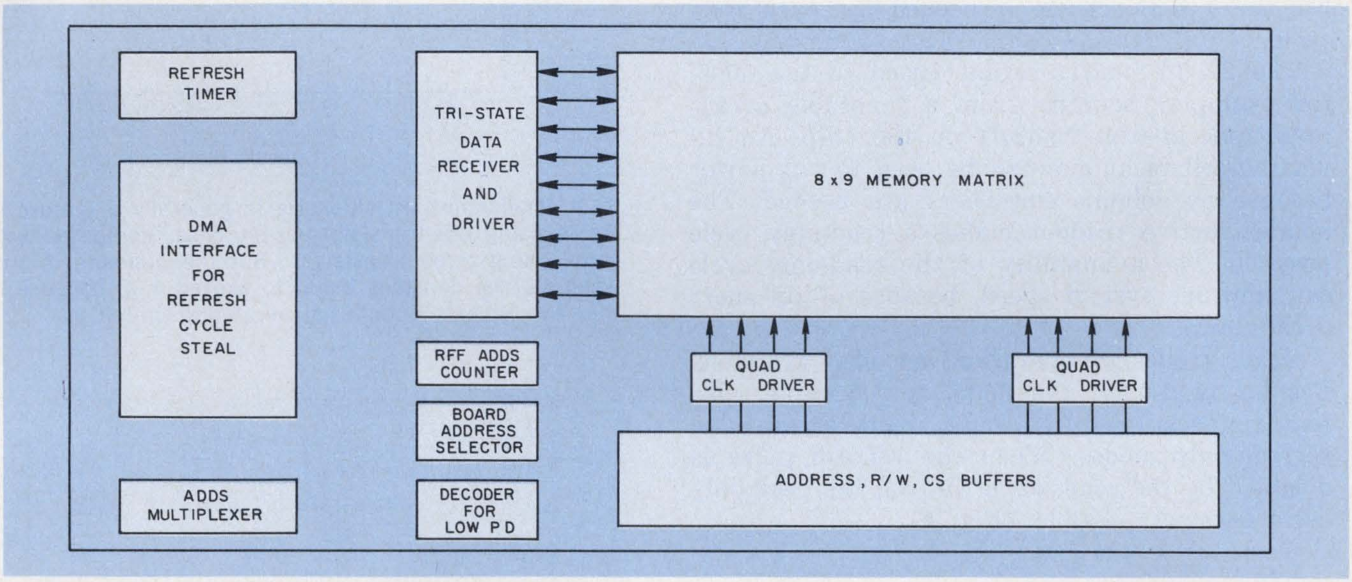
Follow layout guidelines

Board layouts require special attention to overcome such problems as large capacitive capacitive charging currents. These occur with MOS memories during clock-signal transitions.

Fast-switching control lines can couple noise to adjacent lines and thus cause system failure. But reduction of such crosstalk is possible by observance of the following 10 guidelines:

1. Run address lines in parallel with each





2. **A 32-k-word × 9-bit memory board** (photo) uses interchangeable 4-k RAMs from AMI and Motorola Semiconductor. The single board directly replaces four boards using 1-k dynamic (1103-type) RAMs. It is also a quarter the size of an equivalent core system, which dissipates about 14 times more power. A block diagram indicates some of the additional circuits needed. The extra units cost less than $100.

other and at right angles to the clock signals to minimize unwanted cross-coupling.

2. Run the read/write line in parallel with the address line.

3. Shield clock-enable signals from each other and from other signal lines—such as those for data and addresses—by either voltage or ground lines. Form these voltage and ground lines into a mesh pattern to minimize surge-current effects.

4. Run chip-select and address lines in parallel.

5. Place data-in/data-out lines on the opposite side of the board from, and perpendicular to, control lines—such as clock, address and chip select.

6. Keep TTL signal lead away from other leads and ground lines carrying surge currents.

7. Make the distance between clock drivers (including booster stages) and the memory array as short as possible to minimize lead lengths.

8. Provide adequate power-supply bypass capacitors within the array. Use ceramic capacitors with at least 0.05-μF of low-inductance capacitors, and bypass the V_{BB} supply to V_{SS} rather than V_{DD}.

9. Try to provide a ground plane on one side of the board with interconnections and supply on the other. Where this causes layout problems, a good compromise is to make the ground bus as wide as possible.

10. Make the track runs and layout as nearly symmetrical as possible. Aim for the shortest lead lengths throughout.

4-k RAMs employ various cell structures

Commercially available 4-k RAMs employ one of two basic cells: the one-transistor-per-bit (1-T/B) type and the three-transistor-per-bit (3-T/B) type. The former consists of one switching transistor and one storage capacitor; the latter has three MOS devices, which form a dynamic inverter.

Generally the 1-T/B cell area is smaller than that of the 3-T/B. But the 1-T/B scheme requires a more complete sensing scheme and sophisticated peripheral circuitry. Also, the 1-T/B cell has destructive readout, which requires data refresh following each read activity within the same cycle. In a small array the 3-T/B cell yields a smaller over-all chip size (Fig. 3). However, with 4-k RAMs both schemes result in comparable chip sizes.

Most RAMs use 3-T/B cells in one of three forms: 2X-2Y, 2X-1Y and 1X-1Y. X indicates the number of word lines and Y the bit lines associated with each cell. The 2X-2Y form is used in 1103-type 1-k RAMs.

The 1X-1Y type has the smallest cell area. However, it requires complex peripheral design and critical internal timing control. And because it has destructive readout, refresh similar to that for the 1-T/B scheme is needed for each read cycle.

The 2X-1Y configuration (used in the 6605, for example) benefits from a favorable array-to-peripheral-area tradeoff on the chip. An inverting-cell technique can be used to cut power because no column amplifiers are needed. The nondestructive readout makes a read-only cycle possible. The availability of the read-only cycle can improve system speed, because of its short cycle time.

Other modes of operation are also available. Besides read-only, the 6605, for example, also features read-modified-write, read-refresh and refresh-only modes. When the refresh pulse is disabled by the read-write control, the read-only cycle becomes possible (Fig. 4).

How does the RAM cell work?

A single-railed, three-transistor cell is shown in Fig. 5. It has 3-1/2 interconnect lines per bit, with the ground line shared by the adjacent cell.

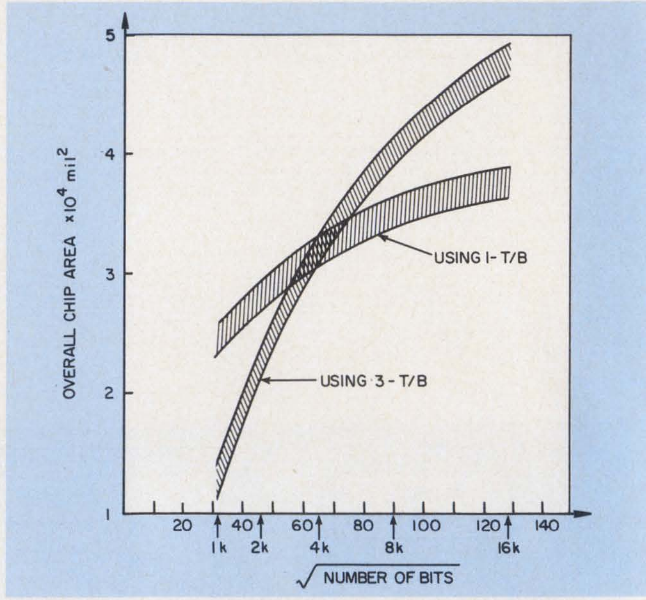
Cells with a common word line constitute "rows," and those sharing the same bit lines form "columns." Because of the n-channel fabrication employed for most 4-k RAMs, logic ONE refers to the most positive level and logic ZERO refers to a less positive level.

A read-modify write cycle of the 6605 illustrates the basic cell operation. It consists of these three steps.

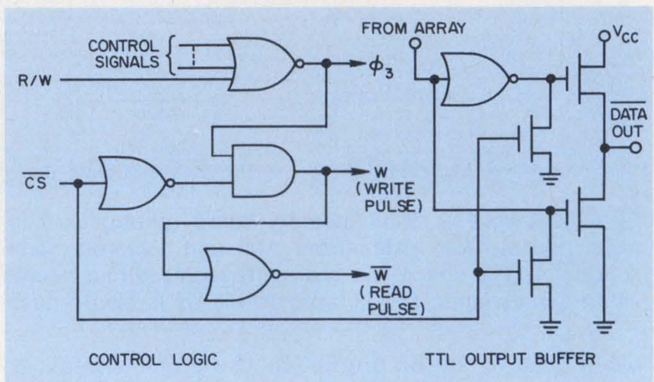
Step 1. At the beginning of the cycle, all bit lines in the array are preconditioned to a logic ONE level.

Step 2. To read the cell, the selected read-enable line goes positive. All bit lines in the same row become conditionally discharged, depending on information stored in the associated storage capacitor C_S. As a result, stored data are transferred from the cells to the bit lines in inverted form. In each cycle only one bit line communicates with the output circuit. The cell associated with selected word and bit lines is said to be accessed.

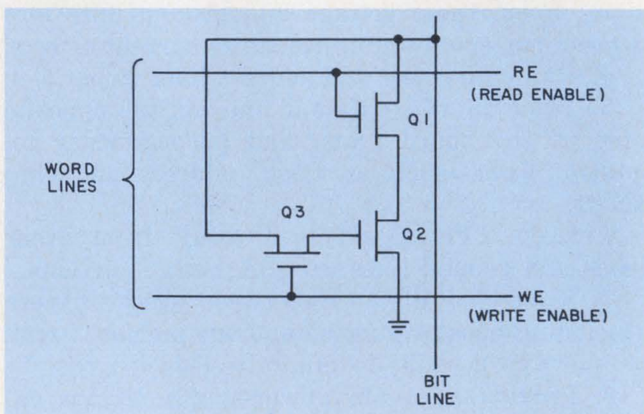
Step 3. To write the cell, the write-enable line is turned on, forcing the associated capacitor,



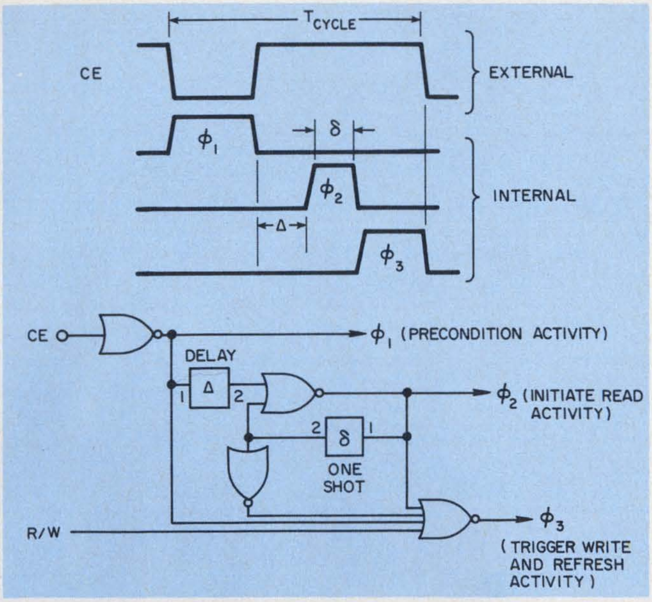
3. **A smaller over-all chip size** is generally a feature of RAMs using one-transistor-per-bit cells, compared with those using three transistors. But the opposite is true when storage densities begin to exceed 4 k, because of the requirements of internal peripheral circuitry.



4. **Operation modes are determined by the chip-select** (CS) signal and the read-write (R/W) control signals in the 6605. Information readout is nondestructive and refresh of the entire memory occurs by a cycling of each of the 32 addresses every 2 ms.



5. **This three-transistor-per-bit cell** forms the basis of the 6605 4-k RAM. On the chip, the present cell measures 3.4 mil² with a new cell design of 2.5 mil² expected to appear on the market in the near future.



6. **A timing generation scheme is needed** for the operation sequence. Three sequential pulses—ϕ_1, ϕ_2 and ϕ_3—are triggered by a single external clock (CE). The period of the CE signal defines the memory cycle. Delay $\Delta = \phi_1 - \phi_2$ is required by the decoder circuit employed.

C_S, to take the voltage of the bit line established by the input buffer. The unselected cells of the same row are refreshed by a sharing of the bit-line charges with the corresponding storage capacitors.

Data refresh re-establishes information in the row of cells in a complementary form. Therefore it is necessary to keep track of the number of times that the transmission gate, Q_3, has been turned on, to avoid destruction of data. The required function is achieved in the 6605 by the use of an additional row of memory cells.

The operation sequence uses a three-phase generator (Fig. 6). Triggered by an external, high- level chip-enable clock, the timing generator sequentially produces three pulses to perform these functions: precondition the cell (ϕ_1), initiate the read cycle (ϕ_2) and trigger the write and refresh activity (ϕ_3).

Peripheral circuitry provides support

Peripheral circuitry is generally provided on the chip for timing control, decoding, address-buffer enable and data-control logic. For example, a delay-control circuit in the 6605 ensures stabilization on X and Y decoders to avoid multiple selection. Delay is obtained through a dummy decoder that has the same geometry and layout as the ones used.

Decoders ensure the access of only one cell per cycle through the selection of only one word line and one bit line. The word-line selection is performed by the X decoders, and the bit line selection is performed by the Y decoders. Both decoders are NOR-dynamic circuits.

The address buffer samples and stores external TTL address signals during the early part of the CE on-time. The buffer then latches them to a stable value and generates a pair of MOS-level signals that drive the decoders.

Data-control cells

The 6605 also has an extra column of cells (totalling 32) to control data. The cells keep track of the number of inversions of stored information. They are identical to the standard RAM cells with the exception that they cannot be written into.

Each time a row of cells is refreshed, the data-control cells also complements just like all the other cells in that row. The bit line associated with the data-control cell performs EXCLUSIVE-OR functions with the input and output data, so the I/O circuits can determine whether there should be an extra inversion.

No column amplifiers are associated with any of the 128-bit lines in this inverting-cell scheme. Hence circuitry can be simplified and power dissipation can be minimized.

Outputs simplify interface

Many 4-k RAMs can accommodate either TTL or ECL interfaces. The TTL-output version of the 6605, for example, provides data comparison and a three-state output buffer on the chip. Signals from both the data-control cell and the selected memory cell are compared and provide correct data to the output buffer. The output is disabled (floating) when either CE is low or $\overline{CS}$ is high. Output data are inverted with respect to data input.

In a current-sourcing version, an internal comparator and TTL output buffer are bypassed. The output terminals provided can drive directly either a dual comparator or an ECL EXCLUSIVE-OR gate for system compatibility and enhanced access time. Again the outputs are disabled (floating) when either CE is low or $\overline{CS}$ is high.

When signal CE is low, the power dissipation of the device is minimized. In this condition, the device is in the standby mode. However, if the standby mode is maintained for more than 2 ms, then signal CE must be returned high for a refresh operation. ■■

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INFORMATION RETRIEVAL NUMBER 236

Threshold logic can cut gate count.

Though threshold gates are complex, MSI and LSI arrays with digital summing can implement them easily.

First of two articles

The number of gates and interconnections in a digital system can be cut with threshold logic. And with modern MSI and LSI circuit technology, the extra complexity of a threshold gate should prove to be only a small disadvantage.

Threshold logic is a marriage between the stark decisiveness of Boolean algebra and the soft flexibility of analog methods. In contrast with the Boolean AND/OR/NOT or NOR/NAND logic gate, each input to a threshold gate may have a different weight. A threshold gate produces an output when the sum of the weights of its inputs exceeds a predetermined level, or threshold. As a result, threshold gates are more powerful building blocks than Boolean gates.

Threshold gates can provide all the basic Boolean functions. In addition a single threshold gate can implement complex switching functions that would require several Boolean gates.

Thresholds combine binary with analog

Each threshold gate input has binary-valued inputs x_1, $x_2, \cdots x_n$, with analog-valued weights a_1, $a_2, \cdots a_n$, respectively, associated with each input and a binary-valued output y. The output from such a gate is:

$$y = 1 \text{ if } \langle a_1x_1 + a_2x_2 + \cdots a_nx_n \rangle \text{ is } \geq \text{ some value } t, \quad (1)$$

$$y = 0 \text{ if } \langle a_1x_1 + a_2x_2 + \cdots a_nx_n \rangle \text{ is } < t, \quad (2)$$

where t is the gate threshold value. Normal arithmetic rules of multiplication and addition apply in the above expressions.

To differentiate between Boolean and threshold functions, Boolean expressions employ [ ] for outer brackets and ( ) for inner brackets. Within these defining brackets, + and · take the normal Boolean meaning of OR and AND, respectively. The dot may be omitted where no ambiguity occurs.

Threshold expressions employ < > for outer brackets and { } for inner brackets. Within these defining brackets, the normal arithmetic rules of multiplication and addition hold.

More compactly expressed, Eqs. 1 and 2 become:

$$y = 1 \text{ if } \sum_{i=1}^{n} a_i x_i \geq t, \quad (3)$$

$$= 0 \text{ if } \sum_{i=1}^{n} a_i x_i < t. \quad (4)$$

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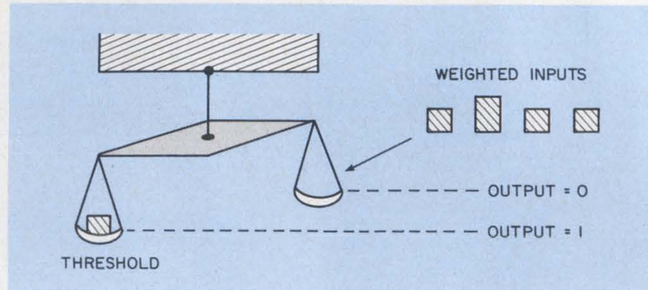
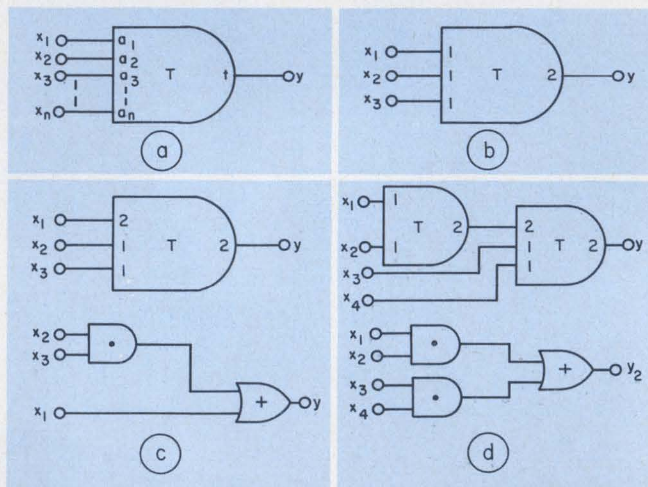
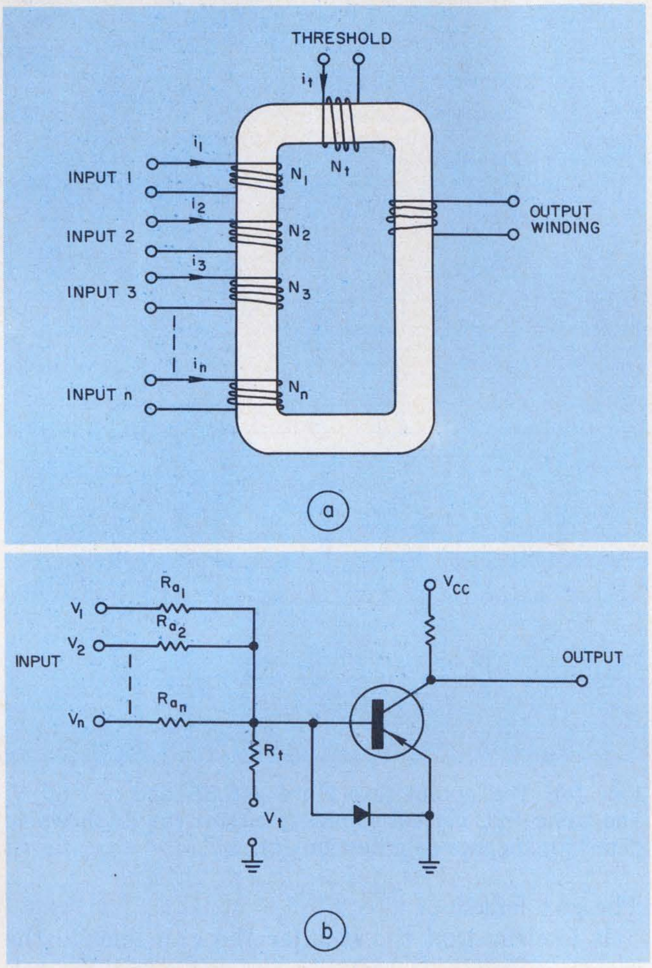


1. **A mechanical analogy of a threshold gate** shows that the inputs are weighted. And when their summed total equals or exceeds the threshold level, the output is a binary transition from logic ZERO to ONE.



2. A **generalized threshold gate can be symbolically represented** (a). The three-input gate (b) performs majority logic, since it provides an output when any two out of the three inputs are ONEs. More complex gates (c and d) perform the functions depicted by the Boolean equivalent circuits shown directly under each T gate.



3. **Though obsolete, the magnetic core type of threshold gate** (a) is very versatile. It uses square-hysteresis-loop material in its core. A discrete-component threshold circuit (b) uses resistors to provide weighting for the input. It was designed originally for use in a computer to test threshold-logic theory and practice.

A simple mechanical analogy of the action of a threshold gate is shown in Fig. 1 and symbolic representations in Fig. 2.

In theory, the individual weights, a_i, and the threshold value, t, can be any real numbers, positive or negative, integer or noninteger. In practice, however, usually only real, positive integers (1, 2, 3, $\cdots$) are used.

The threshold gate is a generalization of Boolean ORs, ANDs and majority logic. If all the weights are one and the threshold is also one, the threshold gate becomes an OR. If the weights are all one and the threshold is n, the sum of all the weights, the gate becomes an AND. Majority logic is obtained also with all $a_i = 1$, but the threshold is set at h + 1, where h is equal to the nearest integral number that is less than or equal to half the number of inputs (Fig. 2b).

In addition threshold gates can be designed to provide complemented outputs. Inputs to threshold gates can also be applied in complemented form, $[\overline{x_i}]$, exactly as with normal Boolean gates.

As an example of a more complicated Boolean logic function, consider Fig. 2c:

$$y_1 = [x_1 + x_2x_3] \ . \qquad (5)$$

This function can be realized by a single threshold gate with t = 2:

$$y_1 = < 2x_1 + x_2 + x_3 >_2 . \qquad (6)$$

To verify this, observe that the weight of x_1 alone is sufficient to equal the threshold and that the sum of the weights of x_2 and x_3 also equals the threshold. To implement this same function with AND/OR logic requires two gates—one to form the AND of x_2 and x_3, and one to OR the output of the first gate with x_1.

The following example is more complicated:

$$y_2 = [x_1x_2 + x_3x_4] \ . \qquad (7)$$

This function requires three gates of the AND/OR type. A threshold-gate realization of the function in Eq. 7 can be obtained in two steps. First note that x_1x_2 is a simple AND function that can be realized by the threshold gate

$$y_3 = [x_1x_2] = < x_1 + x_2 >_2 . \qquad (8)$$

The original function y_2 can then be expressed in terms of y_3 as

$$y_2 = [y_3 + x_3x_4] \qquad (9)$$

and can thus be realized as in Eq. 6:

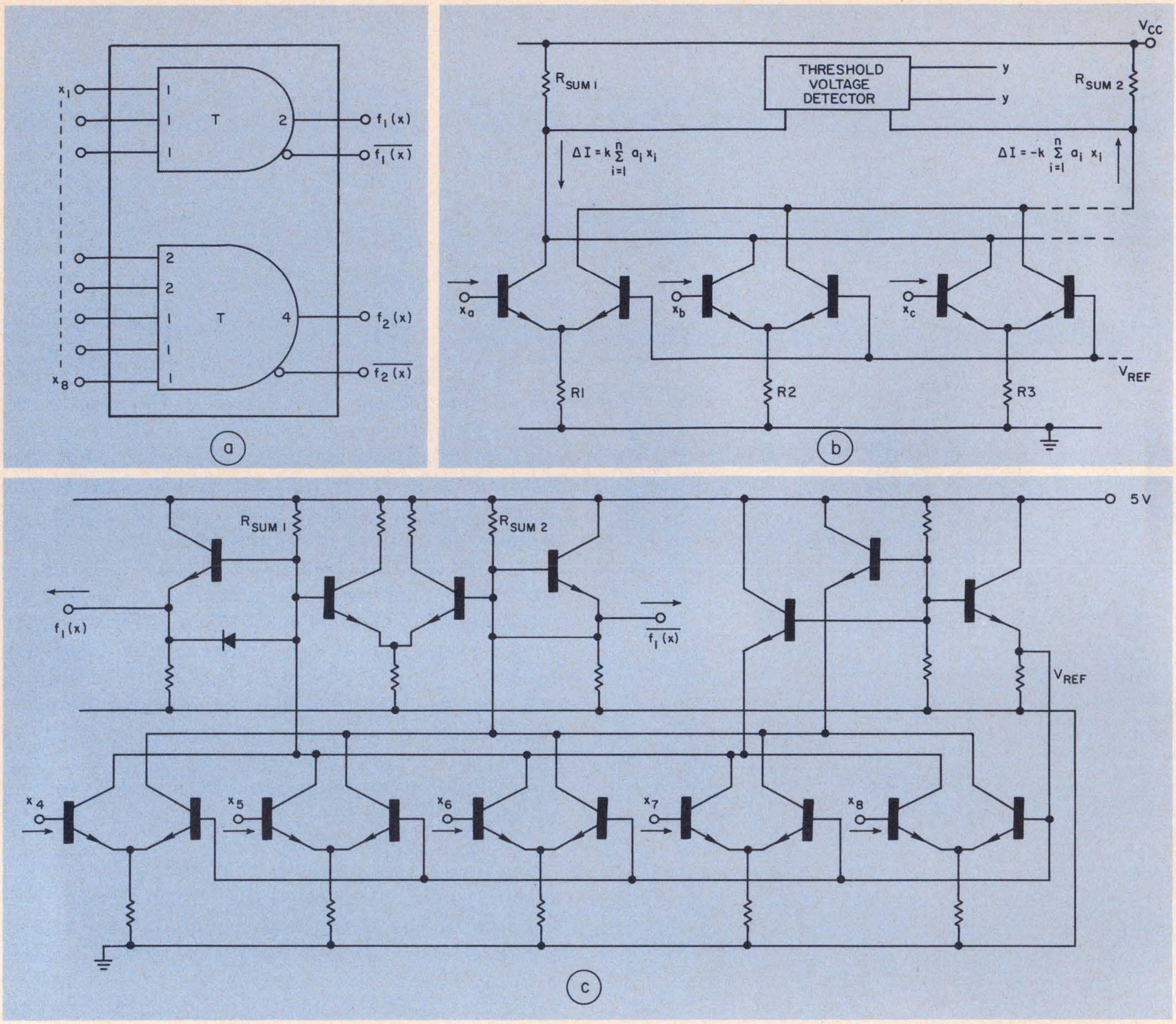
$$y_2 = < 2y_3 + x_3 + x_4 >_2 . \qquad (10)$$

Substitution from Eq. 8 for y_3 yields the two-gate threshold form in Fig. 2d:

$$y_2 = < 2\{x_1 + x_2\}_2 + x_3 + x_4 >_2 . \qquad (11)$$

In both examples, fewer threshold gates are needed than Boolean gates. This is the attractive feature of threshold logic.

However, the advantages of gate reduction are bought at the expense of tighter tolerances on gate components and signal levels. The signal-



4. **A 14-pin DIP dual-gate, threshold-logic** unit, developed by RCA in 1967, provides a majority-logic three-input gate and a second five-input gate with a threshold of four (a). The output levels are −0.85 and −1.60 V. The basic ECL current-summing circuit (b) is shown in detail for the five-gate section (c).

level change required to cause a threshold gate's ZERO to become a ONE (or vice versa) is called the gap. A small gap requires tight tolerances.

Small gaps are difficult to attain

In Eq. 6 the threshold may have any value greater than 1 and less than or equal to 2. The interval between these numbers is the gap. More precisely, for any threshold gate, let u be the smallest value of the weighted-sum for which the input gate can have unity output, and let ℓ be the largest value for which the gate can have zero output. The gap in which the threshold may lie is then the interval specified by z, where $\ell < z \leq u$. The shorthand ratio $u : \ell$ can be used to denote the gap. With this notation, the gate of Eq. 6 becomes

$$y_1 = < 2x_1 + x_2 + x_3 >_{2:1}. \quad (12)$$

The gap length is $u - \ell$.

It is clear that the smaller the gap length, the more difficult it is to build the gate; tighter tolerances and more stable components and circuits are needed. And small gaps reduce the gate's ability to resist noise.

Also, the larger the sum of the possible input weights for a given gap length, the more precisely must the gate be built. Thus there are practical upper limits to the number of inputs that a threshold gate might contain and to the degree of complexity attainable in a single gate.

Implementing threshold logic

Present and proposed threshold-logic gate circuits are, of course, integrated circuits. But to see how a threshold gate works, let's examine an obsolete one (Fig. 3a), which is theoretically more versatile than any currently available solid-state gate. It has the following characteristics:

- Reversal of the input connections to any input winding provides a negative input weighting.
- Any input winding can be interchanged with the threshold winding, N_t.

The ideal action of this gate requires a certain minimum total input ampere-turns,

$$\sum_{i=1}^{n} i_i N_i,$$

to saturate the core against the action of the biasing, or threshold, ampere-turns, $i_t N_t$. Thus there are n + 1 control windings for n input variables. If $N_t \neq N_i$, interchange of the threshold winding with individual input windings produces a family of threshold gates with the same threshold element.

However, tolerance problems, high cost and low response speeds rule out this gate for most applications.

The first electronic threshold-logic gates were discrete-component gates (Fig. 3b). A resistor adding network computed the weighted sum, and the transistor bias determined the threshold level. Such circuits were developed mainly for use in a simple digital-computer exercise, to confirm the potential of threshold-logic gates for reducing the number of gates in a system.[1]

A monolithic IC implementation of threshold gates by RCA in 1967 fits two threshold-logic gates in one 14-pin DIP.[2] One gate is a three-input unit and the other provides five inputs; both have true and complemented outputs. The circuit is a nonsaturating emitter-coupled-logic circuit, which can have extremely high speeds of response (Fig. 4b). The binary inputs, x_i, switch preset units of current into summing resistors, R_{sum1} and R_{sum2}. The weight that corresponds to each input is controlled by individual emitter resistors, R_1, R_2, etc. And the threshold is controlled by the summing resistors. A differential voltage-detection circuit monitors the voltage difference between these resistors.

Fig. 4a shows symbolically the weighting and threshold of the two gates—a five-input and a three-input gate.

The three-input circuit is a two-out-of-three majority gate:

$$[x_1x_2 + x_2x_3 + x_1x_3] = <x_1 + x_2 + x_3>_{2:1}.$$

And the other gate is more complex:

$$< 2x_4 + 2x_5 + x_6 + x_7 + x_8 >_{4:3},$$

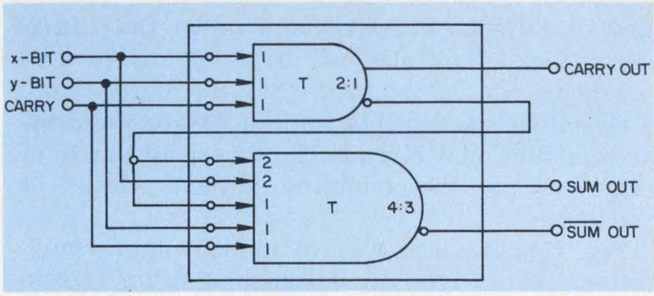
which can generate the logic function

$$[x_4x_5 + (x_4 + x_5)(x_6x_7 + x_6x_8 + x_7x_8)] .$$

The second gate can be made to generate a large class of logic functions. For example, set $x_4 = 1$ and $x_6 = 0$. This gives

$$< 2\{1\} + 2x_5 + 1\{0\} + x_7 + x_8 >_{4:3},$$

which is equivalent to



5. **A full binary adder** can be implemented economically with the RCA two-gate threshold unit.

$$< 2x_5 + x_7 + x_8 >_{2:1} = [x_5 + x_7x_8] .$$

Similarly set $x_4 = x_6$, and

$$<3x_4 + 2x_5 + x_7 + x_8 >_{4:3}$$

becomes the logic function

$$[x_4 (x_5 + x_7 + x_8) + x_5x_7x_8] .$$

A practical example is a stage of a full binary adder (Fig. 5). The inputs are x and y, and the input carry is k. The sum output is S, and the carry output is k′. The logic functions required are

$$k' = [xy + xk + yk] ,$$

and

$$S = [\bar{k} (\bar{x}\bar{y} + \bar{x}y) + k (\bar{x}\bar{y} + xy)] .$$

The carry is a simple majority function that can be realized by the majority gate as

$$k' = < x + y + k >_{2:1}.$$

The sum function, in an equivalent form, is

$$S = [\bar{k}' (x + y + k) + xyk] ,$$

which can be realized as

$$S = <2\bar{k}' + x + y + x >_{3:2}.$$

This particular form for S cannot be obtained directly from the gate. However, an equivalent form of S that can be achieved is

$$S = < 3\bar{k}' + 2x + y + k >_{4:3}.$$

To obtain this implementation, set

$$k = x_4 = x_6$$
$$x = x_5$$
$$y = x_7$$
$$k = x_8 .$$

The RCA threshold-gate configuration was intended for a special application. Therefore it does not necessarily represent the optimum 14-pin DIP gate for general random-logic use.

More recent implementations are found in NASA and U.S. Air Force development work.[3,4] Improvements make the gate circuits compatible with TTL logic gates.[5]

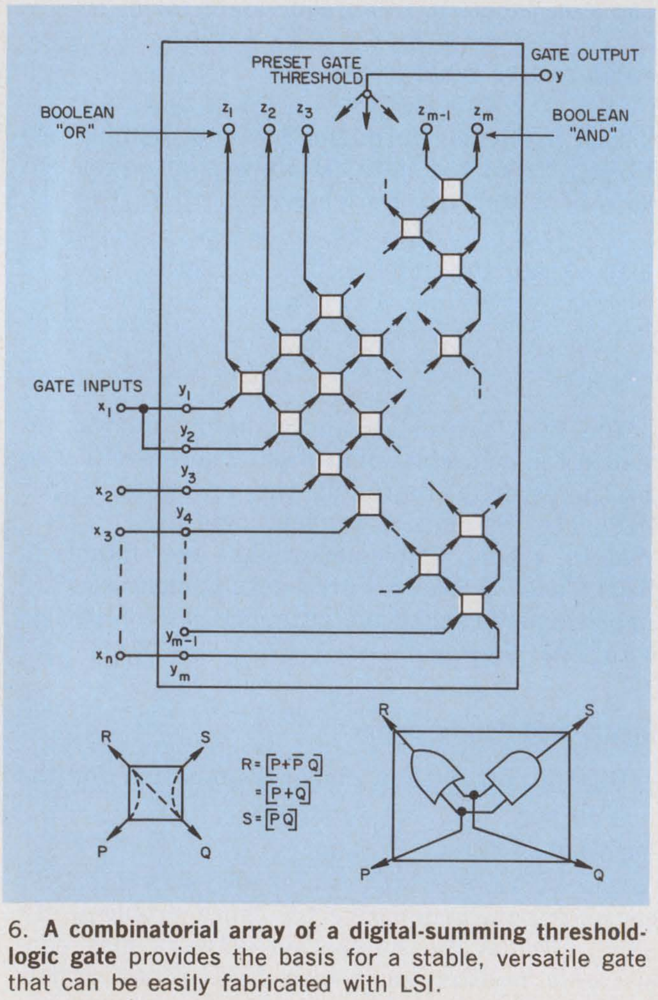
Digital addition is better

Digital rather than analog summation for the basic gate action, $\sum_{i=1}^{n} a_i x_i$, can eliminate cumulative tolerance problems. In serial circuits the summation network may consist of a multiplexer, which feeds input signals into an output counter register under the control of a clock. Multiples of an input to provide weighting can be obtained when the digital input is repeatedly loaded into the counter, as required. In combinational circuits, however, an array of gates can do the summing without clocks or registers.

Fig. 6 shows one way to implement a combinational array-type of digital-summation threshold-logic (DSTL) gate. It consists of a triangular array of identical cells. In each cell a ONE input signal at Q cascades diagonally to the left and appears at output R, unless a ONE is at P. A ONE input signal at P always appears at output R, and its presence deflects any ONE input at Q to output S.

In the complete array a ONE applied at any input, y_i, cascades through the array and appears at an output line, z_i, in a strict order that fills the z_i output lines from left to right. An input, x_i, which requires a weighting of unity, is connected to only one y_i input line. And for an input weighting of two or more, the x_i input is connected in parallel to two or more y_i input lines.

The gate threshold value is selected by appropriate choice of an output line, z_i. With this gate, tolerance problems of the gate threshold value are virtually eliminated.



6. **A combinatorial array of a digital-summing threshold-logic gate** provides the basis for a stable, versatile gate that can be easily fabricated with LSI.

A close examination of the cell array reveals the following:

- No matter how the input signals are configured on the y_i input lines, the summed output signals on the z_i lines always fill up with ONEs from left to right. The lines always empty with ZEROs from right to left. Ripple-through does not occur when the input configuration changes.
- Although m cell input lines are always necessary, where

$$m = \sum_{i=1}^{n} a_i,$$

it is not necessary to implement all m output lines, z_1 to z_m. The cell outputs can be truncated at gate threshold value t, if desired. If such truncation is done, a triangular array of cells, as depicted in the top righthand corner of Fig. 6, becomes redundant. The complete array is then reduced from a triangular to a trapezoidal array.
- The multiple-cell output lines allow multi-threshold operation in the same assembly. The two extreme output points, z_i and z_m, provide the conventional OR and AND relationships from the one assembly.

Though this implementation of a threshold gate may use many conventional Boolean gates to produce one threshold-logic assembly, LSI techniques can easily handle the component density. The symmetrical array structure is particularly advantageous; it can lead to the manufacture of one standard triangular cell array for a wide range of gate configurations. The actual gate connection can be produced in the final metalization and connection process.

The speed of response of such a threshold-logic gate depends not only upon the speed of response of an individual cell, but also upon the path that a particular input signal takes through the cell structure. On the average, for general-purpose DSTL gates, the gate response time is about five times the response time of one cell. Though this is an order of magnitude slower than the fast ECL, analog-summation gates, it is more than adequate for most applications. ■■

The next article will discuss the application of Chow parameters in the design of logic networks.

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Implement complex Boolean expressions

with a single threshold gate derived from Chow parameters. Multilevel threshold logic? Karnaugh patterns help here.

Second of two articles

Many—but not all—Boolean functions can be realized with a single threshold-logic gate. The OR/AND functions and the several others listed in Table 1 are all implementable with a single threshold gate. But an odd-parity, three-bit function, for example, would need more than a single threshold gate.

When a given function, f(x), is a so-called linearly separable function, then numbers $|b_i|$ complied for f(x) appear in Chow's table of parameters (Table 2), and the required weighting magnitudes $|a_i|$, can be read off. If, however, the compiled numbers are not in the table, then f(x) is not linearly separable and the function can't be implemented with just one threshold-logic gate. Here, Karnaugh mapping helps in the design of multilevel threshold-logic circuits.

Table 2 is based upon C. K. Chow's basic work[1] in threshold-logic theory. It lists all possible single-gate threshold functions for up to five input variables in a compact, easy-to-use manner. Chow first proved that any threshold function of n variables can be unambiguously defined by n + 1 integer numbers. Other theorists then demonstrated that if these n + 1 integer numbers are arranged in numerical order and positive signs only are considered, each such "positive canonic-characteristic vector" defines a whole class of linearly separable functions. All functions with the same Chow parameters can be realized with the same threshold gate by appropriate arrangement of connections or negation operations on gate inputs and the output.

Using the Chow parameters

The table is very compact. For example, the tabulation of 21 entries for ≤ 5 covers a total of 94,572 different linearly separable functions.

The n + 1 Chow parameters for any function $f(x_1, \cdots, x_n)$ are identified as $b_0, b_1, b_2, \cdots, b_n$. The $|b_i|$ values for any given function are determined as follows:

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- Prepare a truth table of all combinations of the inputs to the function, f(x), and list them with the function's output.
- Determine the value of b_0, where b_0 = number of input terms, for which f(x) = 1 minus number of input terms, for which f(x) = 0. All b_i terms may be either positive or negative. Write down the sign as well as the magnitude.
- Determine the value of b_1, where b_1 = number of times the input variable x_1 and the output value of its function agree minus the number of of times they disagree.
- Determine the values for $b_2, \cdots, b_n$ in a similar way, where b_i = number of agreements between x_i and f(x) minus the number of disagreements.
- List the thus determined Chow parameter values in magnitude order, the largest magnitude on the left. This final positive canonic sequence of numbers is the sequence that is found in the table.

As an illustration of the use of these parameters, consider the linearly separable function

$$f(x_1, \cdots, x_5) = [x_1(x_2x_3 + x_2\bar{x}_4 + x_3\bar{x}_4x_5) + x_2(x_1x_5 + x_3\bar{x}_4)] .$$

Determination of the Chow parameters yields:

b_0	b_1	b_2	b_3	b_4	b_5
−12	+12	+16	+8	−8	+4

Now rearrange the parameters in magnitude order, and the positive canonic $|b_1|$ sequence

Table 1. Functions for $n \leq 3$ realizable with single threshold gates

Boolean function	Threshold realization
$y = x_1$	$y = \langle x_1 \rangle_1$
$y = [x_1 + x_2]$—OR	$y = \langle x_1 + x_2 \rangle_1$
$y = [x_1x_2]$ —AND	$y = \langle x_1 + x_2 \rangle_2$
$y = [x_1 + x_2 + x_3]$	$y = \langle x_1 + x_2 + x_3 \rangle_1$
$y = [x_1x_2 + x_2x_3 + x_1x_3]$	$y = \langle x_1 + x_2 + x_3 \rangle_2$
$y = [x_1x_2x_3]$	$y = \langle x_1 + x_2 + x_3 \rangle_3$
$y = [x_1 + x_2x_3]$	$y = \langle 2x_1 + x_2 + x_3 \rangle_2$
$y = [x_1(x_2 + x_3)]$	$y = \langle 2x_1 + x_2 + x_3 \rangle_3$

Examples of functions that need more than one threshold gate for realization are

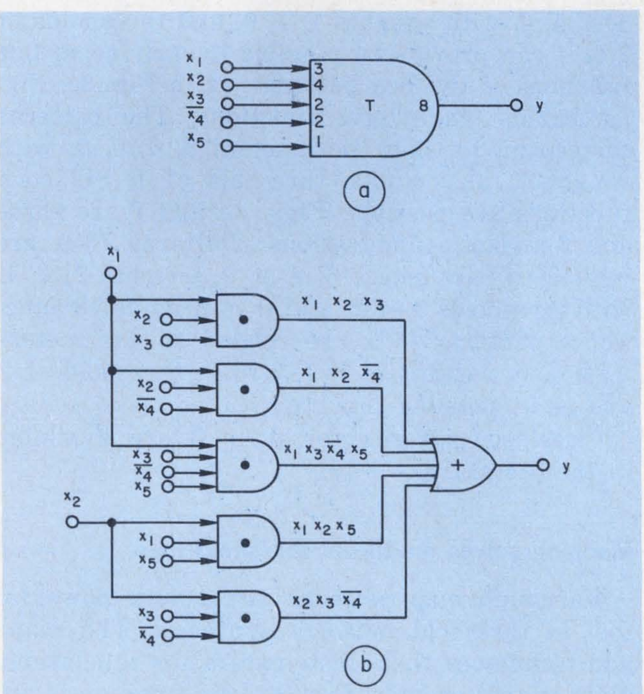
$$y = [x_1x_2 + x_2x_3 + x_1x_3 + \bar{x}_2\bar{x}_3]$$

and the odd-parity function

$$y = [x_1\bar{x}_2\bar{x}_3 + \bar{x}_1x_2\bar{x}_3 + \bar{x}_1\bar{x}_2x_3 + x_1x_2x_3] .$$

Table 2. Chow parameters

No. of input variables n	Chow parameter magnitudes $\lvert b_i \rvert$	Required weighting magnitudes $\lvert a_i \rvert$
≦3	8 0 0 0	1 0 0 0
	6 2 2 2	2 1 1 1
	4 4 4 0	1 1 1 0
≦4	16 0 0 0 0	1 0 0 0 0
	14 2 2 2 2	3 1 1 1 1
	12 4 4 4 0	2 1 1 1 0
	10 6 6 2 2	3 2 2 1 1
	8 8 8 0 0	1 1 1 0 0
	8 8 4 4 4	2 2 1 1 1
	6 6 6 6 6	1 1 1 1 1
≦5	32 0 0 0 0 0	1 0 0 0 0 0
	30 2 2 2 2 2	4 1 1 1 1 1
	28 4 4 4 4 0	3 1 1 1 1 0
	26 6 6 6 2 2	5 2 2 2 1 1
	24 8 8 4 4 4	4 2 2 1 1 1
	24 8 8 8 0 0	2 1 1 1 0 0
	22 10 10 6 2 2	5 3 3 2 1 1
	22 10 6 6 6 6	3 2 1 1 1 1
	20 12 12 4 4 0	3 2 2 1 1 0
	20 12 8 8 4 4	4 3 2 2 1 1
	20 8 8 8 8 8	2 1 1 1 1 1
	18 14 14 2 2 2	4 3 3 1 1 1
	18 14 10 6 6 2	5 4 3 2 2 1
	18 10 10 10 6 6	3 2 2 2 1 1
	16 16 16 0 0 0	1 1 1 0 0 0
	16 16 12 4 4 4	3 3 2 1 1 1
	16 16 8 8 8 0	2 2 1 1 1 0
	16 12 12 8 8 4	4 3 3 2 2 1
	14 14 14 6 6 6	2 2 2 1 1 1
	14 14 10 10 10 2	3 3 2 2 2 1
	12 12 12 12 12 0	1 1 1 1 1 0



1. **One threshold gate** can generally do the job of many Boolean gates. And linearly separable functions can usually be implemented with a single threshold gate.

becomes:

$\lvert b_2 \rvert$	$\lvert b_0 \rvert$	$\lvert b_1 \rvert$	$\lvert b_3 \rvert$	$\lvert b_4 \rvert$	$\lvert b_5 \rvert$
16	12	12	8	8	4

This sequence of numbers can be found in Table 2. Therefore the given fraction is a linearly separable function.

Also from Table 2, the corresponding weighting values $\lvert a_i \rvert$ are:

4 3 3 2 2 1

Reorder the weighting values by ascending index numbers and apply the same sign as that of the original Chow parameters, and you get:

Input variable x_i	Chow parameter b_i	Resultant Weight a_i
x_1	+12	+3
x_2	+16	+4
x_3	+8	+2
x_4	−8	−2
x_5	+4	+1

The gate threshold value is related to b_i values by the expression

$$t = 1/2\,\{\alpha - \beta + 1\},$$

where

$$\alpha = \sum_{i=1}^{n} a_i$$

and β = the parameter value $\lvert a_i \rvert$ associated with b_0, but with the sign of the originally computed value for b_0. Thus, in our chosen example

$$t = 1/2\,\{(3+4+2-2+1) - (-3) + 1\} = 6.$$

The threshold realization for the function is therefore

$$f(x_1, \cdots, x_5) = \langle 3x_1 + 4x_2 + 2x_3 - 2x_4 + x_5 \rangle_6.$$

How to handle negative weights

However, a negative weighting for an input is not usually practical. In this example, the weight of −2 is obtained for x_4. To handle this negative quantity, substitute $\{1 - \overline{x}_4\}$ for x_4; the two are numerically equal. This substitution gives:

$$f(x) = \langle 3x_1 + 4x_2 + 2x_3 - 2\{1 - \overline{x}_4\} + x_5 \rangle_6,$$
$$= \langle 3x_1 + 4x_2 + 2x_3 - 2 + 2\overline{x}_4 + x_5 \rangle_6.$$

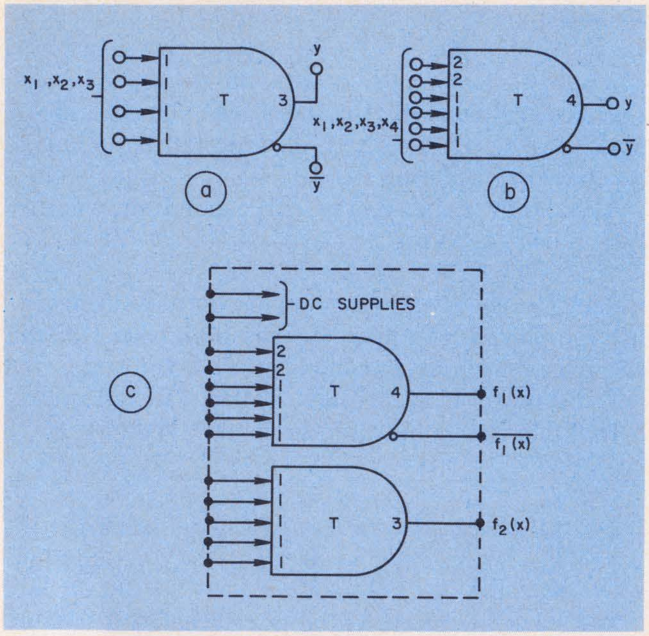
Take the constant −2 outside the threshold summation and increase the threshold value to correspond. You then obtain

$$f(x) = \langle 3x_1 + 4x_2 + 2x_3 + 2\overline{x}_4 + x_5 \rangle_8.$$

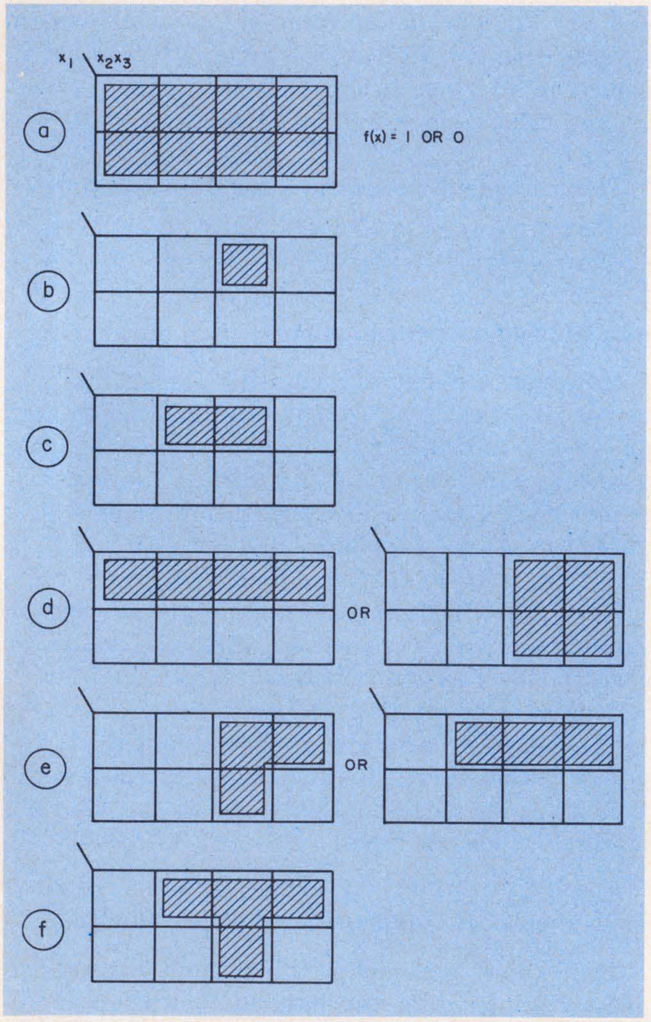
The symbolic solution is shown in Fig. 1, together with a corresponding Boolean implementation. Thus one threshold gate can do the job that needs six Boolean types.

General-purpose, optimum assemblies studied

The Chow parameter tabulations can assist greatly in deciding the best configuration for a "universal" threshold-logic gate—a gate in a given package that can implement the widest



2. **Configurations of "universal" threshold gates** for functions where n≦3 (a) and n≦4 (b) can be easily packaged in DIPs. A 16-pin DIP (c) can contain at least one n≦4 universal threshold gate plus one five-input unity-weighted gate, which is somewhat more versatile than an n≦3 gate.



3. **Each Karnaugh pattern defines a specific threshold-gate** configuration for the n≦3 Chow parameters.

possible range of linearly separable functions. In arranging such an optimum configuration, you must consider two important threshold-logic properties:

1. Two or more gate inputs may be hard-wired together to provide one input of a higher effective weighting.

2. An unused gate input may be tied to a permanent logic ONE level. This reduces the gate threshold for the remaining inputs by an amount equal to the weight of a_i of this input from t to $t - a_i$.

Recently suggested solutions for "universal" threshold-logic gate configurations can provide all possible threshold functions of n inputs for n = 3, 4 and 5.[2] An example of such a gate is the 16-pin DIP version shown in Fig. 2.

Chow and Karnaugh get together

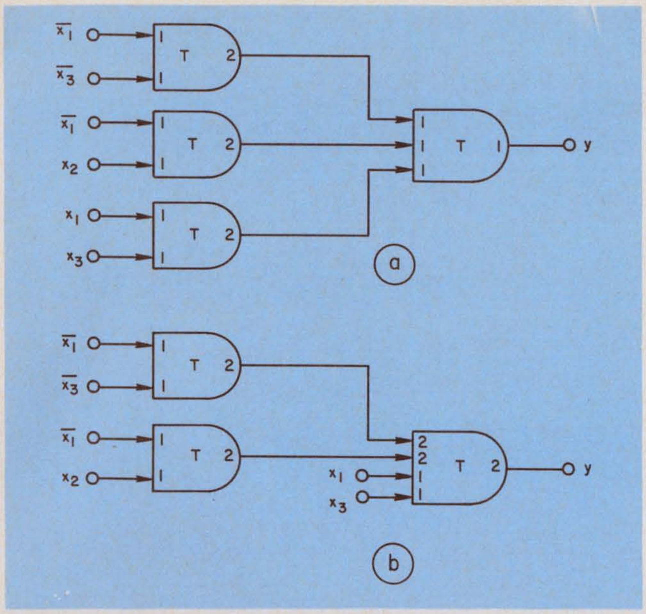
Each line in a Chow-parameter tabulation defines a corresponding pattern class when the function is plotted on a Karnaugh map. For the simple case of ≧ 3, Fig. 3 shows the possible Karnaugh patterns. The first Chow parameters, 8, 0, 0, 0, provide the weights 0, 0, 0 and a threshold of zero, which is the trivial case of f(x) = 1 or 0, as illustrated by the pattern in Fig. 3a.

The pattern in Fig. 3b is for parameters 6, 2, 2, 2 and corresponding weights 1, 1, 1, with thresholds of 3 or 1. This single-box pattern corresponds to 16 linearly separable, three-term Boolean functions—one for each of the eight boxes. And there are two sets of eight functions because of the two threshold levels. Parameters 4, 4, 4, 0, with weights 1, 1, 0, and thresholds of 2 or 1 can provide 24 possible linearly separable functions of two-box patterns, as in Fig. 3c. Fig. 3d depicts single-term functions. The patterns correspond to Chow parameters 8, 0, 0, 0, with weights 1, 0, 0 and a threshold of 1. Six such functions are possible. Figs. 3e and f are three and four-box configurations: Patterns (3e) are related to parameters 6, 2, 2, 2, weights 2, 1, 1, with thresholds 3 or 2, and they provide 48 functions; patterns (3f) are related to parameters 4, 4, 4, 0, weights 1, 1, 1, with a threshold of 2 and eight possible functions.

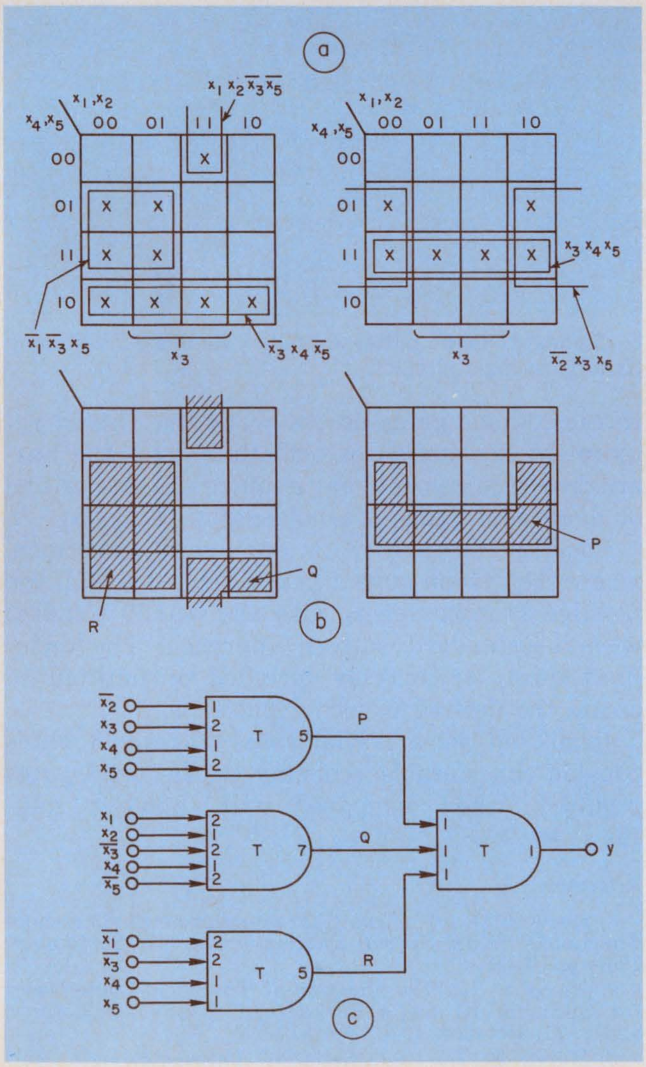
Classified patterns for n > 3 are available in the literature.[3]

Mapping solves multilevel threshold logic

Karnaugh map patterns are a very powerful tool in threshold network synthesis. The maps add techniques that Chow-parameter tabulations alone cannot provide. If a Boolean function is not linearly separable (its Chow paramenters are not listed in Table 2), then a multilevel threshold-logic solution must be sought. Multilevel solu-



4. **Nonlinearly separable functions** can always be combined with an OR (a), but there may be a more efficient way to do it (b).



5. **A five-function expression** can be mapped on two four-function Karnaugh maps (a), and the resulting standard patterns (b) are readily implemented with threshold gates (c).

tions may also be required, even though the function is linearly separable, if only specific types of threshold-logic gates can be used.

A multilevel threshold-gate implementation of a minimized sum-of-products Boolean expression is always possible by use of a separate threshold gate for each product term and the ORing of them together. Fig. 4a illustrates such a simple technique for the Boolean expression

$$f(x) = [\overline{x}_1\overline{x}_3 + \overline{x}_1 x_2 + x_1 x_3] .$$

But this is an inefficient solution. A gate can be saved (Fig. 4b).

Except in simple cases, such direct translations from Boolean equations to threshold logic rarely use the full potential of threshold relationships and almost always produce inefficient solutions. Classified Karnaugh map patterns allow a more efficient approach. For network synthesis, the Boolean function is first plotted on an appropriate Karnaugh-map layout. When more than four input variables must be handled, pairs of four-variable maps are used.

Fig. 5 shows how a five-variable function can be converted to threshold logic with the use of mapping. The function is

$$f(x) = [x_1 x_2 \overline{x}_3 \overline{x}_5 + \overline{x}_1 \overline{x}_3 x_5 + \overline{x}_2 x_3 x_5 + x_3 x_4 x_5 + \overline{x}_3 x_4 \overline{x}_5] .$$

Note that the variable x_3 appears in all terms. Therefore two four-variable maps may be used—one for x_3 and the other for $\overline{x_3}$ (Fig. 5a).

Standard threshold patterns P, Q and R (Fig. 5b) then allow the selection of the ORed threshold-logic implementation of Fig. 5c:

$$y(x) = < \{\overline{x}_2 + 2x_3 + x_4 + 2x_5\}_5 + \{2x_1 + x_2 + 2\overline{x}_3 + x_4 + 2\overline{x}_5\}_7 + \{2\overline{x}_1 + 2\overline{x}_3 + x_4 + x_5\}_5 >_1 .$$

Another example—one that includes a provision for avoiding a logic "hazard"—is shown in Fig. 6. When variables change state, if adjacent patterns on the map overlap by at least one box, an open circuit, or hazard, will not occur when the circuit changes to the adjacent state.[4]

In Fig. 6a the nonlinearly separable function

$$f(x) = [\overline{x}_1 x_2 \overline{x}_3 + x_1 x_2 x_4 + \overline{x}_2 x_3]$$

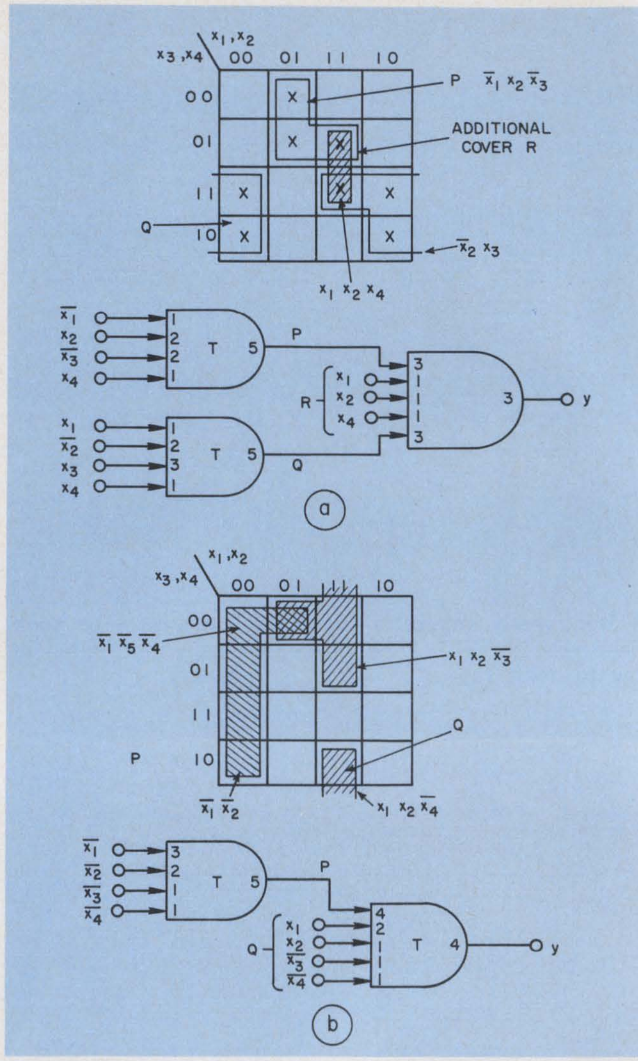
is mapped. Groupings labeled P, Q and R are implemented in threshold logic. However, group R provides the extra antihazard overlap, though standard groups P and Q alone can provide all the needed Boolean functions.

Similarly in Fig. 6b the function is

$$f(x) = [\overline{x_1 x_2} + \overline{x_1 x_3 x_4} + x_1 x_2(\overline{x_3} + \overline{x_4})],$$

but here the standard patterns P and Q already overlap; thus no additional cover is needed.

The shapes provided by the standard patterns of threshold functions are of great help when hazard-free implementations are sought, because the patterns often provide the asymmetry needed to accomplish an overlap. Thus hazard-free realizations can be achieved without the use of any additional logic, as in Fig. 6b, where only two



6. **Standard map patterns** help eliminate switching hazards in logic circuits.

threshold-logic gates do the work that would require six Boolean gates. At other times the hazard-free requirement may require the use of one or more additional threshold gates (Fig. 6a).

Boolean functions with don't-care conditions, where the system output is not defined for all the possible 2^n input terms, also are readily handled with the standard pattern approach. The undefined terms are merely included or omitted to create the desired covering patterns.

In all but some trivial cases, threshold gates provide considerable economy in the total gates required, when compared with Boolean solutions. ■■

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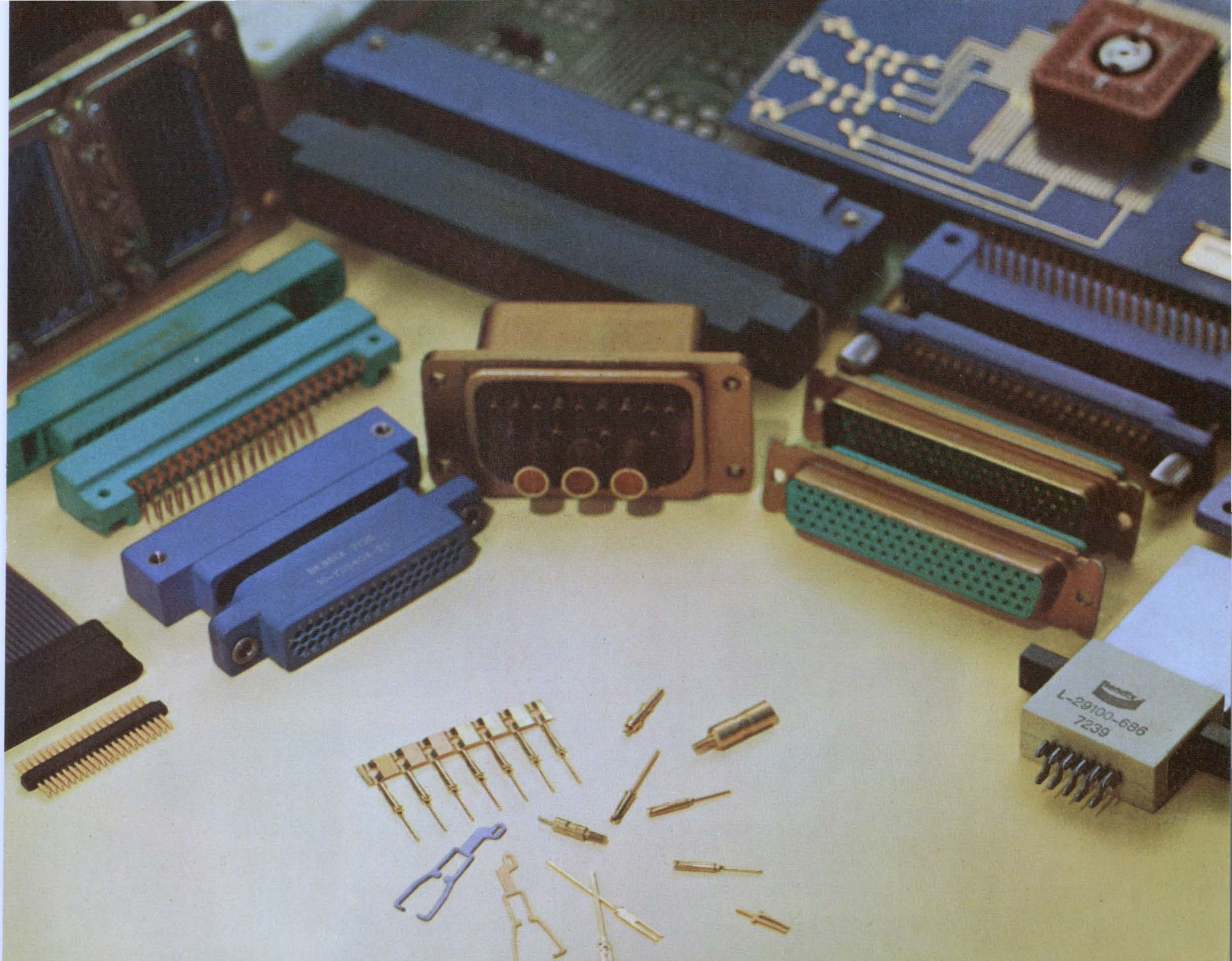

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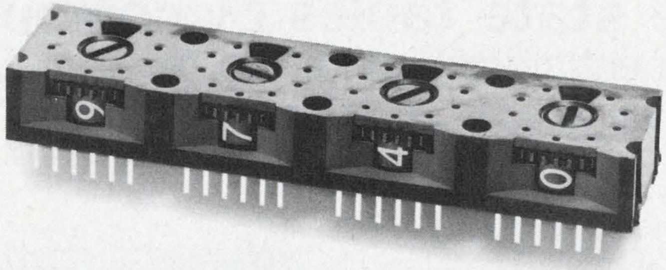

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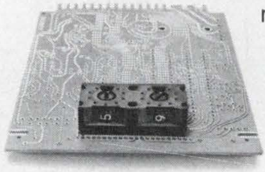

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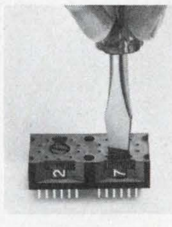

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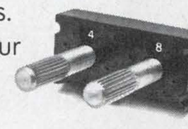

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Reduce state tables by computer.

Your sequential logic will be correct and less costly. The program capitalizes on don't cares to improve the design.

Second of two articles

Here's a Computer-Aided Design (CAD) program that finds a minimum function description for sequential machines with up to 16 memory states and eight input combinations.

The manual design equivalent requires a designer to plow through seven-variable Karnaugh maps to develop an efficient realization. And confronted by circuits with don't-care next states or outputs, the designer is lucky if he finds any solution. With or without don't-cares, CAD doesn't care. It grinds out an efficient solution. Don't-cares actually help; such circuits usually can be implemented with less hardware.

All the program needs as input is the design requirements in the form of a state table. It goes right to work to simplify the functions in important ways. First an algorithm minimizes the number of memory states. This reduces hardware cost, since with fewer states, fewer memory and logic elements will be used. Next a binary code is assigned to each state. The rules used for the code assignment further reduce the number of gates needed. Finally the Boolean functions for the next state inputs to the memory elements, and for the machine's outputs, are developed.

The portions of the program presented in this article deal exclusively with state minimization. The additional subroutines for state binary assignments and minimization of combinatorial logic will appear in part three of this series.

Circuits with memory, classified as sequential circuits, consist of a combinatorial logic section, and delay elements or memory section. The program is designed for use with synchronous sequential circuits, those in which the next-state transitions are initiated by a clock pulse. D-type flip-flops implement the memory elements (Fig. 1). Current inputs x_i and current flip-flop outputs, y_i, combine to produce the system outputs, z_i, and also determine the next states, Y_i, of the flip-flops.

To begin a sequential network, the design objectives are expressed in the form of a state

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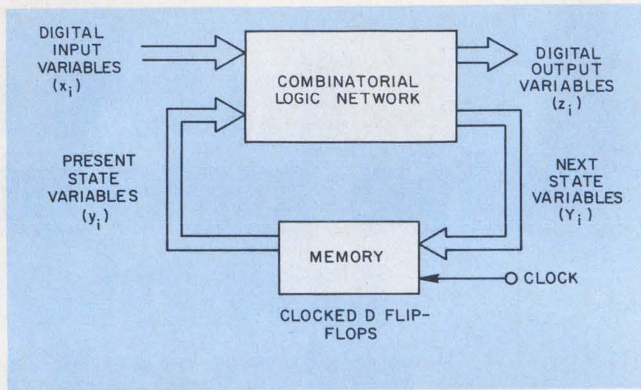


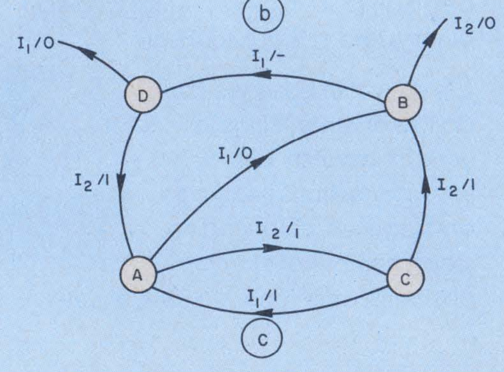
1. **Sequential machines** generate outputs that depend on the current state and input. Delay elements or clocked flip-flops constitute the memory.

MEMORY STATE NOW	NEXT MEMORY STATE WHEN INPUT IS:		OUTPUT WHEN INPUT IS:	
	I_1	I_2	I_1	I_2
A	B	C	0	1
B	D	–	–	0
C	A	B	1	1
D	–	A	0	1

(a)

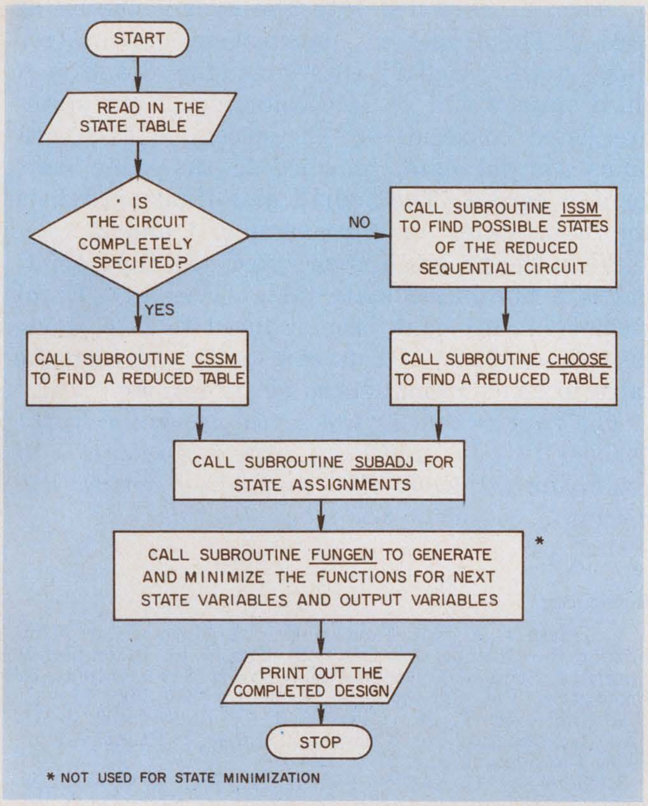
MEMORY STATE NOW	INPUT IS I_1 NEXT STATE/OUTPUT	INPUT IS I_2 NEXT STATE/OUTPUT
A	B/0	C/1
B	D/–	–/0
C	A/1	B/1
D	–/0	A/1

(b)



(c)

2. **Design requirements** can be specified by a state table (a), its more compact form (b) or an equivalent flow diagram (c).



3. **The program handles** incomplete or complete specifications, and supplies reduced state tables.

(a)

PRESENT STATE	NEXT STATE / OUTPUT x = 0	x = 1
A	A/–	C/1
B	B/–	A/–
C	G/–	E/0
D	C/1	C/–
E	A/1	C/–
F	D/–	A/–
G	G/–	G/–
H	H/–	D/–

(b)

PRESENT STATE \ INPUTS	NEXT STATES 1	NEXT STATES 2	OUTPUT 1	OUTPUT 2
1	1	3	0	2
2	2	1	0	0
3	7	5	0	1
4	3	3	2	0
5	1	3	2	0
6	4	1	0	0
7	7	7	0	0
8	8	4	0	0

(c)

DATA CARD	1 2	3 4	5 6	7 8	9 10	11 12	13 14	15 16	17 18	19 20	· · ·	COMMENTS
1	2	8										N, L
2	1	3	2	1	7	5	3	3	1	3	· · ·	NEXT STATES
3	0	2	0	0	0	1	2	0	2	0	· · ·	OUTPUTS
4	1	2										INPUT CODES

(d)

PRESENT STATE \ INPUT	NEXT STATES 1	NEXT STATES 2	OUTPUTS 1	OUTPUTS 2
1	1	3	2	2
2	2	1	0	1
3	2	4	2	1
4	1	4	2	1
5	3	1	0	1

(e)

	x = 0	x = 1
A	A/1	C/1
B	B/–	A/0
C	B/1	D/0
D	A/1	D/0
E	C/–	A/0

4. **Sample state table input** (a) is converted to more convenient form for input to computer (b), (c). The computer program reduces the eight states to five (d), which is equivalent to (e).

table. The table (Fig. 2a) shows one input line (thus two binary conditions, I_1 and I_2), and two memory output lines with four states, A through D. The required output and next memory states are expressed as functions of present input and memory states. Thus the first line of the table can be read as follows: "If the present input is I_1 and present memory state is A, present output is binary 0, and next state is B. But if the present input is I_2 (present memory state remaining A), present output is binary 1 and next state is C."

A "—" entry is a don't-care condition, which arises from prohibited combinations, or those that are irrelevant, and may be arbitrarily assigned to 0 or 1. Circuits without don't-care conditions are said to be completely specified; those with don't-cares are incompletely specified.

Some designers prefer a more compact form of state table (Fig. 2b). Still others prefer a state diagram (Fig. 2c). In the diagram, circles represent memory states; arrows, transitions from present input to output, and point to next state. For example, with the machine in state A, when the input is I_1, the output is 0 and the next state is B. But when the input is I_2, the output is 1 and the next state is C.

Flow chart shows the computer program

Fig. 3 outlines the design program. Operation can begin when the state table is read in. If there are don't-cares, a subroutine ISSM is called.[1] The next routines or their alternates apply an algorithm that minimizes the number of memory states. State assignments are attempted such that the resulting minterms of the next-state equations can be combined as extensively as possible. The following two rules are used:[2,3]

1. Two states leading to the same next state with the same input condition are given codes that differ in only one bit position. Such codes are

Computer code conventions

Binary coded input or output	Computer code used
0	1
1	2
00	1
10	3
11	4
110	7
(don't care)	0

Symbolic coded states	Computer code used
A	1
B	2
C	3
D	4
E	5
F	6
G	7
.	.
.	.
.	.
(don't care)	0

called logically adjacent.

2. Next states with input combinations that differ in one bit position are paired by the assignment of logically adjacent codes.

Finally, if used, subroutine FUNGEN generates all the minterms and don't cares associated with each output and next-state variable, so that the resultant functions are minimized.

Let's use the program on the state table requirement shown in Fig. 4a. There's one input line (x = 0 or 1) and eight memory states, A through H. Three output states are possible: 0, 1, or the don't-care. For convenience, enter data to the computer from the chart rewritten in decimal integer format (Fig. 4b). The table provides the translation for input/output binary data and the alphabetic memory states. The don't-care condition is assigned decimal 0. For all other states, add one to the decimal value of the binary code. Thus, don't-care and binary 0,1 become decimal 0,1,2. Alphabetic memory states are replaced by their ordered decimal equivalent; a don't-care state, by 0.

To enter the data on cards is now easy (Fig. 4b,c). On card 1, N (the number of input combinations) goes into column 2, and L (the number of memory states) in column 4. State information is coded into the even columns of card 2. The first-next, memory-state, pair (for input states 1 and 2) enters columns 2 and 4. A third state would go into column 6. Next states are listed consecutively in successive even columns. Output data, punched in the same way, go into card 3. The fourth and final card lists the input states; in our example, 1 and 2.

When the program is executed, the first printout is a minimized state table (Fig. 4d). Eight memory states have been reduced to five, a reduction of 37.5%. You can easily convert the table to conventional form (Fig. 4e). ■■

The first article in the series appeared in the October 11 issue and dealt with minimization of combinatorial logic. The concluding article will discuss a complete design application.

References:

1. Grasselli, A. and Luccio, F., "A Method for Minimizing the Number of Internal States in Incompletely Specified Sequential Networks," *IEEE Transactions on Computers*, Vol. EC-14, June, 1965, pp. 350-359.
2. Nagle, H. T. Jr., Carroll, B. D. and Irwin, J. D., "An Introduction to Computer Logic," Prentice-Hall, 1975, Chapters 7 and 9.
3. Shiva, S. G. and Nagle, H. T. Jr., "A Computer-Aided Procedure for Complete Design of Sequential Machines," Project THEMIS, Tech. Report No. AU-T-26; Auburn Univ., March, 1973.

Program for state minimization of sequential machines

Fortran mainline

```
C  MAIN PROGRAM TO DESIGN THE SEQUENTIAL MACHINE
C***** ARRAYS ARE SET UP FOR  16 STATE, 8 INPUT MACHINES***
C  N=NUMBER OF INPUTS
C  L=NUMBER OF STATES
C  M=NUMBER OF OUTPUTS
C  NS=NEXT STATE FUNCTION.
C  W=OUTPUT FUNCTION
C  INPUT=ARRAY OF INPUTS
C  NS(N,L),W(N,L),B(L),B1(L),NSMED(N,L),NS1(N,L),W1(N,L)
C  IASSGN(L),ISI(L),ISTATE(L),IADJCN(L,L),IA(L),IG(L),
C  IALLAD(MAX. NO. OF INPUT COMBINATIONS POSSIBLE)
C  IOUT(N,L),NEW(N,L),NOUT(N,L),INPUT(N),
C  INSET(SAME AS  IALLAD)
C  NOSET(K,N),MSET(N,L),PSET(N,K),NSSET(N;K),AR(N1,K)
C  X IS ARBITRARY  APROXIMATELY 10 TO 25 IN MINIM
C    N1=N/2 IF N IS EVEN,  (N/2)+1 IF N IS ODD
C
C  EACH ARRAY SHOULD HAVE THE MAX. DIMENSION OF ITS USE
C  AS GIVEN BY THE FOLLOWING TABLE
C    ARRAY                         USE
C
C
C            IN SEQ.  MACHINE                     IN MINIM
C
C            K=L*(L-1)/2                         N=ORDER OF THE FUNCTION=8
C   C        NOST(K)                             C(NN)        NN=2**N
C  PRIMI    PCLAS(K)                             PRIMI(NN)
C  PRIMJ(K)     PSNO(K)                          PRIMJ(NN)
C  NUM         NSNO(K)                           NUM(NN)
C   DONT       IMASK(K)                          DONT(NN)
C  MINT        CE(K)                              MINT(NN)
C  MINAX       NLF(K)                             MINAX(NN)
C  MIN         NIS(K)                            MIN(NN)
C  IR          ARR(K)                             IR(NN)
C  IADJCN       IADJCN(L,L),NSMED(N,L)
C   B          IASSGN(L),MSNO(L)                 LITCNT(X)
C   B1         ISI(L)           MCLAS(L)          CONSI(X)
C  IALLAD       IALLAD(N)                        CONSJ(X)
C  IRAY     IOCT(11)                       IRAY(N)
      INTEGER NS(8,16),W(8,16),B(16),B1(16),NS1(8,16),W1(8,16),
     1IADJCN(16,16),IALLAD(16),IA(16),IG(16),NEW(8,16),NOUT(8,16),
     2INPUT(16),INSET(16),NSDNT(256),PSET(8,120),NSSET(8,120),
     3AR(4,120),NSNO(120)
C     FOR DIMENSION DETAILS OF THESE ARRAYS SEE       PART 1
      DIMENSION IRAY(16),ICONS(10,8),COUNT(10)
      DIMENSION NUM(200),IR(256),MINAX(256)
      INTEGER C(256),D,MIN(256),DONT(256),MINT(256),EMP
      INTEGER DIF,PRIMI(256),PRIMJ(256),ESENI(200),ESENJ(200)
      INTEGER ESARY(100,8),MASK(8),MATCNT(10)
      INTEGER ONE,ZERO,DASH,WAIT(10)
      COMMON/COM2/C
C   READ IN STATE TABLE
1     READ(5,20,END=100)N,L
      READ(5,20)((NS(I,J),I=1,N),J=1,L)
      READ(5,20)((W(I,J),I=1,N),J=1,L)
20    FORMAT(40I2)
      READ(5,20)(INPUT(I),I=1,N)
      LFLAG=0
C   WRITE THE STATE TABLE
      WRITE(6,30)
30    FORMAT(' ',15X,'STATE TABLE')
      WRITE(6,330)
330   FORMAT('0',14X,'NEXT STATES',10X,'OUTPUTS')
      WRITE(6,331)(INPUT(I),I=1,N)
331   FORMAT('0INPUTS',2X,8I3)
      WRITE(6,332)(INPUT(I),I=1,N)
332   FORMAT('+',30X,8I3)
      WRITE(6,333)
333   FORMAT(' PRESENT'/' STATE')
      DO 31 J=1,L
      WRITE(6,40)J,(NS(I,J),I=1,N)
40    FORMAT('0',3X,I3,4X,8I3)
      WRITE(6,50)(W(I,J),I=1,N)
50    FORMAT('+',40X,8I3)
31    CONTINUE
C  IS THE CIRCUIT COMPLETLY SPECIFIED
      MAXOUT=W(1,1)
      DO 60 I=1,N
      DO 60 J=1,L
      IF(W(I,J).LT.MAXOUT)GO TO 60
      MAXOUT=W(I,J)
60    CONTINUE
C  MAXOUT IS THE HIGHEST NUMERICAL VALUE OF OUTPUT
COMPUTE THE NUMBER OF LITERALS II REQUIRED FOR OUTPUT
      II=1
7     IF(2**II.GE.MAXOUT)GO TO 8
      II=II+1
      GO TO 7
8     III=2**II
      DO 5 I=1,L
      DO 5 J=1,N
      IF(W(J,I).EQ.0.OR.NS(J,I).EQ.0) GO TO 6
5     CONTINUE
C     IT IS A COMPLETELY SPECIFIED MACHINE
      CALL CSSM(N,L,W,NS,B,B1,IADJCN,NS1,W1,KK,KFLAG)
      IF(KFLAG.EQ.1)GO TO 1
      IF(KFLAG.EQ.0)GO TO 9
501   DO 500 I=1,L
      DO 500 J=1,N
      NS1(J,I)=NS(J,I)
      W1(J,I)=W(J,I)
500   CONTINUE
      KK=L
      GO TO 9
C  INCOMPLETELY SPECIFIED MACHINE
6     CALL ISSM(NS,W,N,L,B1,IG,NS1,W1,KK,IFLAG,DONT,
```

```
      1B,NEW,IA,C,PRIMI,PSET,PRIMJ,NSSET,NUM,MINT,MIN,MINAX,
      2AP,IR,IP,IPC,IPP,LFLAG)
       IF(IFLAG.EQ.0)GO TO 9
       IF(IFLAG.EQ.3)GO TO 1
       IF(IFLAG.EQ.1)GO TO 200
       KK=L
       DO 705 I1=1,N
       DO 705 I2=1,L
       NS1(I1,I2)=NS(I1,I2)
705    W1(I1,I2)=W(I1,I2)
       GO TO 9
200    DO 201 J=1,N
       DO 202 I=1,L
202    IA(I)=0
       DO 203 I=1,III
203    IG(I)=0
C  FIND THE NO. OF TIMES EACH STATE(OUTPUT) OCCURS
C  UNDER THE INPUT.
       DO 204 I=1,L
       IF(NS(J,I).EQ.0)GO TO 205
       IA(NS(J,I))=IA(NS(J,I))+1
205    IF(W(J,I).EQ.0)GO TO 204
       IG(W(J,I))=IG(W(J,I))+1
204    CONTINUE
C  FIND THE MAX. OCCURING STATE
       IM=NS(J,1)
       DO 206 I=2,L
       IF(IA(I).LE.IA(I-1))GO TO 206
       IM=I
206    CONTINUE
C  FIND THE MAX.OCCURING OUTPUT
       IMN=W(J,1)
       DO 207 I=2,III
       IF(IG(I).LE.IG(I-1))GO TO 207
       IMN=I
207    CONTINUE
C  REPLACE UNDEFINED STATE AND OUTPUTS BY ABOVE.
       DO 208 I=1,L
       IF(NS(J,I).NE.0)GO TO 209
       NEW(J,I)=IM
       GO TO 600
209    NEW(J,I)=NS(J,I)
600    IF(W(J,I).NE.0)GO TO 601
       NOUT(J,I)=IMN
       GO TO 208
601    NOUT(J,I)=W(J,I)
208    CONTINUE
201    CONTINUE
       WRITE(6,400)
400    FORMAT('1*** MODIFIED STATE TABLE ***')
       WRITE(6,330)
       DO 401 J=1,L
       WRITE(6,40)J,(NEW(I,J),I=1,N)
       WRITE(6,50)(NOUT(I,J),I=1,N)
401    CONTINUE
       CALL CSSM(N,L,NOUT,NEW,B,B1,IADJCN,NS1,W1,KK,KFLAG)
       IF(KFLAG.EQ.1)GO TO 1
       IF(KFLAG.EQ.0)GO TO 9
       GO TO 501
COMPUTE THE NUMBER OF STATE VARIABLES IY REQUIRED
9      IY=1
11     IF(2**IY.GE.KK)GO TO 12
       IY=IY+1
       GO TO 11
12     NUMBER=2**IY-1
COMPUTE THE NUMBER OF VARIABLES KL REQUIRED FOR INPUT
       MAXIN=INPUT(1)
       DO 301 I=1,N
       IF(INPUT(I).LT.MAXIN)GO TO 301
       MAXIN=INPUT(I)
301    CONTINUE
       KL=1
75     IF(2**KL.GE.MAXIN)GO TO 74
       KL =KL+1
       GO TO 75
74     KKL=2**KL
C   MAKE STATE ASSIGNMENTS
       CALL SUBADJ(NS1,IY,KK,N,NUMBER,IA,B,B1,IADJCN,IALLAD,INPUT,KL)
COMPUTE MINIMIZED BOOLEAN FUNCTIONS
       CALL FUNGEN(N,KK,IY,INPUT,NS1,W1,IA,INSET,KL,KKL,II,IG,
      1NSDNT,B,B1,IALLAD)
CHECK IF END OF INPUT FILE
       WRITE(6,900)
900    FORMAT(1H1)
       GO TO 1
100    STOP
       END
```

Fortran subroutines

```
       SUBROUTINE CSSM(N,L,W,NS,B,B1,NSMED,NS1,W1,KK,KFLAG)
C      FORTRAN SOURCE PROGRAM FOR APPLYING STATE-MINIMZATION
C      ALGORITHM TO A COMPLETELY-SPECIFIED SEQUENTIAL MACHINE.
C      L = NUMBER OF STATES IN MACHINE
C      N = NUMBER OF INPUTS IN MACHINE
C      NS IS THE NEXT STATE FUNCTION.
C      W IS THE OUTPUT FUNCTION.
       INTEGER W(8,16),NS(8,16),B(16),B1(16),A,NSMED(16,16),NS1(8,16),
      1W1(8,16)
       KFLAG=0
       DO 60 I=1,L
       B(I) = 0
60     B1(I) = 0
       J1 = 0
       DO 1 J=1,L
       IF(B(J).NE.0) GO TO 1
       J1 = J1 + 1
       B(J) = J1
       IF(J.EQ.L) GO TO 1
       A = J + 1
       DO 2 K=A,L
       IF(B(K).NE.0) GO TO 2
       DO 4 I=1,N
       IF(W(I,J).NE.W(I,K)) GO TO 2
5      IF(I.NE.N) GO TO 4
       B(K) = J1
4      CONTINUE
2      CONTINUE
1      CONTINUE
       J2 = J1
       IF(J1.EQ.1)GO TO 70
       IF(J1.NE.L)GO TO 40
       WRITE(6,71)
71     FORMAT(' THE STATE TABLE CAN NOT BE REDUCED')
       KFLAG=2
       RETURN
70     WRITE(6,72)
72     FORMAT('  THE STATE TABLE REDUCES TO ONE STATE'/
      1' NOT A SEQUENTIAL MACHINE.SYNTHESIS TERMINATED')
       KFLAG=1
       RETURN
40     J1 = 0
       DO 20 J=1,L
       IF(B1(J).NE.0) GO TO 20
       J1 =J1 + 1
       B1(J) = J1
       IF(J.EQ.L) GO TO 20
       A = J + 1
       DO 21 K=A,L
       IF(B1(K).NE.0) GO TO 21
       IF(B(J).NE.B(K)) GO TO 21
       DO 22 I=1,N
       N1 = NS(I,J)
       N2 = NS(I,K)
       IF(B(N1).NE.B(N2)) GO TO 21
       IF(I.EQ.N) GO TO 23
       GO TO 22
23     B1(K) = J1
22     CONTINUE
21     CONTINUE
20     CONTINUE
       IF(J1.EQ.J2.OR.J1.EQ.L)GO TO 601
       J2 = J1
       DO 50 I=1,L
       B(I) = B1(I)
50     B1(I) = 0
       GO TO 40
601    DO 600 J=1,L
       DO 600 I=1,N
       K=NS(I,J)
600    NSMED(I,J)=B1(K)
       KK=B1(1)
       LL=L-1
       WRITE(6,701)
701    FORMAT('0',10X,'REDUCED TABLE'/' PRES.STATE NEXT STATES
      2',5X,'OUTPUTS')
       DO 503 I=1,LL
       IF(B1(I).GT.B1(I+1))GO TO 503
       KK=B1(I+1)
503    CONTINUE
       K=1
504    DO 500 II=1,L
       IF(B1(II).EQ.K)GO TO 501
500    CONTINUE
501    DO 502 JJ=1,N
       NS1(JJ,K)=NSMED(JJ,II)
       W1(JJ,K)=W(JJ,II)
502    CONTINUE
       IF(K.EQ.KK)GO TO 505
       K=K+1
       GO TO 504
505    DO 700 J=1,KK
       WRITE(6,800)J,(NS1(I,J),I=1,N)
800    FORMAT(' ',I3,4X,8I3)
       WRITE(6,702)(W1(I,J),I=1,N)
702    FORMAT('+',35X,8I3)
700    CONTINUE
400    RETURN
       END
```

```
15     AR(KL,K)=KK
       JK=JK+1
7      CONTINUE
3      CONTINUE
2      CONTINUE
       K=L*(L-1)/2
       DO 9 I=1,K
       DO 9 J=1,NN
       IM=AR(J,I)/(2**16)
       IL=AR(J,I)-2**16*IM
9      CONTINUE
19     A=0
       DO 16 I=1,K
       IF(AR(1,K-I+1).EQ.0.OR.AR(1,K-I+1).EQ.IZ)GO TO 16
       DO 17 J=1,NN
       IF(AR(J,K-I+1).EQ.0)GO TO 17
       IM=AR(J,K-I+1)/(2**16)
       IF(IM.EQ.(2**15-1))GO TO 27
       IF(AR(J,IM).EQ.0)GO TO 18
27     IL=AR(J,K-I+1)-IM*2**16
       IF(IL.EQ.(2**15-1))GO TO 17
       IF(AR(J,IL).EQ.0)GO TO 18
17     CONTINUE
       GO TO 16
18     A=A+1
       AR(1,K-I+1)=0
16     CONTINUE
       IF(A.NE.0)GO TO 19
       DO 22 I=1,L
22     ARR(I)=0
       KK=0
       IKK=0
       DO 23 I=1,K
       JJ=L
       DO 24 II=1,LL
       LIM=L*(II-1)-(II+1)*II/2+JJ
       ITAG=II
       IF((LIM-I).GE.0)GO TO 25
24     CONTINUE
       WRITE(6,30)
30     FORMAT(' ERROR..I  IS TOO LARGE')
       STOP
25     II=ITAG
       JJ=L*(1-II)+I+(II+1)*II/2
       IF(AR(1,I).EQ.0)GO TO 231
       KK=KK+1
       AR(2,KK)=2**(II-1)+2**(JJ-1)
       ARR(II)=1
       ARR(JJ)=1
       GO TO 23
231    IKK=IKK+1
       PCLAS(IKK)=2**(II-1)+2**(JJ-1)
23     CONTINUE
       IF(KK.NE.0)GO TO 62
       WRITE(6,70)
70     FORMAT(' STATE TABLE CAN NOT BE REDUCED')
       IFLAG=2
       RETURN
```

```
      SUBROUTINE ISSM(NS,W,N,L,NSS,NAUX,NS1,W1,IB,IFLAG,MASK,MSNO,
     1MSET,MCLAS,NOST,PCLAS,PSET,PSNO,NSSET,NSNO,CE,NIS,NLF,AR,ARR,
     2IP,IPC,IPP,LFLAG)
C     THIS ROUTINE MINIMIZES THE NUMBER OF STATES IN AN
C     INCOMPLETLY SPECIFIED SEQUENTIAL CIRCUIT
      INTEGER P,A,AAR
      INTEGER NS1(8,16),W1(8,16),NSS(16),NAUX(16),B(16)
      INTEGER MSNO(16),MSET(8,16),MCLAS(16),NOST(256),PCLAS(256),
     1PSET(8,120),PSNO(256),NSSET(8,120),NSNO(200),
     2MASK(256),CE(256),NIS(256),NLF(256),AR(4,120),NS(8,16),W(8,16),
     3ARR(256)
      IFLAG=0
      NN=N/2
      NN=NN+(N-2*NN)
63    K=L*(L-1)/2
      IZ=(2**15-1)+(2**16)*(2**15-1)
      DO 1 I=1,K
      DO 1 J=1,NN
      AR(J,I)=0
1     CONTINUE
      LL=L-1
      DO 2 II=1,LL
      LJ=II+1
      DO 3 JJ=LJ,L
      DO 4 IJ=1,N
      IF(W(IJ,II).EQ.0.OR.W(IJ,JJ).EQ.0)GO TO 4
      IF(W(IJ,II).NE.W(IJ,JJ))GO TO 3
4     CONTINUE
      DO 5 IJ=1,N
      IF(NS(IJ,II).EQ.0.OR.NS(IJ,JJ).EQ.0)GO TO 5
      IF(NS(IJ,II).NE.II.OR.NS(IJ,II).NE.JJ)GO TO 6
      IF(NS(IJ,JJ).NE.II.OR.NS(IJ,JJ).NE.JJ)GO TO 6
5     CONTINUE
      K=II*L-(II+1)*II/2-(L-JJ)
      DO 14 IJ=1,NN
      AR(IJ,K)=IZ
14    CONTINUE
      GO TO 3
6     K=II*L-(II+1)*II/2-(L-JJ)
      KL=1
      JK=-1
      DO 7 IJ=1,N
      IF(NS(IJ,II).EQ.0.OR.NS(IJ,JJ).EQ.0)GO TO 11
      IF(NS(IJ,II).EQ.NS(IJ,JJ))GO TO 11
      IF(NS(IJ,II).GT.NS(IJ,JJ))GO TO 13
      I=NS(IJ,II)
      J=NS(IJ,JJ)
      GO TO 8
13    J=NS(IJ,II)
      I=NS(IJ,JJ)
8     KK=I*L-(I+1)*I/2-(L-J)
      GO TO 12
11    KK=2**15-1
12    IF(JK.EQ.-1)GO TO 15
      AR(KL,K)=AR(KL,K)+2**16*KK
      JK=-1
      KL=KL+1
      GO TO 7
62    ICHEAT=KK*10
      DO 26 I=1,L
      IF(ARR(I).EQ.1)GO TO 26
      KK=KK+1
      AR(2,KK)=2**(I-1)
26    CONTINUE
      CALL MAXCOM(AR,KK,L,ARR,IFLAG,LFLAG)
301   CONTINUE
      IF(ICHEAT.GT.K)GO TO 461
      LMIN=2
      GO TO 463
461   CONTINUE
      DO 46 I=1,IKK
46    AR(2,I)=PCLAS(I)
      CALL MAXCOM(AR,IKK,L,PCLAS,IFLAG,LFLAG)
      LMIN=0
      DO 34 J=1,L
      IF(IAND(2**(J-1),PCLAS(1)).NE.2**(J-1))GO TO 34
      LMIN=LMIN+1
34    CONTINUE
463   CONTINUE
      CALL CHOOSE(ARR,KK,NS,W,N,L,NS1,W1,IB,MASK,
     1NSS,NAUX,IFLAG,NOST,PCLAS,PSET,PSNO,NSSET,NSNO,CE,NIS,NLF,MSNO,
     2MSET,MCLAS,AR,IP,IPC,IPP,LFLAG,LMIN)
      RETURN
      END


      SUBROUTINE MAXCOM(AR,KK,L,ARR,IFLAG,LFLAG)
      INTEGER AAR,A,P
      INTEGER AR(4,120),ARR(256)
      IMAT=1
46    IJK=0
      KKK=KK-1
      DO 31 I=1,KKK
      III=I+1
      DO 32 J=III,KK
      ICNT=0
      IA=0
      DO 33 IP=1,L
      IPP=2**(IP-1)
      IJ=IAND(AR(2,J),IPP)
      II=IAND(AR(2,I),IPP)
      IF(II.EQ.IPP.AND.IJ.EQ.IPP)GO TO 34
      IF(II.EQ.IPP.OR.IJ.EQ.IPP)GO TO 35
      GO TO 33
35    IA=IOR(IA,IPP)
      GO TO 33
34    ICNT=ICNT+1
33    CONTINUE
      IF(ICNT.NE.IMAT)GO TO 32
      DO 36 IB=1,KK
      IF(IAND(IA,AR(2,IB)).EQ.IA)GO TO 38
36    CONTINUE
      GO TO 32
38    AAR=IOR(AR(2,J),AR(2,I))
      IF(IJK.EQ.0)GO TO 51
      DO 52 IB=1,IJK
      IF(AAR.EQ.AR(1,IB))GO TO 32
52    CONTINUE
51    IJK=IJK+1
      AR(1,IJK)=AAR
32    CONTINUE
31    CONTINUE
      IF(IJK.EQ.0)GO TO 47
      DO 43 J=1,KK
      DO 44 IJ=1,IJK
      IL=0
      DO 61 JK=1,L
      IF(IAND(AR(2,J),2**(JK-1)).NE.2**(JK-1).OR.
     1IAND(AR(1,IJ),2**(JK-1)).NE.2**(JK-1))GO TO 61
      IL=IL+1
61    CONTINUE
      IF(IL.GE.(IMAT+1))GO TO 43
44    CONTINUE
      IF(IJK.LT.450)GO TO 305
      WRITE(6,306)
306   FORMAT(' MACHINE IS TOO LARGE.CONVERTED TO A
     1COMPLETLY SPECIFIED MACHINE')
      IFLAG=1
      RETURN
305   IJK=IJK+1
      AR(1,IJK)=AR(2,J)
43    CONTINUE
      KK=IJK
      DO 45 I=1,KK
      AR(2,I)=AR(1,I)
45    CONTINUE
      IMAT=IMAT+1
      GO TO 46
47    IF(KK.NE.1)GO TO 200
      WRITE(6,302)
302   FORMAT('  MACHINE REDUCES TO ONE STATE.
     1NOT A SEQUENTIAL MACHINE')
      IFLAG=3
      RETURN
200   DO 101 I=1,KK
101   ARR(I)=AR(2,I)
      RETURN
      END


      SUBROUTINE CHOOSE(ARR,KK,NS,W,N,L,NS1,W1,IB,MASK,
     1NSS,NAUX,IFLAG,NOST,PCLAS,PSET,PSNO,NSSET,NSNO,CE,NIS,NLF,MSNO,
     2MSET,MCLAS,AR,IP,IPC,IPP,LFLAG,LMIN)
      INTEGER P,A,AAR
      DIMENSION IRAY(16)
      INTEGER NSS(16),NAUX(16),NS1(8,16),W1(8,16)
      INTEGER MSNO(16),MSET(8,16),MCLAS(16),NOST(256),PCLAS(256),
     1PSET(8,120),PSNO(256),NSSET(8,120),NSNO(200),
     2MASK(256),CE(256),NIS(256),NLF(256),AR(4,120),NS(8,16),W(8,16),
     3ARR(256)
      DO 1 I=1,KK
      CALL GENP(ARR(I),NAUX,NSNO(I),NS,N,L,NSS)
      IJ=NSNO(I)
      DO 2 J=1,IJ
      NSSET(J,I)=NAUX(J)
2     CONTINUE
1     CONTINUE
      DO 3 I=1,KK
      NOST(I)=0
      DO 4 J=1,L
      IF(IAND(2**(J-1),ARR(I)).NE.2**(J-1))GO TO 4
      NOST(I)=NOST(I)+1
4     CONTINUE
3     CONTINUE
      IP=0
      IPP=1
      IPC=1
11    ITEMP=0
      DO 5 I=IPP,KK
      IP=IP+1
      ITEMP=ITEMP+1
      PCLAS(IP)=ARR(I)
      PSNO(IP)=NSNO(I)
      NOST(IP)=NOST(I)
      IF(NSNO(I).EQ.0)GO TO 21
      IJ=NSNO(I)
      DO 6 J=1,IJ
      PSET(J,IP)=NSSET(J,I)
6     CONTINUE
21    IF(I.EQ.KK)GO TO 5
      IF(NOST(I+1).LT.NOST(I))GO TO 19
5     CONTINUE
19    CONTINUE
      IPP=IPP+ITEMP
      P=1
16    IIP=IP
18    DO 7 I=IPC,IIP
      IF(PSNO(I).EQ.0)GO TO 7
      CALL COMB(PCLAS(I),NOST(I),P,NS,N,L,MASK,PCLAS,PSET,PSNO,NSSET,
     1NSNO,NAUX,CE,NLF,NIS,IP,IPC,IPP,NSS)
7     CONTINUE
      IF(IPP.GT.KK)GO TO 15
      IF(NOST(IPP).EQ.(NOST(IPP-1)-P))GO TO 13
      GO TO 17
13    IPC=IP+1
      GO TO 11
15    IF(NOST(IPP-1)-P.EQ.0)GO TO 12
17    P=P+1
      GO TO 18
12    DO 22 I=1,L
      CALL GENP(2**(I-1),NAUX,NO,NS,N,L,NSS)
      DO 23 JJ=1,IP
      IF(IAND(PCLAS(JJ),2**(I-1)).NE.2**(I-1))GO TO 23
      IF(PSNO(JJ).EQ.0)GO TO 22
      IF(NO.EQ.0)GO TO 23
      KKL=PSNO(JJ)
      DO 24 KL=1,KKL
      DO 25 JK=1,NO
      IF(IAND(PSET(KL,JJ),NAUX(JK)).EQ.PSET(KL,JJ))GO TO 24
25    CONTINUE
      GO TO 23
24    CONTINUE
      GO TO 22
23    CONTINUE
      IP=IP+1
      PCLAS(IP)=2**(I-1)
      PSNO(IP)=NO
      IF(NO.EQ.0)GO TO 22
      DO 26 LM=1,NO
26    PSET(LM,IP)=NAUX(LM)
22    CONTINUE
20    IB=0
      IA=0
      DO 31 I=1,L
      ITEMP=0
      DO 32 J=1,IP
      IF(IAND(PCLAS(J),2**(I-1)).NE.2**(I-1))GO TO 32
      ITEMP=ITEMP+1
      IPT=J
32    CONTINUE
```

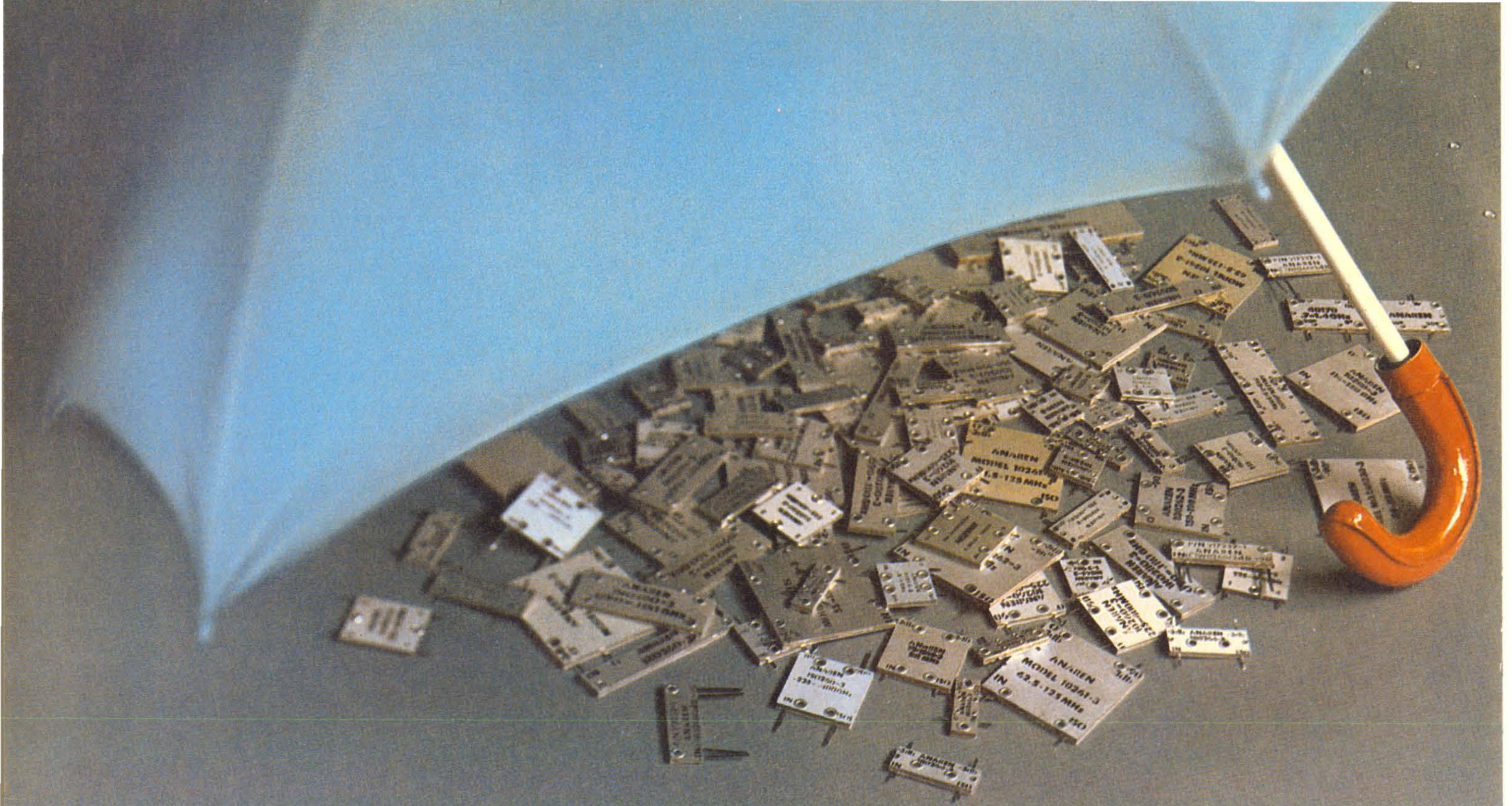
```
      IF(ITEMP.NE.1)GO TO 31
      IA=IOR(IA,PCLAS(IPT))
      IF(IB.EQ.0)GO TO 53
      DO 54 IJ=1,IB
      IF(IPT.EQ.NOST(IJ))GO TO 31
54    CONTINUE
53    IB=IB+1
      NOST(IB)=IPT
31    CONTINUE
      IF(IB.NE.0)GO TO 81
      GO TO 65
81    CONTINUE
      DO 333 I=1,IB
333   CE(I)=PCLAS(NOST(I))
30    IF(IA.NE.2**L-1)GO TO 65
      DO 75 I=1,IB
      IJK=NOST(I)
      IF(PSNO(IJK).EQ.0)GO TO 75
      IKJ=PSNO(IJK)
      DO 76 J=1,IKJ
      DO 77 IJ=1,IB
      IF(IAND(PCLAS(NOST(IJ)),PSET(J,IJK)).EQ.PSET(J,IJK))
     1GO TO 76
77    CONTINUE
      GO TO 65
76    CONTINUE
75    CONTINUE
      DO 82 I=1,IB
82    ARR(I)=PCLAS(NOST(I))
      GO TO 831
65    CALL INTP(NOST,IB,IA,MCLAS,L,KK,IPTR,IFLAG,
     1CE,NIS,NLF,MSNO,MSET,PCLAS,PSET,PSNO,NSSET,NSNO,IP,IPC,IPP,LMIN)
      IF(IFLAG.EQ.2)RETURN
      IF(IPTR.EQ.1)GO TO 83
      IF(IPTR.EQ.2)GO TO 899
      DO 121 K1=1,IB
121   ARR(K1)=MCLAS(K1)
      GO TO 831
83    IB=KK
831   CONTINUE
C   FORM THE NEW STATE TABLE
601   DO 101 I=1,IB
      DO 102 JJ=1,N
      IA=0
      W1(JJ,I)=0
      DO 103 J=1,L
      IF(IAND(ARR(I),2**(J-1)).NE.2**(J-1))GO TO 103
      IF(W(JJ,J).EQ.0)GO TO 104
      W1(JJ,I)=W(JJ,J)
104    IF(NS(JJ,J).EQ.0)GO TO 103
      IA=IOR(IA,2**(NS(JJ,J)-1))
103   CONTINUE
      ICNT=0
      DO 105 IJ=1,IB
      IF(IAND(ARR(IJ),IA).NE.IA)GO TO 105
      ICNT=ICNT+1
      IF(ICNT.GT.1)GO TO 105
      ITEMP=IJ
105   CONTINUE
      IF(ICNT.NE.IB)GO TO 106
      NS1(JJ,I)=0
      GO TO 102
106   NS1(JJ,I)=ITEMP
102   CONTINUE
101   CONTINUE
      GO TO 887
899   DO 898 I=1,L
      DO 898 J=1,N
      NS1(J,I)=NS(J,I)
      W1(J,I)=W(J,I)
898   CONTINUE
      IB=L
887   CONTINUE
      WRITE(6,210)
210   FORMAT('0',10X,'REDUCED TABLE'/
     1' PRES.STATE  NEXT STATE',5X,' OUTPUTS')
      DO 109 J=1,IB
      WRITE(6,110)J,(NS1(I,J),I=1,N)
110   FORMAT(' ',I3,6X,8I3)
      WRITE(6,111)(W1(I,J),I=1,N)
111   FORMAT('+',35X,8I3)
109   CONTINUE
      RETURN
      END


      SUBROUTINE GENP(ARR,NAUX,NSNO,NS,N,L,NSS)
      INTEGER NAUX(16),NS(8,16)
      INTEGER NSS(16),ARR
      DO 2 J=1,N
      NSS(J)=0
      DO 2 K=1,L
      IF(IAND(ARR,2**(K-1)).NE.2**(K-1))GO TO 2
      IF(NS(J,K).EQ.0)GO TO 2
      NSS(J)=IOR(NSS(J),2**(NS(J,K)-1))
2     CONTINUE
      DO 3 J=1,N
      IF(ARR.LT.NSS(J))GO TO 4
      IF(ARR.EQ.NSS(J))GO TO 5
      IF(IAND(ARR,NSS(J)).EQ.NSS(J))GO TO 5
4     DO 11 IJ=1,L
      IF(NSS(J).EQ.2**(IJ-1))GO TO 5
11    CONTINUE
      GO TO 3
5     NSS(J)=0
3     CONTINUE
      DO 6 J=1,N
      DO 6 IJ=1,N
      IF(J.EQ.IJ)GO TO 6
      IF(NSS(J).EQ.0.OR.NSS(IJ).EQ.0)GO TO 6
      IF(NSS(J).LT.NSS(IJ))GO TO 6
      IF(NSS(J).EQ.NSS(IJ))GO TO 7
      IF(IAND(NSS(J),NSS(IJ)).EQ.NSS(IJ))GO TO 7
      GO TO 6
7     NSS(IJ)=0
6     CONTINUE
      NSNO=0
      DO 8 J=1,N
      IF(NSS(J).EQ.0)GO TO 8
      NSNO=NSNO+1
      NAUX(NSNO)=NSS(J)
8     CONTINUE
      RETURN
      END


      SUBROUTINE COMB(PCL,NN,K,NS,N,L,MASK,PCLAS,PSET,PSNO,
     1NSSET,NSNO,NAUX,CE,NLF,NIS,IP,IPC,IPP,NSS)
      INTEGER SPP,PCL,SP,OSP
      INTEGER NS(8,16),PSNO(256),PSET(8,120),PCLAS(256),NAUX(16),
     1MASK(256),CE(256),NIS(256),NLF(256),NSSET(8,120),NSNO(200),
     3NSS(16)
      IT=0
      DO 2 J=1,L
      IF(IAND(2**(J-1),PCL).NE.2**(J-1))GO TO 2
      IT=IT+1
      MASK(IT)=J
2     CONTINUE
25    SP=1
      CE(SP)=0
      NLF(SP)=NN-K
      NIS(SP)=NN
21    IF(NLF(SP).EQ.0)GO TO 22
      OSP=SP
      SP=SP+1
      NLF(SP)=NLF(OSP)-1
      NIS(SP)=NIS(OSP)-1
      CE(SP)=CE(OSP)+1
      GO TO 21
22    IA=0
      SPP=SP-1
      DO 3 J=1,SPP
      IJ=MASK(CE(J)+1)
      IA=IOR(IA,2**(IJ-1))
3     CONTINUE
      CALL GENP(IA,NAUX,NO,NS,N,L,NSS)
      DO 4 JJ=1,IP
      IF(IAND(PCLAS(JJ),IA).NE.IA)GO TO 4
      IF(PSNO(JJ).EQ.0)GO TO 23
      IF(NO.EQ.0)GO TO 4
      KKL=PSNO(JJ)
      DO 5 KL=1,KKL
      DO 6 JK=1,NO
      IF(IAND(PSET(KL,JJ),NAUX(JK)).EQ.PSET(KL,JJ))GO TO 5
6     CONTINUE
      GO TO 4
5     CONTINUE
      GO TO 23
4     CONTINUE
8     IP=IP+1
      PCLAS(IP)=IA
      PSNO(IP)=NO
      IF(NO.EQ.0)GO TO 23
      DO 7 LM=1,NO
7     PSET(LM,IP)=NAUX(LM)
23    SP=SP-1
      IF(SP.EQ.0)RETURN
      CE(SP)=CE(SP)+1
      NIS(SP)=NIS(SP)-1
      IF(CE(SP).EQ.NN.OR.NIS(SP).LT.NLF(SP))GO TO 23
      GO TO 21
      END


      SUBROUTINE INTP(NOST,IB,IA,MCLAS,L,KK,IPTR,IFLAG,
     1CE,NIS,NLF,MSNO,MSET,PCLAS,PSET,PSNO,NSSET,NSNO,IP,IPC,IPP,LMIN)
      INTEGER SP,SPP,OSP
      INTEGER CE(256),NIS(256),NLF(256),NOST(256),MCLAS(16),MSNO(16),
     1MSET(8,16),PCLAS(256),PSET(8,120),PSNO(256),NSSET(8,120),
     2NSNO(200)
      IPTR=0
      IF(L.LT.KK)GO TO 501
      IPTR=1
      IKK=KK
      GO TO 502
501   IKK=L
      IPTR=2
502   CONTINUE
      IF(LMIN.GE.IKK-1)RETURN
      IF(IB.EQ.0)GO TO 1
      IF(IB.EQ.IKK-1)RETURN
511   DO 2 I=1,IB
      MSNO(I)=PSNO(NOST(I))
      MCLAS(I)=PCLAS(NOST(I))
      PCLAS(NOST(I))=-1
      IF(MSNO(I).EQ.0)GO TO 2
      MM=MSNO(I)
      DO 4 J=1,MM
4     MSET(J,I)=PSET(J,NOST(I))
2     CONTINUE
      NN=0
      DO 5 I=1,IP
      IF(PCLAS(I).EQ.-1)GO TO 5
      NN=NN+1
      PSNO(NN)=PSNO(I)
      PCLAS(NN)=PCLAS(I)
      IF(PSNO(I).EQ.0)GO TO 5
      MM=PSNO(I)
      DO 6 J=1,MM
6     PSET(J,NN)=PSET(J,I)
5     CONTINUE
      GO TO 42
1     NN=IP
42    K=IB+NN-LMIN
25    SP=1
      CE(SP)=0
      NLF(SP)=IABS(NN-K)
      NIS(SP)=NN
21    IF(NLF(SP).EQ.0)GO TO 22
      OSP=SP
      SP=SP+1
      NLF(SP)=NLF(OSP)-1
      NIS(SP)=NIS(OSP)-1
      CE(SP)=CE(OSP)+1
      GO TO 21
22    SPP=SP-1
      IAA=IA
      IF(SPP.EQ.0)GO TO 503
      DO 31 J=1,SPP
      IF(PSNO(CE(J)+1).GE.NN-K)GO TO 23
      IF(IAND(IAA,PCLAS(CE(J)+1)).EQ.PCLAS(CE(J)+1))GO TO 23
31    IAA=IOR(IAA,PCLAS(CE(J)+1))


503   CONTINUE
      IF(IAA.NE.2**L-1)GO TO 23
      IBB=IB+SPP
      IF(IBB.LE.LMIN)GO TO 300
      WRITE(6,301)
301   FORMAT('0 NO. OF STATES IN MINIMAL CLASS '/
     1' EXEEDS THE ORIGINAL NO. OF STATES. ORIGINAL'/
     2' STATE TABLE USED')
      IFLAG=2
      RETURN
300   CONTINUE
      IF(SPP.EQ.0)GO TO 504
      DO 32 J=1,SPP
      MCLAS(IB+J)=PCLAS(CE(J)+1)
      MSNO(IB+J)=PSNO(CE(J)+1)
      MM=PSNO(CE(J)+1)
      DO 33 JJ=1,MM
33    MSET(JJ,IB+J)=PSET(JJ,CE(J)+1)
32    CONTINUE
504   CONTINUE
      DO 36 I=1,IBB
      IF(MSNO(I).EQ.0)GO TO 36
      MM=MSNO(I)
      DO 34 J=1,MM
      DO 35 IJ=1,IBB
      IF(IAND(MCLAS(IJ),MSET(J,I)).EQ.MSET(J,I))GO TO 34
35    CONTINUE
      GO TO 23
34    CONTINUE
36    CONTINUE
      IB=IBB
      IPTR=0
      RETURN
23    SP=SP-1
      IF(SP.EQ.0)GO TO 41
      CE(SP)=CE(SP)+1
      NIS(SP)=NIS(SP)-1
      IF(CE(SP).EQ.NN.OR.NIS(SP).LT.NLF(SP))GO TO 23
      GO TO 21
41    LMIN=LMIN+1
      IF(LMIN.LE.IKK-1)GO TO 42
      RETURN
      END
```



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Know your converter codes. When you work with a/d and d/a converters, there are many input and output codes to choose from. Here are some characteristics of each.

The right digital code can help simplify system design when analog-to-digital and digital-to-analog converters are used in the system.

While some custom a/d and d/a converters use special codes, off-the-shelf units employ one of a few common codes adopted by the industry as "standard" (Table 1). Understanding which code to use, and where, is the key to a simpler system design. And the added benefits with a standard code include lower cost of the converter and a wider choice of vendors.

Many designers are perplexed about application. There are unipolar codes—straight binary, complementary binary and binary coded decimal (BCD). There are bipolar codes—sign-magnitude binary, sign-magnitude BCD, offset binary, one's complement and two's complement. Other decimal codes include excess-three, 2421, 5421, 5311 and 74-2-1. And there are also reflective codes—such as the Grey code; and error-detecting codes—like the Hamming.

All codes used in converters are based on the binary numbering system. Any number can be represented in binary by the following

$$N = a_n 2^n + a_{n-1} 2^{n-1} + \dots + a_2 2^2 + a_1 2^1 + a_0 2^0,$$

where each coefficient a assumes a value of one or zero. A fractional binary number can be represented as

$$N = a_1 2^{-1} + a_2 2^{-2} + a_3 2^{-3} + \dots + a_n 2^{-n}.$$

A specific binary fraction is then written, for example, as 0.101101. In most converters it is this fractional binary number that is used for the basic converter code. Conventionally the fractional notation is assumed and the decimal point dropped.

The left-most digit has the most weight, 0.5, and is commonly known as the most-significant-bit (MSB). Thus the right-most digit would have the least weight, $1/2^n$, and is called the least-significant-bit (LSB).

This coding scheme is convenient for converters, since the full-scale range used is simply interpreted in terms of a fraction of full scale. For instance, the fractional code word 101101 has a value of $(1 \times 0.5) + (0 \times 0.25) + (1 \times 0.125) + (1 \times 0.0625) + (0 \times 0.03125) + (1 \times 0.015625)$, or 0.703125 of full-scale value. If all the bits are ONEs, the result is not full scale but rather $(1 - 2^{-n}) \times$ full scale. Thus a 10-bit d/a converter with all bits ON has an input code of 1111 1111 11. If the unit has a +10-V full-scale output range, the actual analog output value is

$$(1 - 2^{-10}) \times 10\ V = +9.990235\ V.$$

The quantization size, or LSB size, is full scale divided by 2^n—which in this case is 9.77 mV.

Eugene Zuch, Senior Engineer, Datel Systems, 1020 Turnpike St., Canton, Mass. 02021.

Table 1. Summary of coding for a/d and d/a converters

	D/a converters	A/d converters
Unipolar	Straight binary	Straight binary
	BCD	BCD
	Complementary binary	Straight bin, invert. analog
	Complementary BCD	BCD, inverted analog
Bipolar	Offset binary	Offset binary
	Complementary off. binary	Two's complement
	Two's complement	Offset bin, invert. analog
		Two's compl, invert. analog
		Sign + mag. binary
		Sign + mag. BCD

Analyzing digital codes

The four most common unipolar codes are straight binary, complementary binary, binary-coded decimal (BCD) and complementary BCD. Of these four, the most popular is straight-binary, positive-true. Positive-true coding means that a logic ONE is defined as the more positive of the two voltage levels for the logic family.

Negative-true logic defines things the other way—the more negative logic level is called ONE and the other level ZERO. Thus, for standard TTL, positive true logic makes the +5-V output logic ONE and 0 V a ZERO. In negative true logic the +5 V is ZERO and 0 V is ONE.

All four of the codes are defined (Table 2) in terms of the fraction of their full-scale values. Full-scale ranges of +5 and +10 V are shown with 12-bit codes.

Table 2. Unipolar codes—12 bit converter

Straight binary and complementary binary

Scale	+10 V FS	+5 V FS	Straight binary	Complementary binary
+FS −1 LSB	+9.9976	+4.9988	1111 1111 1111	0000 0000 0000
+7/8 FS	+8.7500	+4.3750	1110 0000 0000	0001 1111 1111
+3/4 FS	+7.5000	+3.7500	1100 0000 0000	0011 1111 1111
+5/8 FS	+6.2500	+3.1250	1010 0000 0000	0101 1111 1111
+1/2 FS	+5.0000	+2.5000	1000 0000 0000	0111 1111 1111
+3/8 FS	+3.7500	+1.8750	0110 0000 0000	1001 1111 1111
+1/4 FS	+2.5000	+1.2500	0100 0000 0000	1011 1111 1111
+1/8 FS	+1.2500	+0.6250	0010 0000 0000	1101 1111 1111
0+1 LSB	+0.0024	+0.0012	0000 0000 0001	1111 1111 1110
0	0.0000	0.0000	0000 0000 0000	1111 1111 1111

BCD and complementary BCD

Scale	+10 V FS	+5 V FS	Binary coded decimal	Complementary BCD
+FS−1 LSB	+9.99	+4.95	1001 1001 1001	0110 0110 0110
+7/8 FS	+8.75	+4.37	1110 0000 0000	0001 1111 1111
+3/4 FS	+7.50	+3.75	1100 0000 0000	0011 1111 1111
+5/8 FS	+6.25	+3.12	1010 0000 0000	0101 1111 1111
+1/2 FS	+5.00	+2.50	1000 0000 0000	0111 1111 1111
+3/8 FS	+3.75	+1.87	0110 0000 0000	1001 1111 1111
+1/4 FS	+2.50	+1.25	0100 0000 0000	1011 1111 1111
+1/8 FS	+1.25	+0.62	0010 0000 0000	1101 1111 1111
0+1 LSB	+0.01	+0.00	0000 0000 0001	1111 1111 1110
0	0.00	0.00	0000 0000 0000	1111 1111 1111

D/a and a/d converters: The operating basics

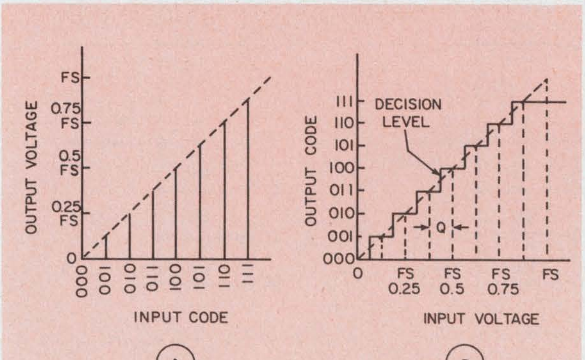
The basic transfer characteristic of an ideal d/a converter forms the plot shown in Fig. A. The d/a takes an input digital code and converts it to an analog output voltage or current. This form of discrete input and discrete output (quantized) gives the transfer function a straight line through the tops of the vertical bars. In general the analog values are completely arbitrary and a large number of binary digital codes can be used. Analog full-scale can be defined as −25.2 to 85.7 V as easily as 0 to 10 V.

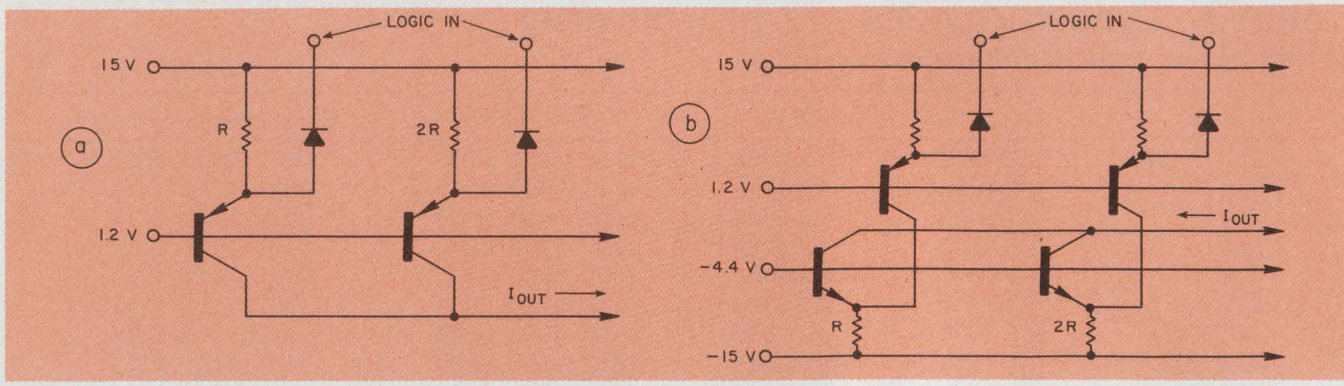
In practice, though, the industry has settled on several codes and very simple ranges for most major applications. For instance, the transfer characteristics in Fig. A are for a d/a converter that uses a 3-bit unipolar binary code and an output defined only in terms of its full-scale value.

The ideal a/d converter (Fig. B) has a staircase transfer characteristic. Here an analog input voltage or current is converted into a digital word. The analog input is quantized into n levels for a converter with n bits resolution. For the ideal converter, the true analog value corresponding to a given output code word is centered between two decision levels. There are 2^N-1 analog decision levels. The quantitization size, Q, is equal to the full-scale range of the converter divided by 2^n.

For the ideal d/a converter, there is a one-to-one correspondence between input and output, but for the a/d there is not, because any analog input within a range of Q will give the same output code word. Thus, for a given code word, the corresponding input analog value could have errors of from 0 to $\pm Q/2$. This quantization error can be reduced only by an increase in converter resolution.

Although the analog input or output ranges are arbitrary, some of the standardized ranges include 0 to +5, 0 to +10, 0 to −5 and 0 to −10 V for unipolar converters, and −2.5 to +2.5, −5 to 5 and −10 to +10 V for bipolar units. Many units on the market are programmable types in which external pin connections determine the range of operation.





1. **Weighted current-source configurations** for straight binary (a) and complementary binary (b) coding generate output current in different directions. The resistor weighting determines the output code.

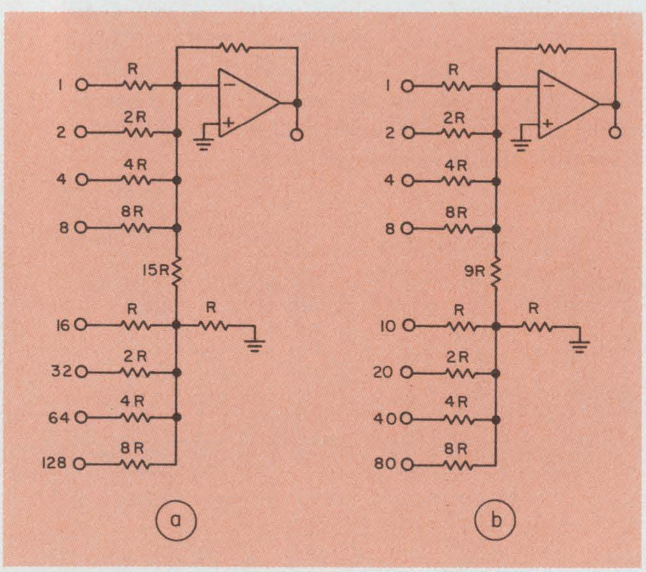
Complementary-binary, positive-true coding is also used in d/a converters. This scheme is used because of the weighted current source configuration employed in many converter designs.

Fig. 1 shows two commonly used weighted-current-source designs. The pnp version (Fig. 1a) delivers a positive output current with straight binary positive-true coding. When the logic input is ONE, or +5 V, the current source is on, since the input diode is back-biased. Thus the current from each ON weighted current source is summed at the common-collector connection and flows to the output. A ZERO input holds the cathode of the input diode at ground and steals the emitter current from the transistor, keeping it off.

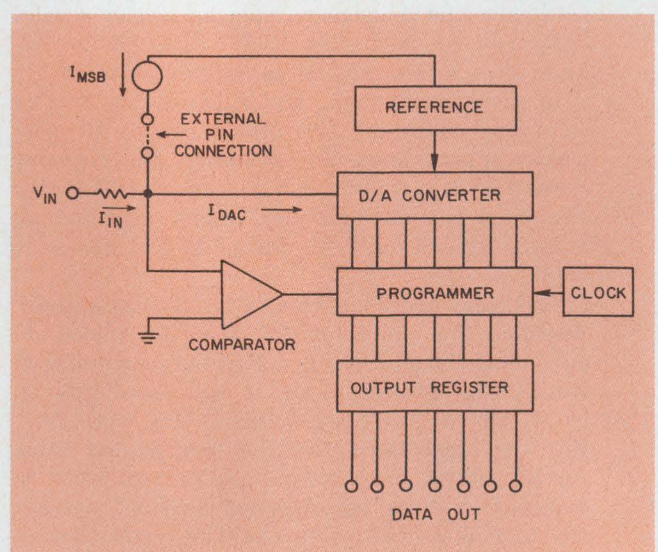
The use of an npn current source (Fig. 1b) produces a negative output current with complementary binary positive-true coding. The pnp transistors operate in the same way as before, but each collector is connected to the emitter of an npn weighted current source, which is turned on or off by the pnp transistor. This basic method finds common use in IC quad current-source circuits.

Complementary binary, positive-true, coding is identical to straight binary negative true; these are just two definitions of the same code. Straight-binary, negative-true, coding is commonly used to interface equipment with many minicomputer input/output busses. Unipolar a/d converters most frequently use the straight binary positive-true coding. They also use straight-binary inverted-analog where the full-scale code word corresponds to the negative full scale analog value.

Another popular code used in many converters is BCD. Table 2 shows three-decade BCD and complementary BCD codes used with converters that have full-scale ranges of +5 or +10 V. BCD is an 8421 weighted code, with four bits used to code each decimal digit. This code is relatively inefficient, since only 10 of the 16 code states for each decade are used. It is, however, a very useful code for interfacing decimal displays and switches with digital systems.



2. **Binary (a) and BCD (b) ladder networks** in d/a converters use the same weighting in the resistor quads but different divider ratios.



3. **Most a/d converters for bipolar operation** are offset by a current equal to the value of the MSB. The half-scale then becomes 100 . . . 0.

With d/a converters, it is especially convenient to have input decimal codes for use with such equipment as digitally programmed power supplies. And, with a/d converters, BCD is particularly popular for the dual-slope type for direct connection to numeric displays.

BCD coding in converters can be achieved in two ways: binary-to-BCD code conversion or direct weighting of internal resistor ladders and current sources. Today it is almost always done by resistor weighting schemes (Fig. 2). Each of the weighted resistors gets switched to a voltage source and thus generates the weighted current for the amplifier. Fig. 2a shows an 8-bit binary ladder network. Due to temperature-tracking constraints, groups of four resistors are used. Then the total resistance variation won't exceed 8-to-1.

In between the groups of four resistors is a current divider composed of two resistors that give a division ratio of 16 to 1 between resistor quads. The BCD ladder configuration is similar, with the same values in each of the groups of four resistors. In this case, however, the current divider has a ratio of 10 to 1 between resistor quads. Thus, because of the difference in internal weighting, BCD-coded converters cannot be pin-strapped for another code; they must be ordered only for BCD use.

Codes can be made bipolar

Most converters have provision for both unipolar and bipolar operation by external pin connection. The unipolar analog range is offset by one-half of full scale, or by the value of MSB current source, to get bipolar operation (Fig. 3). The current source, equal to the MSB current, is derived from the internal voltage reference, so it will track the other weighted current sources with temperature.

For bipolar operation, this current source is connected to the converter's comparator input. Since the current flows in a direction opposite from that of the other weighted sources, its value is subtracted from the input range. With the weighted currents flowing away from the comparator input, the normal input voltage range is positive. Thus the offsetting can change a 0 to +10-V input range into a −5 to +5-V bipolar range.

If the analog range is offset for a converter with straight binary coding, the new coding becomes offset binary. This is the simplest code for a converter to implement, since no change in the coding is required. Table 3 shows offset binary coding for a bipolar converter with a ±5-V input range. All ZEROs in the code correspond to minus full scale. The code word that was originally half-scale becomes the analog zero, 1000 0000 0000. And all ONEs correspond to +5 V less one LSB. Successive-approximation a/d converters also have a serial, straight-binary output. This serial output is the result of the sequential conversion process, and it also becomes offset binary when the converter is connected for bipolar operation.

Three other types of binary codes are shown in Table 3, along with the offset binary. Of all four, the two most commonly used are offset binary and two's complement. Some converters use the sign-magnitude binary, but the one's complement is rarely used.

The two's complement code is the most popular because most digital arithmetic is performed in it; thus most interfacing problems are elim-

Table 3. Bipolar codes—12 bit converter

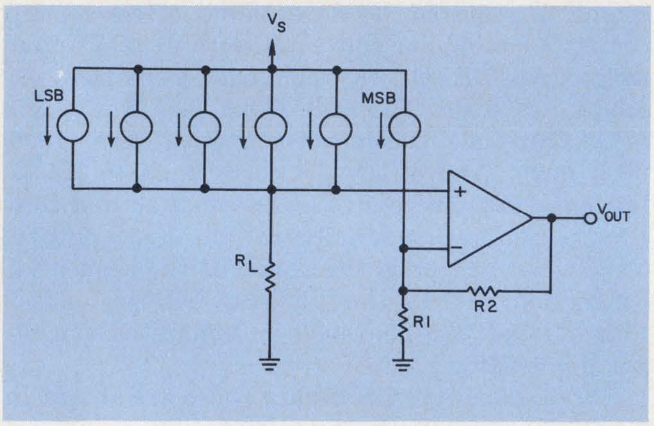
Scale	±5 V FS	Offset binary	Two's complement	One's complement	Sign-mag binary
+FS−1 LSB	+4.9976	1111 1111 1111	0111 1111 1111	0111 1111 1111	1111 1111 1111
+3/4 FS	+3.7500	1110 0000 0000	0110 0000 0000	0110 0000 0000	1110 0000 0000
+1/2 FS	+2.5000	1100 0000 0000	0100 0000 0000	0100 0000 0000	1100 0000 0000
+1/4 FS	+1.2500	1010 0000 0000	0010 0000 0000	0010 0000 0000	1010 0000 0000
0	0.0000	1000 0000 0000	0000 0000 0000	0000 0000 0000*	1000 0000 0000*
−1/4 FS	−1.2500	0110 0000 0000	1110 0000 0000	1101 1111 1111	0010 0000 0000
−1/2 FS	−2.5000	0100 0000 0000	1100 0000 0000	1011 1111 1111	0100 0000 0000
−3/4 FS	−3.7500	0010 0000 0000	1010 0000 0000	1001 1111 1111	0110 0000 0000
−FS+1 LSB	−4.9976	0000 0000 0001	1000 0000 0001	1000 0000 0000	0111 1111 1111
−FS	−5.0000	0000 0000 0000	1000 0000 0000	—	—

*Note: One's complement and sign magnitude binary have two code words for zero as given below; these are designated zero plus and zero minus:

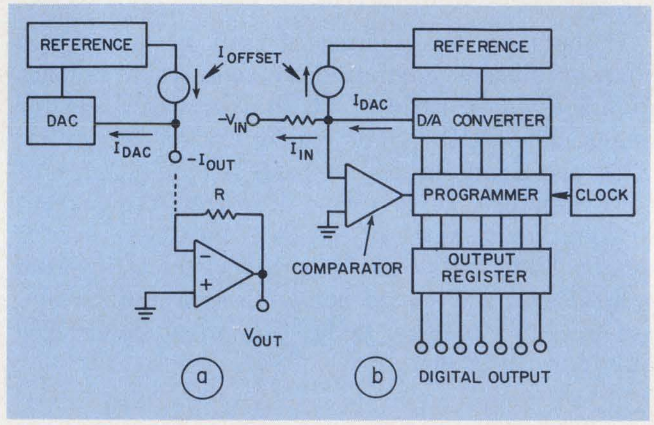
	One's complement	Sign-mag binary
0+	0000 0000 0000	1000 0000 0000
0−	1111 1111 1111	0000 0000 0000

Table 4. Inverted analog offset binary coding comparison

Scale	Normal analog offset binary	Inverted analog offset binary	Normal analog comp. offset binary
+FS		0000 0000 0000	
+1/2 FS	1111 1111 1111	0000 0000 0001	0000 0000 0000
+FS −1 LSB	1100 0000 0000	0100 0000 0000	0011 1111 1111
0	1000 0000 0000	1000 0000 0000	0111 1111 1111
−1/2 FS	0100 0000 0000	1100 0000 0000	1011 1111 1111
−FS +1 LSB	0000 0000 0001	1111 1111 1111	1111 1111 1110
−FS	0000 0000 0000		1111 1111 1111



4. **For two's complement coding** in a d/a, the MSB current-source must go to the opposite terminal from the other weighted sources to avoid output glitches.



5. **The inverted-analog d/a converter** (a) and the inverted-analog a/d converter (b) have negative-going analog output and input values, respectively.

inated. The easiest way to characterize the two's-complement code is to look at the sum of a positive and negative number of the same magnitude; the result is all ZEROs plus a carry.

Visually the only difference between two's complement and offset binary is the left-most bit. In two's complement code it is the complement of the left-most bit in offset binary.

This left-most bit is normally called the MSB; in offset binary it is, in effect, the sign bit, and is so called in the other codes. Thus two's-complement coding is derived from offset binary when the sign bit is complemented and brought out as an additional output.

Coding has its limitations

Both two's-complement and offset-binary codes have magnitudes (if we temporarily forget about the sign bit) that increase from minus full scale to zero, and, with a sign change, from zero to plus full scale. Both codes have a single definition of zero. On the other hand, one's-complement and sign-magnitude codes have magnitudes that increase from zero to plus full scale and from zero to minus full scale. Both of these codes have two code words for zero, as shown in Table 3. Because of the extra code word used for zero, the range of these codes is one LSB less than for offset-binary and two's-complement coding.

For positive numbers, one's-complement is the same as two's-complement. The negative number in one's-complement is obtained when the positive number is complemented. Sign-magnitude coding is identical to offset binary for positive numbers; negative numbers are obtained by use of the positive number with a complemented sign bit.

D/a converters don't usually use two's complement coding. This is because it's hard to invert the MSB weighted current source. If the logic input is inverted, there is an extra digital delay in switching the current source, and this causes large output transients when the current is switched on and off.

The other alternative is to change the direction of the MSB current instead of inverting the digital input. This is also difficult to do and can introduce switching delays.

One satisfactory way of inverting the MSB is shown in Fig. 4. Here a voltage output d/a converter that uses two's-complement coding has the MSB current switched into the negative amplifier input terminal, while the other weighted currents are switched into the load resistor and positive input terminal. Thus opposite-polarity output voltages are produced, and there are no additional switching delays in the MSB.

One other code in Table 1 is the sign-magnitude BCD. This code, used mostly in dual-slope a/d converters, usually requires 13 bits for a three-decade digital display. Of the 13 bits, 12 are for the BCD code and one for the sign bit. An additional output bit for an overrange indication is generally supplied.

Another scheme in Table 1 is inverted analog code. This is also called negative reference coding. While most converters use zero to plus full scale as analog values; the inverted configuration uses zero to minus full scale values. The coding then increases in magnitude when the analog level increases in magnitude from zero to minus full scale. For bipolar coding, normal analog has an increasing code as the analog value goes from minus full scale to plus full scale; inverted analog coding does the opposite—the code increases as the analog value goes from plus full scale to minus.

Why the need for this code? Fig. 5a shows a d/a converter that delivers a negative output current. With bipolar operation and use of the offset current source, the converter provides a code ZERO that corresponds to plus full scale output current. However, if a current-to-voltage converter is used at the output, an inversion takes place, and a normal analog output voltage results.

In Fig. 6b, a d/a converter with positive output current is used in an a/d converter. Since the d/a output current is summed with the offset and input current at the comparator input, a negative input voltage is needed to balance these currents. The analog input thus goes from plus full scale to minus full scale for an increasing output code. Normal analog coding is achieved by use of an inverting amplifier ahead of the analog input terminal.

Inverted analog coding is compared with the normal offset binary coding in Table 4. This comparison shows that if the inverted analog offset binary code is rotated around the zero of the analog voltage, a normal analog offset binary output results. If inverted analog offset binary is compared with normal analog complementary offset binary, the two codes will appear identical except for an offset of one LSB. The relationship between these two codes can be expressed as:

Normal analog complementary binary + 1 LSB = Inverted analog offset binary.

Therefore a converter that uses one of these codes can also be used for the other with an external offset adjustment of 1 LSB. ■■

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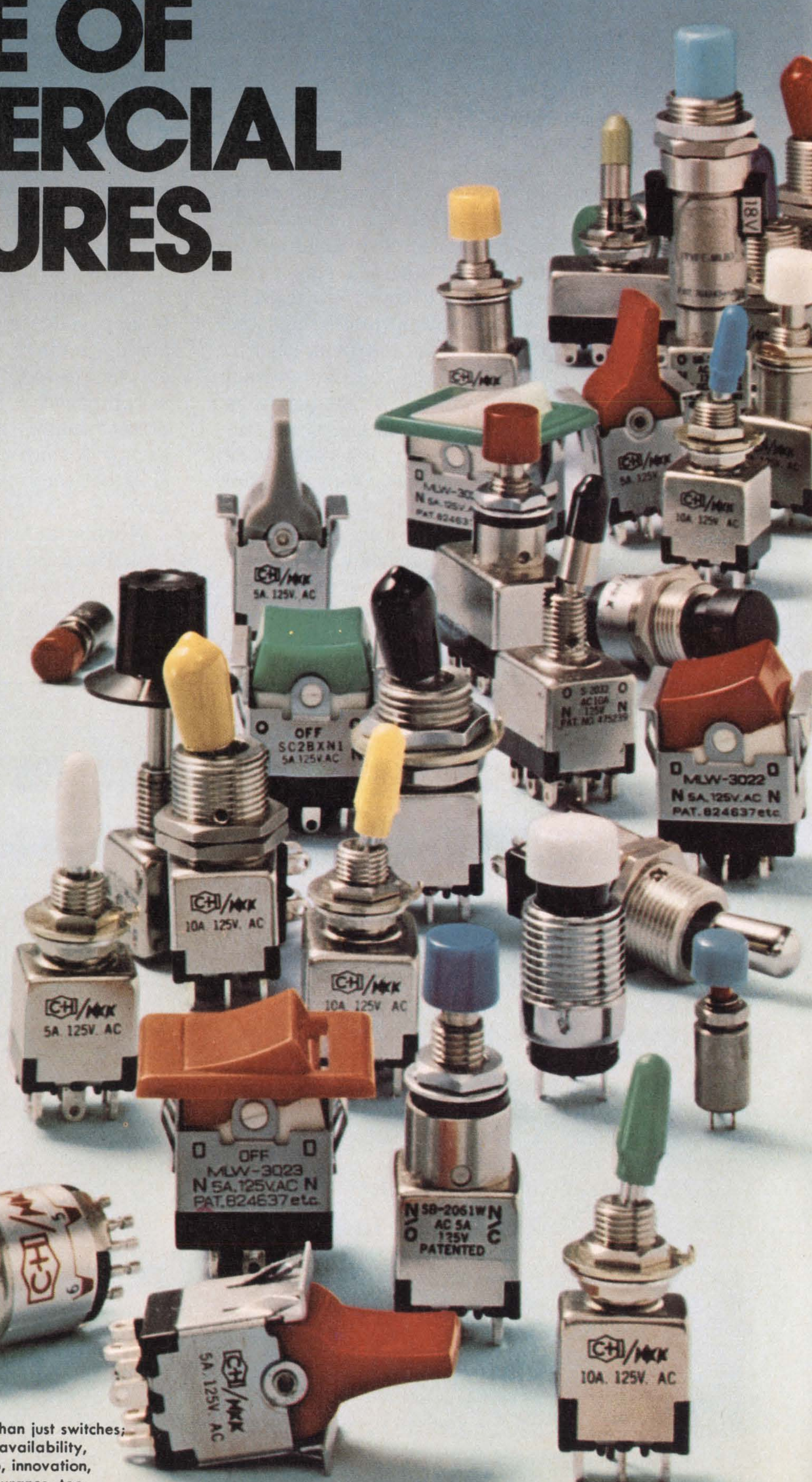

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INFORMATION RETRIEVAL NUMBER 57

Spell out specs and contract language

before taking a job that requires your engineers to integrate from one technical level to another.

If, as an engineer or engineering manager, you have ever had the problem of integrating from one level of technical detail to another without a specific plan or identification of the work required, you probably got into the same trouble we did.

Although the experience I'm going to describe involves a multimillion-dollar contract on a major item, I've seen the same problem happen in companies of just about every size. Whenever a company is trying to get a hundred details to add up to a single output at the next technical level, it is going to have trouble trying to resolve all the interfaces and all the performance details.

Questioning the contract language

We undertook a large development contract with specification and contractual language that we thought we understood at the time, but which we discovered later did not detail many of the technical problems that we would encounter.

In the development of a major system thousands of detailed technical decisions must be made. In making them, we believed we were being asked to perform work that was different from the contract requirements, as we understood them.

The cumulative effect of these decisions was to drive our costs and performance so far from what the original contract allowed that it was necessary for us to ask the customer to adjust the specs, cost and delivery, among other items in the contract.

Immediately we were embroiled in a major argument with the customer over whether he was obliged to change our contract, or whether it was an obligation that we had undertaken with our original bid.

Because of the value of the contract, our original attempt was to itemize the technical issues, which were in the thousands, and try to identify what the impact of each was technically. We then traced back the cost and scheduling, presented that to the customer and negotiated each issue on its merits.

John W. Bishop, General Manager, Test Systems Div., Bendix, Teterboro, N.J. 07608.

Negotiating each issue spawns trouble

This approach presented the following problems:

- *Increased working hours:* Our engineering managers and personnel had to take extra time to itemize each issue, which detracted from their ability to perform within cost and schedule allowances.
- *Distracted customer:* The customer had to take time to review the issues our engineers had itemized, instead of being able to work with us constructively on the program problems. We lost more time through our inability to interface effectively with our customer.
- *Deteriorated relationship of technical groups:* When these issues were mutually discussed, our tech people and the customer's tech people often disagreed—and remained in disagreement.
- *Increased work load:* Because of the mutual importance of the discussion to the program, both company managements had to take a strong interest in the proceedings. Management directions as to how engineering personnel should spend their time and on what tasks were a further constraint on the original timetables. Not only did the engineering manager have his own problems to deal with; he also had to observe a new set of priorities that might have made it more difficult for him to follow than had he been left to his own devices.
- *Disrupted work patterns:* Whenever an issue develops that incurs significant expenses, management has a responsibility to minimize costs—which may mean cutting the work load, reassigning personnel or reducing the force. That kind of reorganization can keep the engineer from finishing his job.
- *Undermined morale:* The engineering group also could see that this situation might result in

John W. Bishop and The Bendix Corporation

Prior to becoming the general manager of the Test Systems Division of The Bendix Corporation, John W. Bishop was an assistant general manager for the Navigation and Control Division, a division he had joined as an accountant back in 1958. He became supervisor of audits and special services in 1960 and in 1965 he was promoted to staff assistant to the director of economic planning. In 1971 he was named assistant controller and later controller for the Bendix Aerospace-Electronics Group, Southfield, Mich.

Bishop holds a bachelor of science degree in business administration from Drake University, Des Moines, Iowa. He and his wife Diane and their four children reside in Franklin Lakes, N.J.

The Bendix Corporation is a worldwide manufacturer of automotive, aerospace, electronic and industrial products, building materials, mobile homes and recreational vehicles. The Test Systems Division of The Bendix Corporation was formed to more extensively apply its capabilities to the growing market of large scale electronic test systems. Responsible for the design and manufacture of both manual and automatic (computer controlled) diagnostic systems for a variety of applications, the operation employs about 900 people in a 135,-000 square-foot facility.

cancellation of our project, which would have a major effect on the division and their own futures. So, along with other work, the managers also had to cope with personnel concerns, their own and those of their people.

Turning on the turnaround

I think that the major solution to this type of problem is to try to sort the problems into correct categories. Try not to make a technical problem out of a contract problem, or vice versa.

The first thing we realized was that we couldn't have the engineers involved in what was, at best, an engineering discussion. We had to get them back to their basic engineering work and arrange to conduct the business discussions with the customer in a different environment.

We sorted the claim discussion out of the day-to-day activities of the technical people in an effort to (1) Try to be sure that they met our schedule and performance; and (2) Try to remove the interferences with technical work that had been generated by the claim.

We formed a separate business task force to negotiate a settlement with the customer that would permit us to continue the program on schedule. Our customer had some very rigid requirements of his own with respect to his customer that we would have jeopardized had we not been able to complete our work on time.

When we separated our technical organization from negotiations, the engineers were much better able to resume their responsibilities. The customer also got some relief, for exactly the same reasons.

The agreement to disagree

At about that time, the relationship between the two technical groups seemed to improve. The task force was the turning point, because the customer had been concerned not only with the discussions about the contractual obligations but also in getting the job done, as we were also.

Secondly, when we were set up as a division, we attempted to prevent any problem from expanding. Many of the areas of contractual discussion had been going on for some time and were not resolved in any way. This meant that every week that passed, the problem got worse.

Under those circumstances, people's attitude got worse. Frustrations were building. The customer and our company agreed that this couldn't continue. We agreed to disagree with respect to past issues, but further agreed to establish baselines for continuing activities that we could both live with. That way we could at least stop the problems from growing.

Because these issues were open, the customer was as guarded in his communications with us as we were with him. And because some of the problems had not been resolved, the customer's people were sometimes reluctant to disclose fully to our people all of the technical aspects of the requirements they were aware of, because they were afraid that the data would be more rocks in our slingshot.

By agreeing to certain ground rules, we made it possible for our technical people to talk to our customer's technical people again without impact on some of the management discussions about the contract in general. That was very important. Once we started communicating again about our technical problems, the work started to progress.

Signs indicate end of long climb

Finally we were able to resolve the entire matter with our customer. In the meantime we had gone to great lengths to help him meet his obligations. That encouraged both our customer and our people. Our people took heart that we really intended to do the job, and their morale and performance continued to improve.

One of the signs that told us the problem had turned around was that we were developing our ability to meet schedules. This meant that our people were not being loaded down with numerous other tasks that were beyond their control.

Another thing we were able to do when we got the business negotiation behind us was to put more detailed visibility into our mutual requirements by an exchange of information. We developed war rooms where schedules were laid out in detail, and these provided visibility for all of our people as well as for our customer's reps. This improved communications. Each group agreed to tell the other where problems were developing and they've begun cooperating with each other to solve these problems as they arise.

Keeping abreast of the action

We're also receiving some new business, which gives us reason to believe that our customer sees an improvement in our ability to support him as a good supplier.

As to whether the problem could have been prevented rather than being forced to a solution after it happened, that's hard to say. Any company that integrates from one level of detail to another has the same problem. The best thing to do is to identify the work in detail. We've learned that when jobs are everybody's business, they turn out to be nobody's business. ■■

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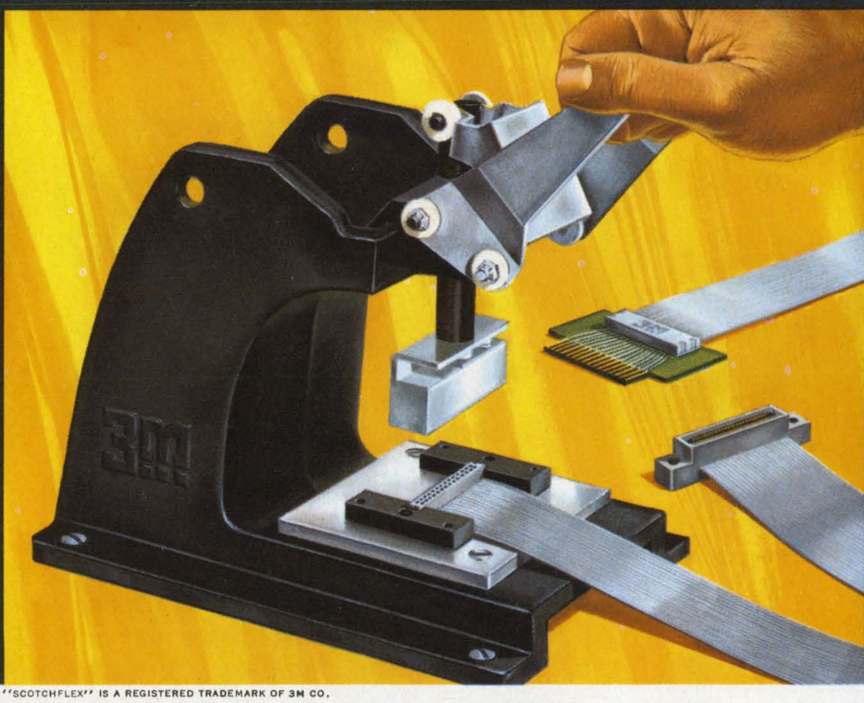

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INFORMATION RETRIEVAL NUMBER 61

Simple serial/parallel transformations aid network analysis and synthesis

By separation of the resistive and reactive parts of an impedance's algebraic equation, simple expressions can be obtained for the transformations between series and parallel circuits. These equations are useful in network analysis, network synthesis and impedance matching. They permit equivalent components to be combined easily with others in complex networks.

Any driving-point impedance can be represented as a two-element circuit—either a series resistance and reactance or a parallel combination. At a given frequency, both configurations have the same impedance. Which pair is most useful will vary at different stages in the solution of a network problem.

For a series circuit, impedance Z is derived from rectangular components R and X. To find the equivalent parallel components, r and x, draw a straight line perpendicular to Z. The intersections of this line with the axes are at the values r and x. Reverse the procedure for a parallel-to-series transformation.

The algebraic expressions for the series and parallel circuit impedances are equal. Thus

$$Z = R + jX = \frac{jrx}{r + jx}.$$

The sign of the reactance is included in the magnitudes x and X.

Equate the real and imaginary parts to obtain

$$rR - xX = 0, \quad (1)$$

$$rX + xR = rx. \quad (2)$$

Then, from Eq. 1, we get

$$\frac{r}{x} = \frac{X}{R}. \quad (3)$$

And from the definition of Q for a series circuit,

$$Q = \frac{X}{R} = \frac{r}{x},$$

if Q is required.

Divide Eq. 2 by x to get

$$\frac{rX}{x} + R = r,$$

and substitute $\frac{X}{R}$ for $\frac{r}{x}$ from Eq. 3 to that

$$\frac{(X)}{R} X + R = r$$

and

$$\frac{X^2 + R^2}{R} = r.$$

But $X^2 + R^2 = Z^2$. Thus the final simple relation is

$$r = \frac{Z^2}{R}. \quad (4)$$

Divide Eq. 2 by r and combine with Eq. 3 to yield

$$x = \frac{Z^2}{X}. \quad (5)$$

With Eqs. 4 and 5, a series circuit can be transformed into a parallel circuit, and vice versa.

James E. McKay, WSB Radio, 1601 Peachtree St., N.E., Atlanta, Ga. 30309.

CIRCLE NO. 311

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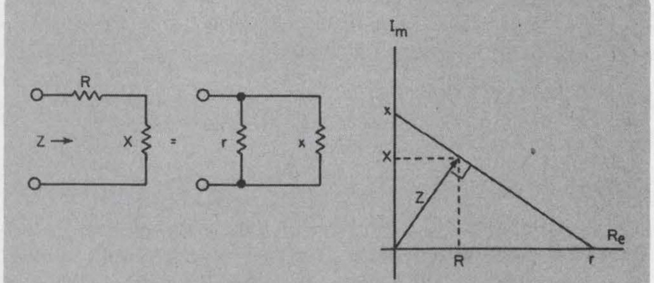
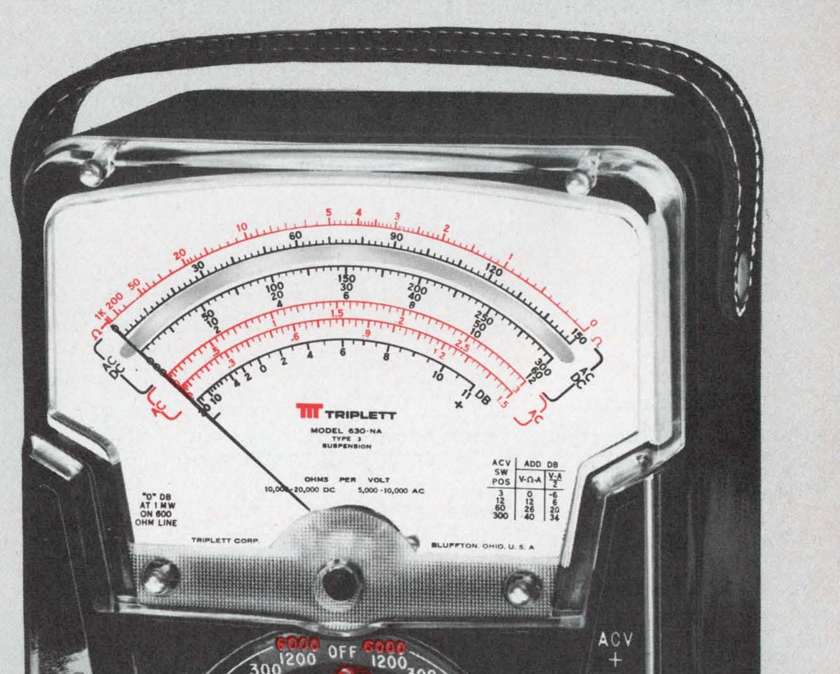


In the graphic or algebraic transformations the driving-point impedances for the series and parallel configurations are equal to each other.

The 70-range circuit reader. 630-NA.



This versatile, general purpose V-O-M ideal for communications/computer circuits, Triplett Model 630-NA, is priced at just $108.

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INFORMATION RETRIEVAL NUMBER 62

Low-power CMOS digital voltmeter built with only six integrated circuits

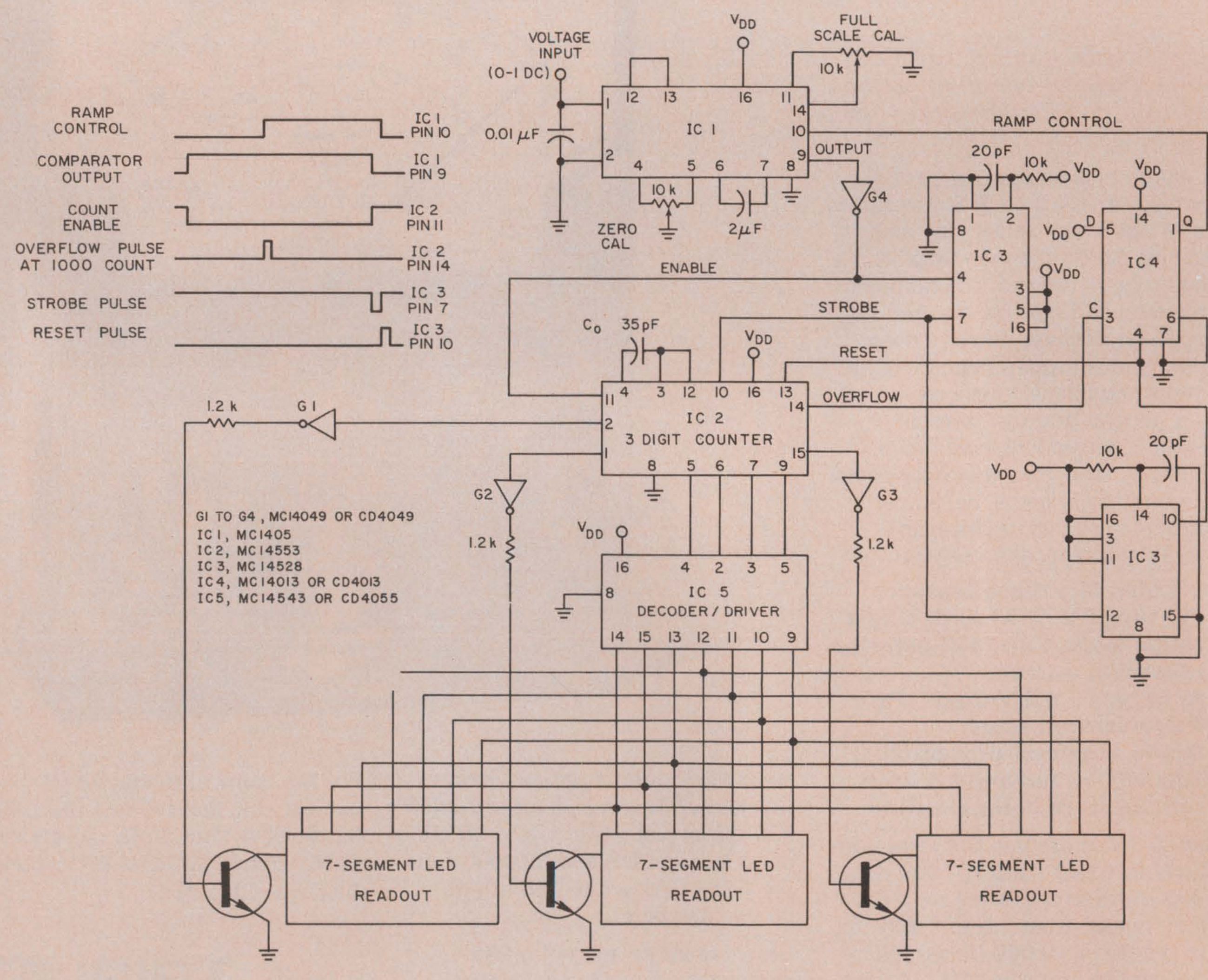
Only six ICs—five CMOS and one linear—are needed to build a low-power three-digit voltmeter (DVM). The meter remains accurate to within 0.3% as power-supply V_{DD} varies from 5 to 15-V dc.

The analog input to the circuit can range from 0 to 1-V dc. Voltage dividers can be used to increase this range. The input first enters a dual-ramp a/d converter, IC_1, which compares the input with an internal reference. CMOS three-decade counter IC_2 has a built-in oscillator, which provides the system's clock. Capacitor C_o controls the frequency of the oscillator.

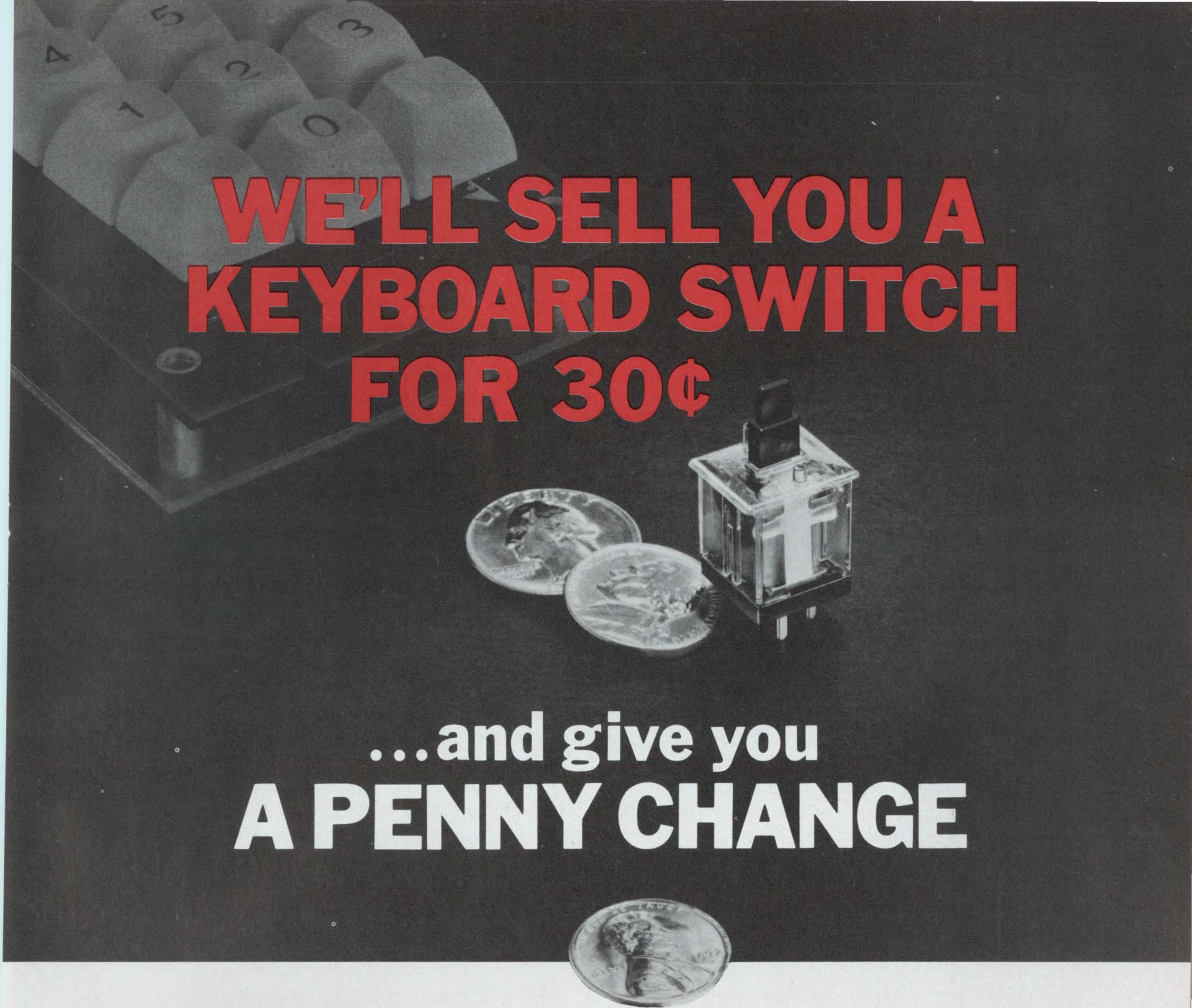
One half of IC_3, which contains two one-shots, strobes counter IC_2, while the other half resets the counter and flip-flop IC_4 after each strobe. The flip-flop provides the ramp control. Decoder driver IC_5 converts the code of the IC_2 counter's BCD output to drive seven-segment digit displays. The three displays are multiplexed by the digit-select outputs from the counter via inverters G_1, G_2 and G_3.

Two potentiometer controls connected to IC_1 calibrate the circuit at the zero and the full-scale ends of the voltage range.

Randy Young, CMOS Design Engineer, Motorola Semiconductor Products, Inc., P.O. Box 2953, Phoenix, Ariz. 85036. CIRCLE No. 312



In this CMOS DVM, one decoder driver is multiplexed to drive three, LED, seven-segment digit displays.



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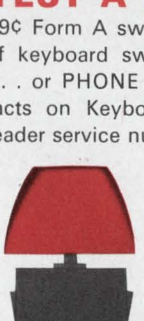

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Simple feedback circuit improves linearity of light-dependent resistors

Linearity and interchangeability of light-dependent resistors (LDRs) are greatly improved by use of a simple feedback technique. Without feedback, the inherent nonlinearity of light-dependent resistors drastically limits their application and performance (Fig. 1).

When used in a circuit such as Fig. 2, over a range from 50 kΩ to 1 MΩ, a linear change in V_I can cause R_{LD} to deviate from perfect linearity by more than 500 to 1. V_O can deviate from linearity by over 12 dB and from a logarithmic curve by more than 40 dB. And substitution of another unmatched LDR, even of the same type and make, can change the output response entirely.

In Fig. 3, the resistance of the reference, LDR_1, is driven by a constant current I_C. As the input voltage increases, the output of A_1 decreases. This effect decreases the current through the LED of LDR_1 which increases the LDR's resistance until $I_C(R_C + R_{LD1}) \approx V_I$ where $I_C \approx V_3/R_C$ and $V_3 \approx 0.6$ V. Therefore a linear change in the input voltage causes a linear change in the resistance, R_{LD1}, of the reference LDR, since $R_{LD1} \approx (V_I/I_C) - R_C$.

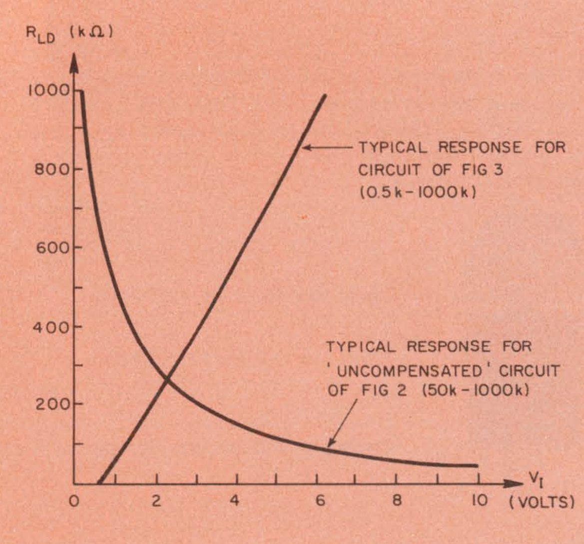
Other LDRs that are driven by the same output of A_1 will then change their resistance in approximately the same way. The best linearity for the second LDR is obtained when the junction voltages of the two LEDs are equal. This is more important than having equal currents through them.

But for the best interchangeability, a compromise should be made between equal junction voltages and equal currents. When the junction voltages of two LDRs are offset from each other in one direction, their current characteristics should be offset in the opposite direction.

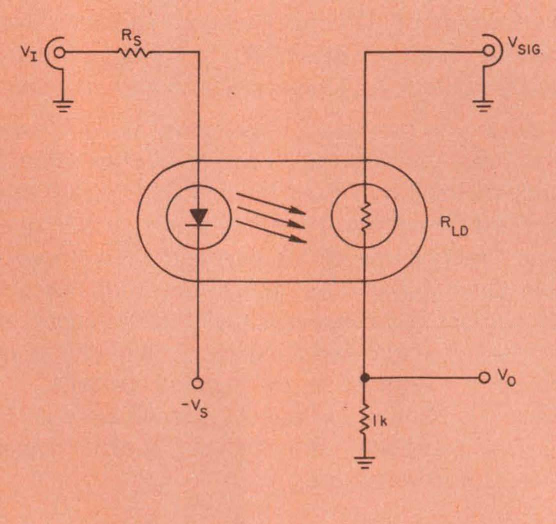
The value of $R_3 = R_4 = 39\ \Omega$ in Fig. 3 limits the change in resistance for a replacement LDR and still provides good linearity. Variation in resistance by a factor of two or more can be expected in the LEDs, but the variation can be compensated by adjustment of R_C. Similarly a difference can be expected between R_{LD1} and R_{LD2}. However, the equation for R_{LD1} is a good estimate for R_{LD2}.

An increased R_C can increase the maximum value of R_{LD2} to perhaps 1 MΩ or more, but the circuit's stability at low values of R_{LD2} (<2 kΩ) is sacrificed.

When $V_I \leqq I_C\ (R_C + R_{LD1}\ (MIN))$, R_{LD2} will not change with a change in V_I. For this reason, it may be desirable to bias the input so R_{LD2} will start to change from $V_I = 0$ V. With the values given, R_{LD2} will deviate generally from linearity by no more than 30% over the range of 2 kΩ to 1 MΩ. If a minimum $R_{LD2} < 1$ kΩ is



1. **Light-dependent resistors are highly nonlinear,** but a feedback circuit can linearize an LDR's response.



2. **An uncompensated LDR circuit has a nonlinear response.** The resistance of the unit, when $V_I = 0$, can be determined by $-V_s$.

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One of the advantages of our new 26EM miniature motor has to do with where it's made: in the U.S.A.

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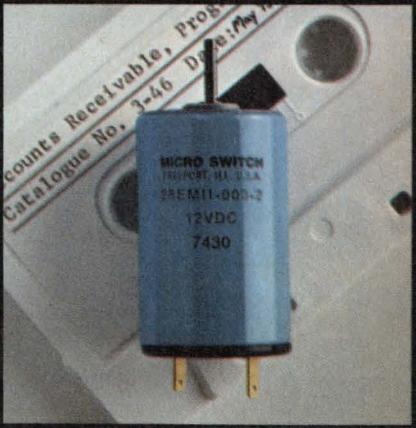

MICRO SWITCH

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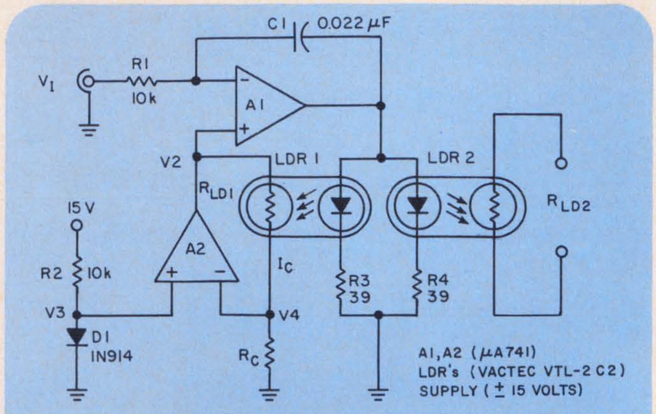
necessary, an emitter-follower to drive the LDRs may be needed, since the A_1 current output limits at about 20 mA.

If R_{LD2} is used as the feedback resistor of another op amp, the gain of the op amp will change in direct proportion to V_I as follows: $A_V = (R_{LD2} + R_A)/R_A \approx (V_I/I_C R_A) - (R_C/R_A) + 1$. R_A is a resistance from the negative input to ground of the op amp. This equation is a rough approximation because of differences between R_{LD2} and R_{LD1}. If $R_A = 1\ k\Omega$, and R_{LD2} (MAX) is set at 1 MΩ, the gain will be adjustable from about 1.5 to 1000, and will normally be within 2 dB of linearity.

Steven C. Chase, Video Engineer, Nebraska E.T.V., P.O. Box 83111, Lincoln, Neb. 68501.

CIRCLE NO. 313



3. **A reference light-dependent resistor,** LDR_1, in a feedback circuit, linearizes the response of LDR_2 to the input voltage V_I.

Sine/square-wave generator speeds amplifier testing

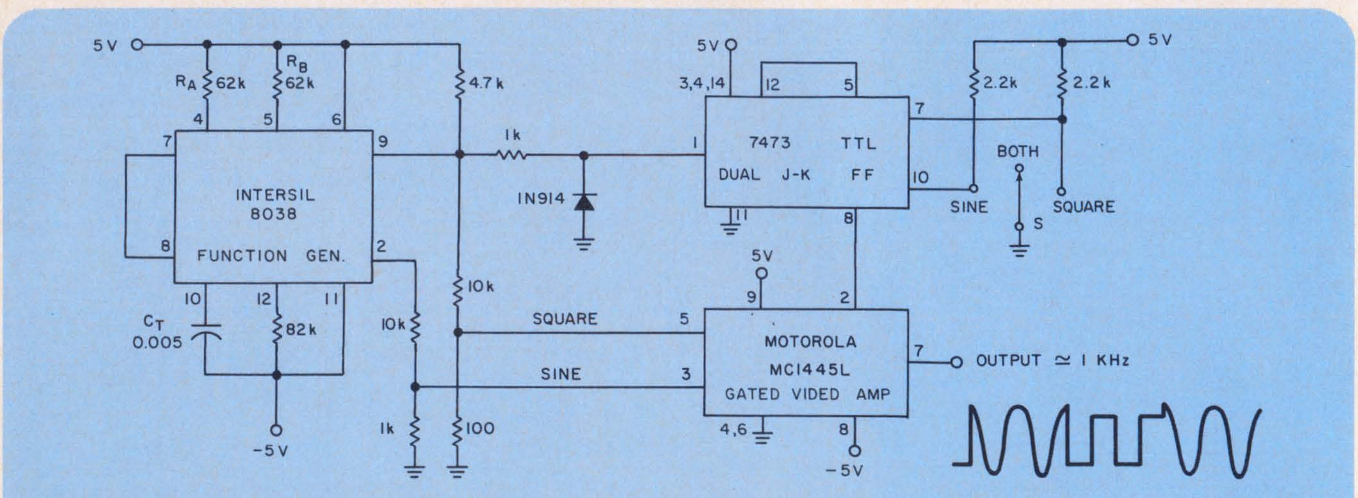
To test a linear amplifier circuit, the engineer usually uses a sine-wave signal to check for clipping and amplitude distortion and a separate square-wave to check for ringing and frequency and phase distortion. Here's a circuit that alternately provides both of these useful signals from a single source and thus eliminates the need for manual back-and-forth switching.

An Intersil 8038 function-generator chip provides both the sine and square waveforms of the operating frequency. The square wave also feeds the count input of a TTL divide-by-four circuit. Its output controls the operation of an MC1445L gated video amplifier to switch between sine and square-wave outputs and allows two cycles of each to pass alternately.

The operating frequency is roughly 1 kHz with the component values shown. The sine-wave amplitude is about 1.5-V, pk to pk, and the square-wave amplitude approximately 0.9 V. If $R_A = R_B$, the duty cycle is near 50%, and the operating frequency is $0.3/R_A C_T$. Switch S selects sine-square wave, square-only or sine-only operation.

Harold J. Turner Jr., Senior Technical Editor, McGraw-Hill Continuing Education Center, 3939 Wisconsin Ave., Washington, D.C. 20016.

CIRCLE NO. 314



Handy sine/square-wave generator can be built with three ICs and a few other simple parts.

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GTE SYLVANIA

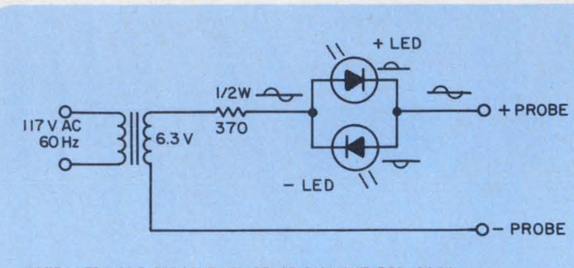
LED test set uses only four components, and it's short-circuit proof, to boot

A simple and inexpensive power supply for testing LED lamps, numeric displays and isolators can minimize testing time. The circuit shown allows in-circuit or out-of-circuit testing of all types of LED indicators.

Two LEDs built into the test set are connected in parallel opposition. As shown in the diagram, the combination is wired in series with a current-limiting resistor and a 6.3-V transformer secondary. If the output of the test set is shorted, or if a low-resistance path is placed on the output, both LEDs will light. When the output is connected with the positive lead on the anode of a LED, the positive LED will light along with the LED under test. And when the negative test lead is connected to the anode of a LED, the negative LED indicator will light along with the LED under test.

LEDs will appear to be continuously lighted, since the 60-Hz line will not appear as a flicker. This test set is especially useful for checking infrared LEDs, since you get a visual indicator if the LED is functioning. The value of the current-limiting resistor can be determined by the amount of load current desired; for 20 mA, it was selected to be 370Ω.

Calvin Graf, USAF, 207 Zornia, San Antonio, Tex. 78213. CIRCLE NO. 315



A simple test set uses only two LEDs and a resistor to check any type of LED display.

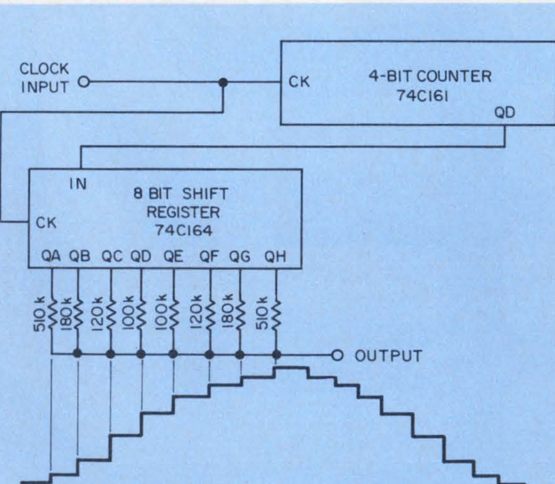
Generate sine waves digitally with two ICs and eight resistors

To produce digitally generated sine waves, all you need are a 4-bit binary counter, an 8-bit shift register and eight standard resistors. The result is a 16-step approximation to a sine wave with a period 16 times that of the input clock.

You can obtain greater resolution with a longer shift register and counter, and more resistors. The values of the resistors are proportioned to produce a half-cosine wave. In the example shown, the nearest standard resistor values are used. The counter output to the register is HIGH for half a cosine-wave cycle and LOW for the other half. Therefore ONEs fill the register progressively during the first half, and ZEROs during the second half of a cycle. Thus for an 8-bit shift register, a divide-by-16 counter is needed.

Vince Bogda, Manager of Hardware Development, Danray, Inc., Dallax, Tex. 75240.

CIRCLE NO. 316



Digital sine-wave generator uses standard-valued resistors to produce a 16-step approximation.

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TDK SUPER FERRITE

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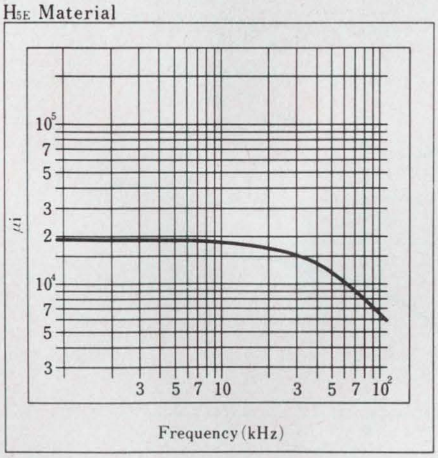
μ_i: 18,000 (H_{5E} material)
$\tan\delta/\mu_i$: 1.2×10^{-6} (H_{6H3} material)

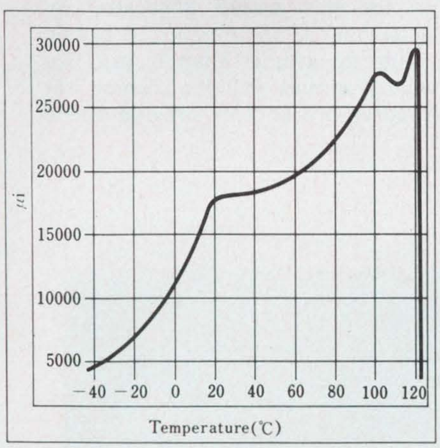
Note the extraordinary characteristics shown below. Initial permeability is a miraculous 18,000, which has never been achieved before. A relative loss factor of 1.2×10^{-6} is also a breakthrough in the low-loss characteristic.

TDK Super Ferrites do not merely possess excellent characteristics, their efficiency when machined to various configurations is also very high. Performance characteristics are very stable throughout usage. Now you can fully utilize these amazing new ferrites.

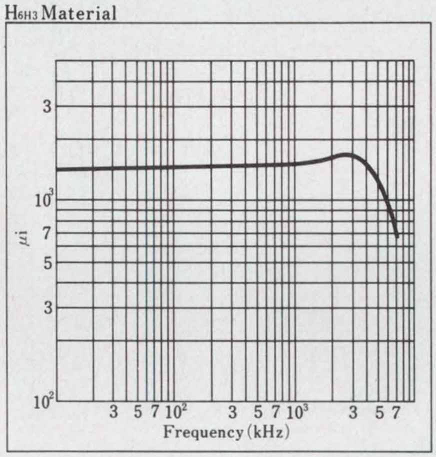
We recommend pot, EP, and toroidal configurations for H5E material; and pot and RM for H6H3 material. Further miniaturization of high performance equipment is now possible. Use TDK Super Ferrites for breakthroughs in filter or transformer design.

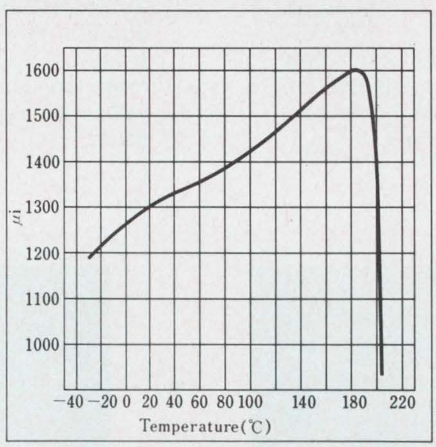
H5E Material





H6H3 Material





	H5E	H6H3
Initial permeability (μ_i)	18.000	1.300
Relative loss factor ($\tan\delta/\mu_i$) $\times10^{-6}$	<15 (10kHz)	<1.2 (0.1MHz)
Relative temperature coefficient ($\alpha\mu i/\mu_i$ /°C) $\times10^{-6}$		0.4~0.8 (0~+40°C)
Curie temperature (Tc) °C	>115	>200
Relative hystresis. coefficient(h_{10})oersted	<20 (10kHz)	<6 (0.1MHz)
Disaccommodation factor (D.F.) $\times10^{-6}$	<1	<5

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Generate a linear sweep of uniform duty cycle and amplitude

With just a few components, the circuit shown provides a simple triggered sweep generator for CRT testing. The generator has a linear sweep and constant duty cycle (ratio between the sweep and holdoff times). And the sweep amplitude remains constant at all sweep speeds.

The circuit uses a unijunction transistor (UJT) Q_1 as an oscillator, and a transistor, Q_3, as a current source to provide I_1, which charges the sweep capacitor C_T (Fig. 1). Q_2 terminates the unblanking gate and resets the trigger generator (not shown).

Current I_2 holds Q_1's emitter current slightly greater than its I_v value to provide the holdoff time (Fig. 2a). This occurs at the end of the sweep. The current comes from Q_2's bias network. Diode D_1 prevents reverse breakdown of Q_2, and D_2 prevents Q_2 from saturating. The sweep time is

$$T_s = \frac{C_T V_c}{I_1},$$

and holdoff time is

$$T_{hf} = \ln 2\ (R_1 C_T),$$

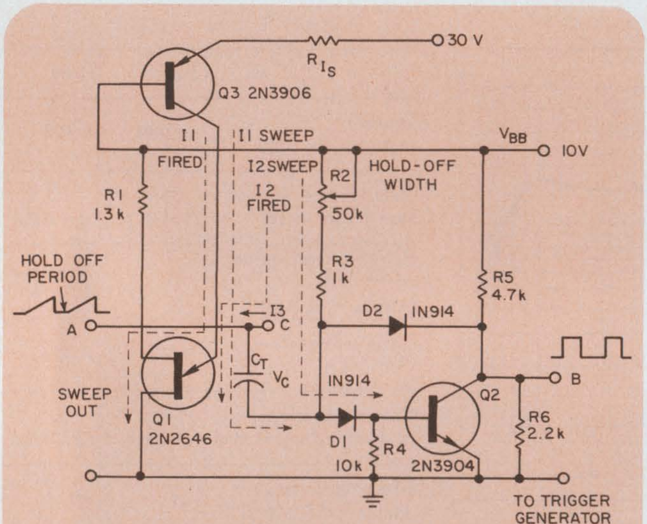
where

$$R_T = R_2 + R_3.$$

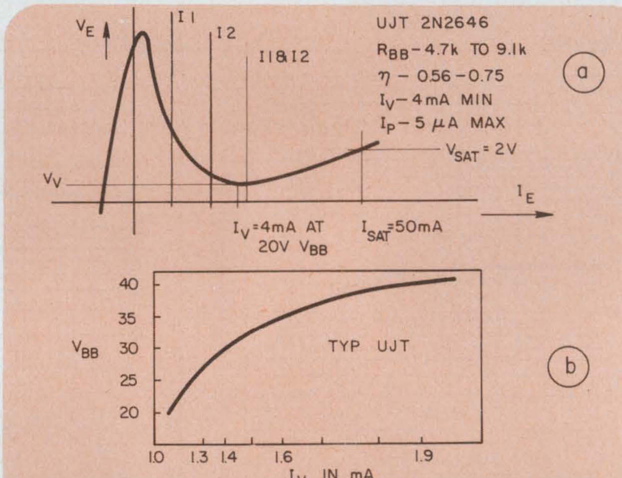
To achieve a holdoff period (Fig. 1), $I_1 + I_2$ must be greater than I_v at all times. Extra current, I_3, from the trigger circuit, is used at C to hold the sweep OFF between triggers. This current should equal I_2.

The circuit can be triggered many ways. When I_3 is removed, the sweep runs free and stops only when I_3 is re-applied at the end of the sweep cycle.

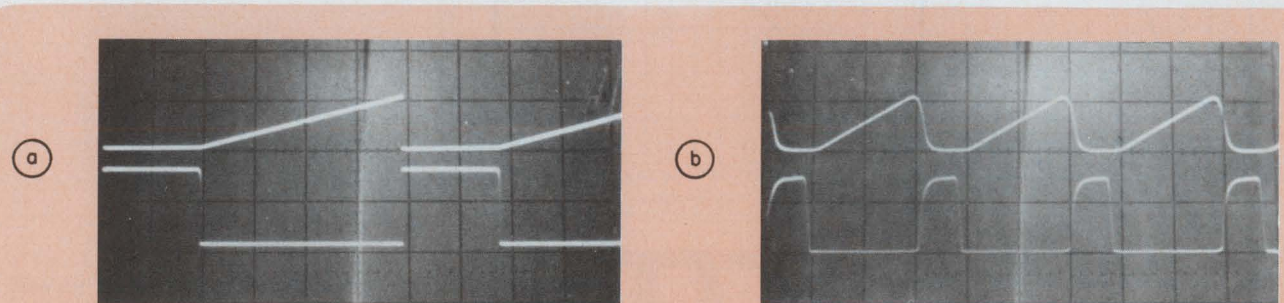
If I_3 is applied at the end of a sweep cycle, the sweep remains off until it is removed for the next cycle. The source for I_3 depends upon the application. A voltage comparator, such as the MLM111, can make a reasonable trigger circuit for a simple oscilloscope. In a particular application, a timed gate pulse from a divide-by-10 counter was used to run the sweep for 10 cycles.



1. **In this sweep generator,** the sweep is not only linear, but the holdoff time and duty cycle are uniform. And the amplitude of the output holds constant over the full range of sweep speeds.



2. **Correct design for this sweep generator** requires that you determine I_v accurately. To obtain holdoff, $I_2 + I_3$ must be greater than I_v (a). But most typical I_v vs V_{BB} curves (b) don't show low values of V_{BB}. A curve tracer can provide these data.



3. **The sweep generator** covers easily a wide range of speeds; traces range from 0.5 ms to 0.5 μs per div.

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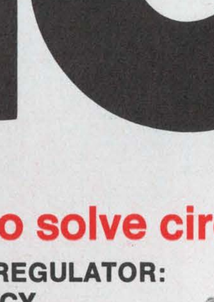

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This produced a 10-line raster for CRT light-output checks.

Holdoff is desired in oscilloscope applications to provide amplifiers and associated circuits with settling time. In the light-check application, the light output at known cathode duty cycles was measured with the beam ON during sweep, and OFF during holdoff.

To set up this circuit properly, an accurate I_v value is required for the UJT used. I_v varies with V_{BB}. Also it is not normally specified in the range needed for this application. Some specs provide a curve for I_v with V_{BB} varying (Fig. 2b). However, values of V_{BB} that are low enough are seldom included. A curve tracer can help solve this problem. With most general-purpose UJTs, a value for V_{BB} of less than 10 V usually has a low value of I_v so that C_T values are reasonable.

Cyril Smith, Production Engineer, Hewlett-Packard Co., Oscilloscope Div., 1900 Garden of the Gods Rd., Colorado Springs, Colo. 80907.

CIRCLE NO. 317

Reference voltage can be varied and the optimum zener current maintained

A simple modification of a popular voltage-reference circuit (National Semiconductor Corp. AN-20) allows you to change the reference voltage without changing the zener current. When you use zener reference diodes, it's important to adjust the zener current to the manufacturer's recommended value to achieve the diode's best temperature spec.

The modification consists of the addition of resistor R_x. Resistor ratio R_2/R_1 is chosen so that with $R_x = 0$, reference voltage V_{REF} is somewhat lower than desired (use Eq. 1). Then R_3 is calculated, and the closest stock value is used. A convenient value for R_1 is selected, and R_2 is trimmed for a voltage drop across R_3 of $I_{ZT}R_3$.

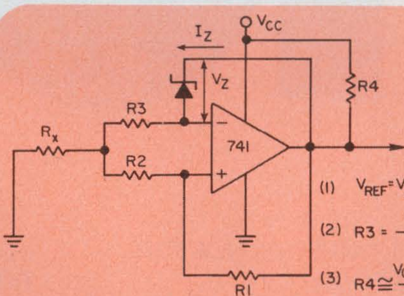
Now the reference voltage can be increased to the desired value by an increase in R_x. The zener current does not change when R_x is changed. Resistor R_4 helps the op amp supply the zener current.

As an example, if you want $V_{REF} = +9.00$ V, with $V_{cc} = 15$-V nominal, and if the zener diode you use provides 6.357 V at a recommended current of 7.50 mA, then $R_3 = 215\ \Omega$ and $R_4 = 820\ \Omega$. With $R_2 = 787\ \Omega$ shunted with 27.4 kΩ, the drop across R_3 is 1.612 V. Resistor R_x, when set to 106.0 Ω, provides $V_{REF} = 9.000$ V. Voltage V_{cc} can be varied from 12.2 to 20 V with no change in V_{REF}.

With $V_{cc} = 15$ V, the reference voltages V_{REF} are as follows: 7.976 V for $R_x = 0\ \Omega$, 8.942 V for $R_x = 100.0\ \Omega$ and 9.908 V for $R_x = 200.0\ \Omega$. And the current I_Z is constant at $I_Z = 7.50$ mA in each case.

Horace T. Jones, Project Engineer, Tri-Com, Inc., Rockville, Md. 20850.

CIRCLE NO. 318



$$(1)\quad V_{REF} = V_Z\left[1 + \frac{R2}{R1} + \frac{R_x}{R1}\left(1 + \frac{R2}{R3}\right)\right]$$

$$(2)\quad R3 = \frac{V_Z(R2/R1)}{I_{ZT}}$$

$$(3)\quad R4 \cong \frac{V_{CC}\,(\text{NOMINAL}) - V_{REF}\,(\text{DESIRED})}{I_{ZT}}$$

When you change R_x to adjust V_{REF}, the zener current, I_Z, does not change.

IFD Winner of June 21, 1974

Dale T. Pohlman, Exar Integrated Systems, Inc., Sunnyvale, Calif. 94086. His idea "Timer/Counter Chip Synthesizes Frequencies, And It Needs Only a Few Extra Parts" has been voted the Most Valubale of Issue Award.

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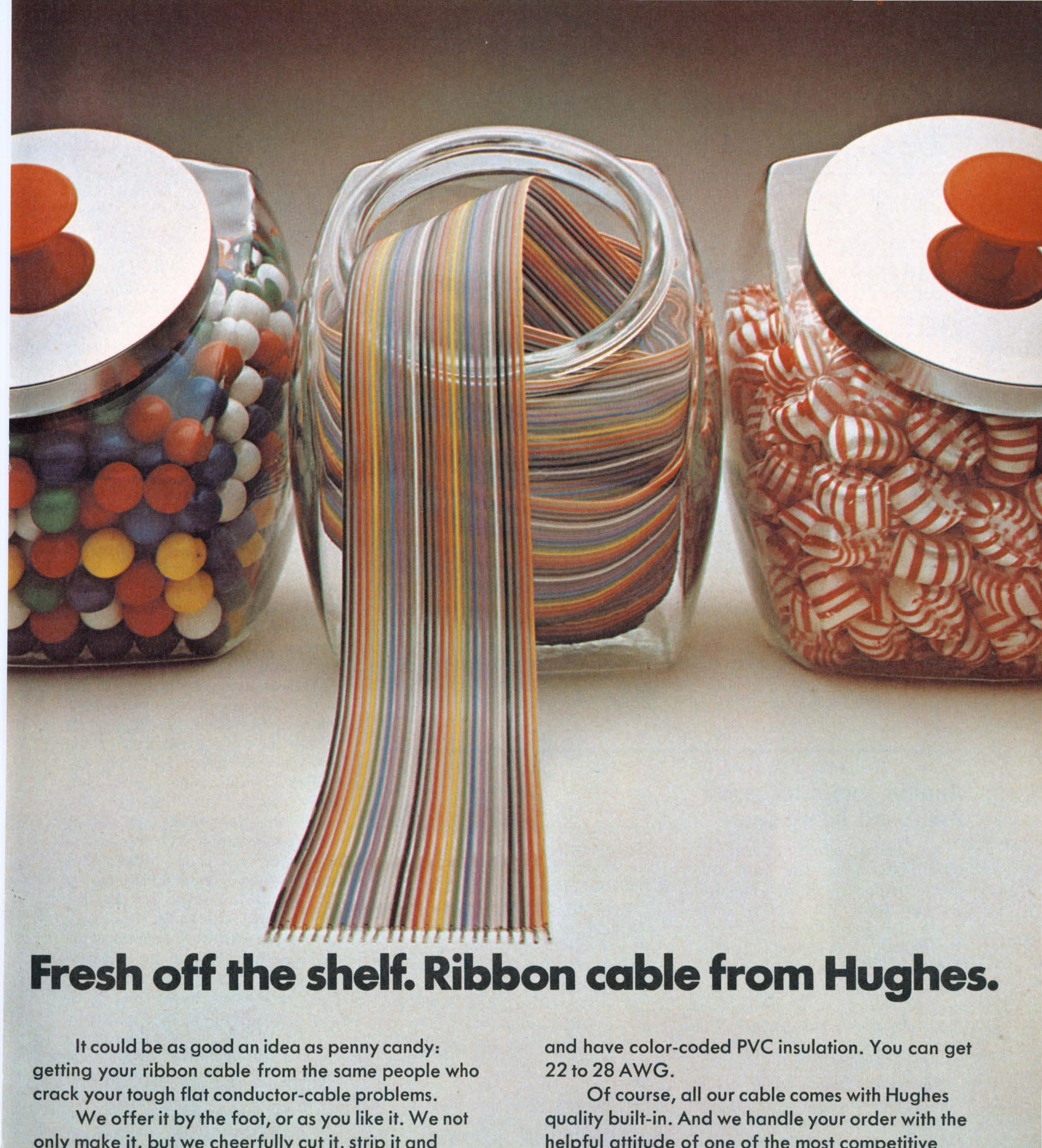

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international technology

MW communications system has third highest capacity

What is described as a microwave communications system with the third highest capacity in the world will be installed in Sweden by GTE Telecommunicazioni S.p.A., Milan, Italy. The 2700-channel system will be used in a 40-mile, high-traffic transmission link.

Only two other communications networks in the world—one in Italy and the other in Venezuela—are reported to have such high-capacity systems. Most microwave communications systems have 600 or 960 channels. Some advanced networks have 1200 and 1800 channels.

The Swedish equipment will transmit voice communications over a two-hop microwave path between Jonkoping and Gudhem. A repeater station on the 40-mile-long link is planned at Harja.

The Swedish system, designated FV 21, was designed to overcome microwave-frequency congestion that has developed in recent years on high-traffic communication routes between large cities. Each radio channel of the FV 21 can carry a color or black-and-white TV program plus four superimposed sound transmissions. The system includes a CTR 130B solid-state transceiver and a CMF 18/2700/140 modulator-demodulator.

Analog computer gives improved heart data

An analog electronic computer that determines the amplitude and orientation of spatial heart vectors from the vector components has been developed by the Hungarian Instrument Research Institute. The computer can be applied to any kind of electro or vectorcardiograph. The diagnostic data obtainable are reported superior to that of electrocardiograph signals recorded in the usual way.

The cardiograph signals are directly connected to the computer input. The computer produces continuously the absolute value and the two spatial angles of the resulting spatial vector in the form of analog voltages. On a multichannel recorder, connected to the output of the computer, the vector components can be recorded, and the following values can be read: the amplitude of the heart vectors, their inclination to the X-Z plane (elevation) and the inclination of their projection in the X-Z plane to the axis X (azimuth).

The computer specifications are as follows:

- Lead system: Frank-type (resistance unit = 50 kΩ).
- Input resistance: >100 MΩ.
- Common-mode rejection: >80 dB.
- Voltage gain: 60 dB.
- Frequency range: 0.1 to 400 Hz (−3 dB) $[V]=\sqrt{X^2 + Y^2 - Z^2}$.
- Input signal, max: 1 V.
- Accuracy: 5%.
- Output resistance: < 100 Ω.

Phone exchange uses mini relays and MOS

A new telephone exchange, the EBX 100, which uses minireed relays with TTL and MOS logic, has been developed by Philips Telecommunications in the Netherlands.

The electronic logic, which controls relay switching, uses a main, or common, control unit and several smaller peripheral controllers and registers. The common control unit contains read-only memories that are preprogrammed to provide all the routing and most of the control signals for any type of call.

Frequency drift cut in Gunn oscillators

A varactor diode coupled to a Gunn diode has reduced the undesired frequency drift—or chirp—of X and J-band Gunn diode oscillators from as much as 100 MHz to 2 MHz, according to researchers at the Allen Clarke Research Centre, Plessey Co., Ltd., Northants, England.

When pulsed Gunn diodes are used as the signal sources in portable radar systems, the chirp must be less than the bandwidth of the receiver—or about 2 MHz, the Plessey investigators point out. Their solution has been to integrate the Gunn-diode, pulse-bias voltage in a simple RC circuit. The RC output is a ramp voltage that is applied to a varactor diode.

The time constant of the RC circuit is adjusted so the frequency variation produced by the varactor diode is equal to and the opposite of the Gunn oscillator chirp. The Plessey workers have built a J-band, chirp-compensated oscillator in a WG20 waveguide cavity, with the varactor mounted close to one sidewall and in the same longitudinal plane as the Gunn diode.

The basic oscillator range can be adjusted with a mechanical tuning screw from 15.5 to 18 GHz, while the varactor is capable of electronic tuning over a 150-MHz range. A thermistor was also incorporated to reduce the chirp dependencies on temperature.

With this design, chirps that would normally have a spread of from 30 to 100 MHz were reduced to less than 2 MHz.

Stirling engine powers remote ac generator

A new design for an electrical generator, developed at Britain's Harwell Laboratories in Didcot, is a modified Stirling engine. The propane-fueled thermomechanical device provides a continuous supply of ac power at between 10 and 500 W.

Designed for unattended use at remote sites, the generator has an efficiency of 8 to 10%—considerably less than that of large power stations but better than the 2 to 3% of propane-fired thermocouple generators.

The Stirling generator contains few moving parts. A reservoir of helium gas is alternately heated and cooled, causing pressure changes upon a metal diaphragm at a frequency of 110 Hz. The diaphragm rotates the armature of the generator.

The design will be field tested as the power source for a microwave repeater station in New Guinea and for a new oceanographic research buoy.

Small Doppler radar is low-cost and rugged

A low-cost, rugged Doppler radar in which all microwave circuitry—with the exception of the Gunn-diode source—is mounted on an 18 × 16 × 0.5-mm alumina substrate has been developed by L. W. Chua of Mullard Research Laboratories in Redhill, England. The device, still in prototype form, is small enough to be used in special apparatus, such as aids for the blind or a "too-close" warning system for automobiles. While the new radar was designed to incorporate a slotline antenna on the substrate, it is adaptable for use with a waveguide horn.

Multiplex phone system is fully solid-state

A frequency-division multiplex telephone system with capacities from 12 to 10,800 channels has

(continued on page 161)


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INFORMATION RETRIEVAL NUMBER 70

(continued from page 159)

been produced by GTE International in Milan, Italy. The MP 25 system is fully solid-state, using monolithic integrated circuits. It is smaller than previous equipment and is reported to have improved electrical performance, high reliability, standardized units, variable station capacities and low power consumption.

Channel modulation is achieved by premodulation at 24 kHz and then modulation with the 88-to-132-kHz carriers. This method allows the use of identical channel modem units and permits maximum efficiency for the 24-to-28-kHz filters. Internal carrier and pilot generation starts from the fundamental frequencies of 12 and 124 kHz, provided by a master oscillator whose stability is 5×10^{-8} over a three-month period.

The channel and group carriers and pilots have the same stability as the master oscillator, because they are derived by division and modulation only. Supergroup carriers are phase-locked to 124 kHz. Facilities are provided to compare 60 or 300 kHz coming from distant stations to the locally generated frequency.

Logic circuits control alarms, and light-emitting diodes indicate when a unit has failed.

Stock IC transducer checks blood pressure

Small size, a low output of 2.5 V and an accuracy comparable to that of European transducers several times more costly led to the use of the National Semiconductor LX 1600A IC pressure transducer in an experimental blood-pressure monitor.

Applied in a medical setup at the J.F. and C. Heymanns Institute at Ghent, Belgium, the transducer—originally developed for use in autos, air-conditioning and meteorology—was mounted in a protective plastic housing with electrical and pressure fittings. To obtain systolic-diastolic pressure variations, the pressure cavity in the transducer was filled with mineral oil.

A three-way stopcock in the system permits flushing and zero-setting. The transducer is insensitive to ambient vibration.

Optical reader used in automatic phoning

An optical mark-reading device for automatic telephone dialing has been developed by Deutsche Fernsprecher GmbH of Marburg, West Germany. The user fills in key areas on his optical card—areas that correspond to often-dialed telephone numbers. He then feeds the card into the Fernsprecher reader, which converts the coded areas to telephone dialing signals sent out over the line.

Light spot on a map gives plane's position

A novel air-navigation system that shows the aircraft's position as a light spot on a map, without the need for reference signals from ground stations, has been developed by Teldix GmbH of West Germany in collaboration with Stuttgart University. The aircraft's position is incrementally computed from ground-speed information supplied by a Doppler radar plus directional information from a gyroscope.

GATES - INS4000, INS4001, INS4002, INS4011, INS4012, INS4019, INS4023 , INS4025

BUFFERS - INS4007, INS4009, INS4010, INS4049, INS4050

FLIP FLOPS - INS4013, INS4027

COUNTERS - INS4017, INS4018, INS4020, INS4022, INS4024, INS4029, INS4040, INS14510, INS14516

REGISTERS - INS4035, INS4042

SWITCHES - INS4016, INS4051, INS4052, INS4201

MEMORIES - INS4061, INS4200

ARITHMETIC FUNCTIONS - INS4008, INS4030, INS14581, INS14582

DECODER - INS4028

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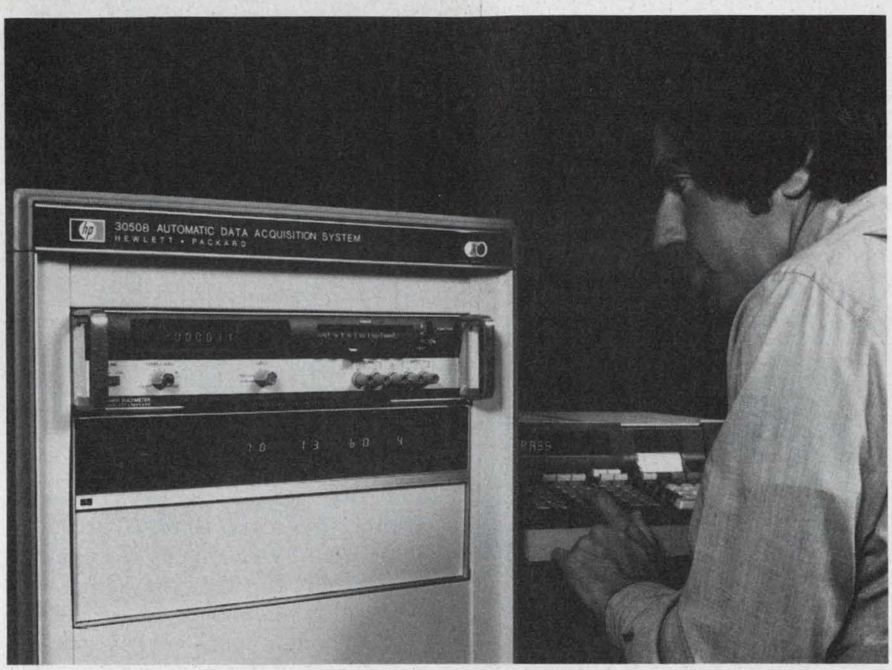
Calculator-based acquisition system handles remote sites by phone line



Hewlett-Packard Data Systems, 11000 Wolfe Rd., Cupertino, CA 95014. (408) 257-7000. See text; 2 wks.

A system that consists of a scanner, digital multimeter and calculator team can give excellent cost performance for data acquisition and reduction. With the HP 3050B system you can also add a common carrier (phone-line) interface; then one man at one calculator can monitor unattended sites as easily as he dials a phone call.

The scanner-multimeter combination handles up to 520 channels with up to 4 readings/s under calculator control. The link between the instruments and the calculator is the HP Interface Bus (HP-IB). For use with an optional modem, a Common Carrier Interface unit (CCI) converts the 16 parallel lines of the bus to serial form. A second CCI at the other end of the line converts the data back to parallel form.

The basic 3050B system measures dc in five ranges from 100 mV to 200 V with 1-μV resolution. Ac is measured in four ranges from 2 V to 200 V with 10-μV resolution over a frequency range of 20 Hz to 250 kHz. And the unit measures 100Ω to 10 MΩ with 1-mΩ resolution.

The system can operate with low-level devices such as thermocouples that generate potentials of 22 μV/°F. The common-mode ratio is 120 dB; floating measurements are made with a switched guard connection for each channel. This limits the amount of common-mode noise that appear as normal-mode noise along with the low-level input. The integrating DMM also rejects power-line frequencies with greater than 50 dB normal-mode ratio. And spurious thermocouple effects are held to less than 3-μV differential from the scanner input.

If desired, programmable calculator can interchange processed data with large HP computers, and the calculator easily performs mathematical operations that range from transducer linearization to statistical analysis. There is no need to write complex programs for the host computer or waste the host's time on data reduction.

For local operation, you just hook the calculator to the scanner or you can use the CCI modules back-to-back for separations up to 3000 feet with a double-twisted pair.

Existing optional modems allow you to operate over the DDD network or private lines at a 300-baud rate. All data and control sequences can be transmitted and received with manual or automatic dial-up, but the system throughput is reduced. HP eventually plans to supply 1200-baud modems that will allow the system to run at normal speed over two-wire lines.

Price of the 3050B System ranges from $14,000 to $25,000 and depends on the number of channels and accessories. The base price includes a 10-channel assembly and the 9820A (algebraic) calculator with 1.7-k words of memory. Other calculators that can be incorporated in the system include the 9821A (algebraic) or 9830A (Basic language). Prices for the CCI module start at $1000 (without modem) and range up to $3000 with automatic dial-up and modem.

CIRCLE NO. 255

Semi memory system stores 3.5 Mbits

Monolithic Systems Corp., 2700 S. Shoshone, Englewood, Colo. 80110. (303) 761-2275.

Monostore VII, a memory system based on 4-k NMOS RAMs, provides up to 3.5 Mbits in a 5.25 × 19 × 20-in package. Individual cards are available in 4 k × 16 or 16 k × 8 organizations. Standard operate times are 500 ns access and 700 ns cycle times.

CIRCLE NO. 257

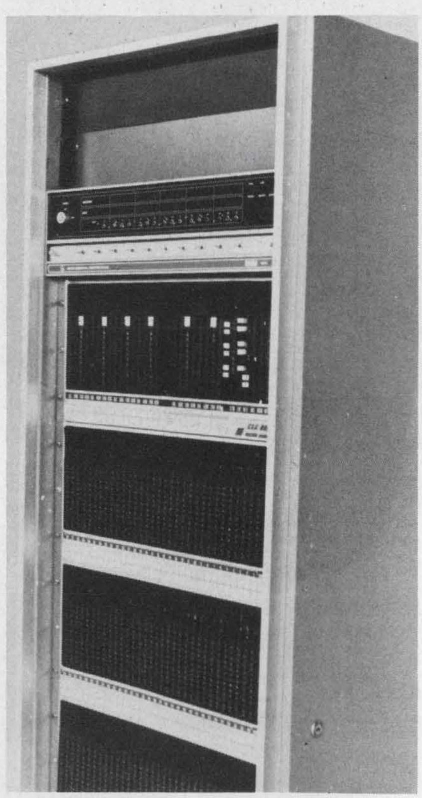
Wire-line modems carry data for 10 miles

DataStat, 246 Sobrante Way, Sunnyvale, Calif. 94086. (408) 732-7618. From $660.

Synchronous communications over 10 miles of wire are provided by the SLD series of short haul modems. Phase shift keying is used and data rates to 50 kbit/s are available. Four models are available each with a different maximum data rate. All models have six selectable speeds in 2:1 steps.

CIRCLE NO. 258

Controller lets mini handle 128 data lines

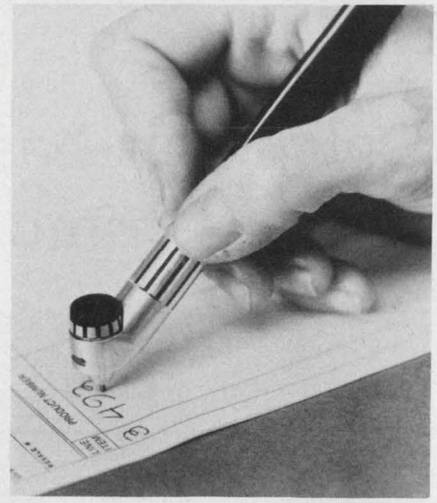


Micom Systems, 20426 Carisco St., Chatsworth, Calif. 91311. (213) 882-6890. See text; 90 days.

The Model 1005 communications controller allows Nova minis to handle up to 128 asynchronous or synchronous data lines. Sixteen programmable speeds are available —up to 19.2 k bit/s. Modem controls are provided or the user can select simple input/output drivers. A typical system with 50 modems attached costs $9050.

CIRCLE NO. 259

Data entry performed from written numbers



Xebec Systems, 566 San Xavier Ave., Sunnyvale, Calif. 94086. (408) 732-9444.

A special ball-point pen together with external recognition circuitry translate hand-printed data to a popular computer language—ASCII code. Dubbed the Alphabec-70, the unit recognizes 10 digits and six control symbols. Three events occur as a user prints a character: The name of the character is spoken, the character recognized is displayed on a digital readout, the character is temporarily stored in memory. According to the manufacturer, the system may replace many of the 700,000 estimated keyboard devices now in use.

CIRCLE NO. 260

Two-port memory aids dual-processor systems

Cambridge Memories, 12 Crosby Dr., Bedford, Mass. 01730. (617) 271-6502.

The CMI dual-port memory is sharable between two PDP-11 processors with the master processor in control of priority if desired. In a simultaneous access to memory, the rule is first come, first served. But the processor connected to port A can set the unit with address 764776 and thereby be the exclusive user. For dual bus processors the memory increases throughput with concurrent data transfer between CPU and direct-memory access devices. Capacity can range from 8 k to 124-k words (16-bits).

CIRCLE NO. 261

Monsanto introduces its *HT* SERIES (a breakthrough in High Technology) with three new Frequency Counters

Monsanto's new HT Series (High Technology) instruments designed specifically for communications, is the 8700 family of Frequency Counters. As a part of Monsanto's ongoing R & D program to produce digital instrumentation of optimum reliability and performance, these counters offer outstanding specifications. Only through the judicious use of tested technology, human engineering principles, and state-of-the-art circuitry and components, could the demanding standards of this series be accomplished. To further fulfill the promise of the series, each instrument is housed and protected in a contemporary, designer-styled aluminum enclosure that facilitates calibration and maintenance while providing an appearance as advanced as the technological innovations it contains.

8700 Series prices range from

$595.

The 8700 Series of Frequency Counters consists of three separate models with ranges of 150 MHz, 550 MHz and 1 GHz.

All models feature: Frequency and Ratio mode/Opti-ranging for optimum display resolution/Full 9 digit, Monsanto, easy-to-read amber LED display/10 mV rms sensitivity with AGC/Selectable input impedances of 50 ohms and 1 megohm/High stability oven controlled crystal oscillator/Options included: parallel BCD output, IF subtraction, higher stability TCXO oscillator, high overload input protection/Available from stock/Generous OEM quantity discounts.

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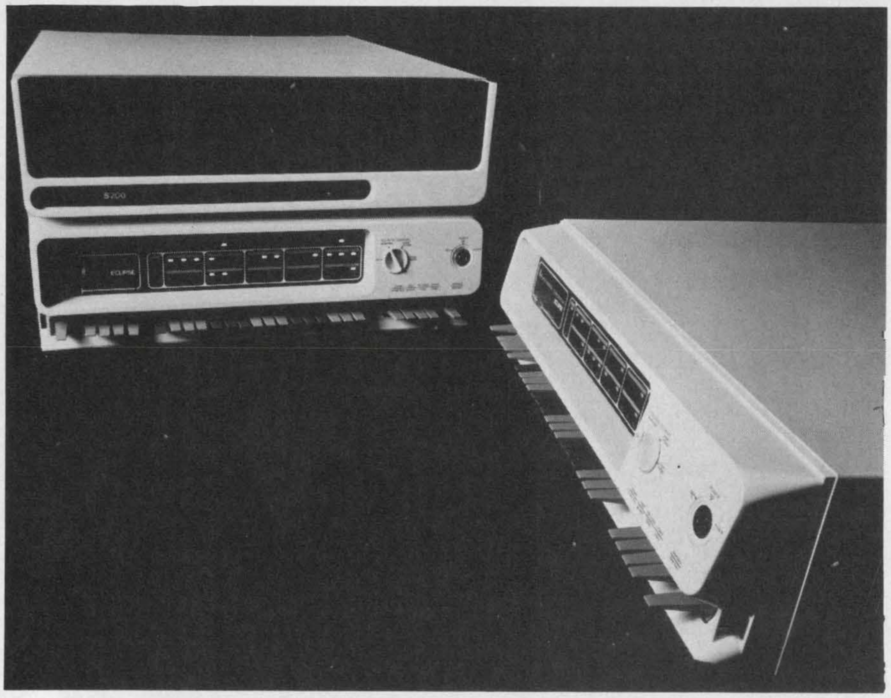
INFORMATION RETRIEVAL NUMBER 205

FOR DEMONSTRATION CIRCLE #206

Mini with core or semi offers 200-ns speed and error control



Data General Corp., Route 9, Southboro, MA 01772. (617) 485-9100. See text; Spring.

With cache memory and microprogrammable central processors, the first two models of Data General's new Eclipse line can attain 200-ns cycle times and correct single-bit errors.

User orientation is evident in the first two models of the line, the S100 and S200. Both can operate with 800-ns core or a 700-ns semiconductor memory—or a mixture of the two without additional controllers or interfaces.

The S100, with a 64-byte capacity, is the smaller of the two computers. It accommodates six standard Data General PC boards. It is designed mainly for users who incorporate a mini as part of a larger product.

The S200, intended for large-scale systems builders or end users, is 10.5 in. high and holds 16 PC boards.

The error-detection/correction memories use 21 bits; noncorrecting units are 16 bits long. The extra five bits are for a computation made by both memory and CPU when they exchange data. The error check requires no extra CPU time; an error takes 300 ns to correct.

The cache memory is a cluster of 200-ns bipolar units arranged in four blocks of four words each. Each memory board contains one cache. When addressing memory, the CPU checks the cache and main memory. If the work is in cache, the data are transferred to the CPU in 200 ns.

Because computer programs tend to be sequential, the probability is high that the next location addressed is adjacent to the initial location. If it is, the computer speed approaches 200 ns. A last-used algorithm helps the cache track the program.

A writable control store gives users access to 256 instructions of 56 bits each for specialized applications. Hardware memory stacks supported by machine instructions improve program efficiency and facilitate control of multiple tasks, interrupts and subroutines.

Additional memory modules available

Memory modules 16 kbytes	Cache	Price
Core	No	$2700
Core with error correction	No	$3700
Semiconductor	Yes	$5200
Semiconductor with error correction	Yes	$4200

The Eclipse instruction set is more powerful than that of the Nova; it has over 40 new instructions. But existing Nova programs will run on the new machines. And a floating point processor is available for parallel operation with the CPU.

The user can choose from a mix of core and semi memory in accordance with budget and operating requirements (see table).

Memory access can be interleaved for faster throughput. The effective cycle time can be decreased up to 45% with eight-way core interleaving. Semiconductor memory can be interleaved up to four ways with a proportional increase performance.

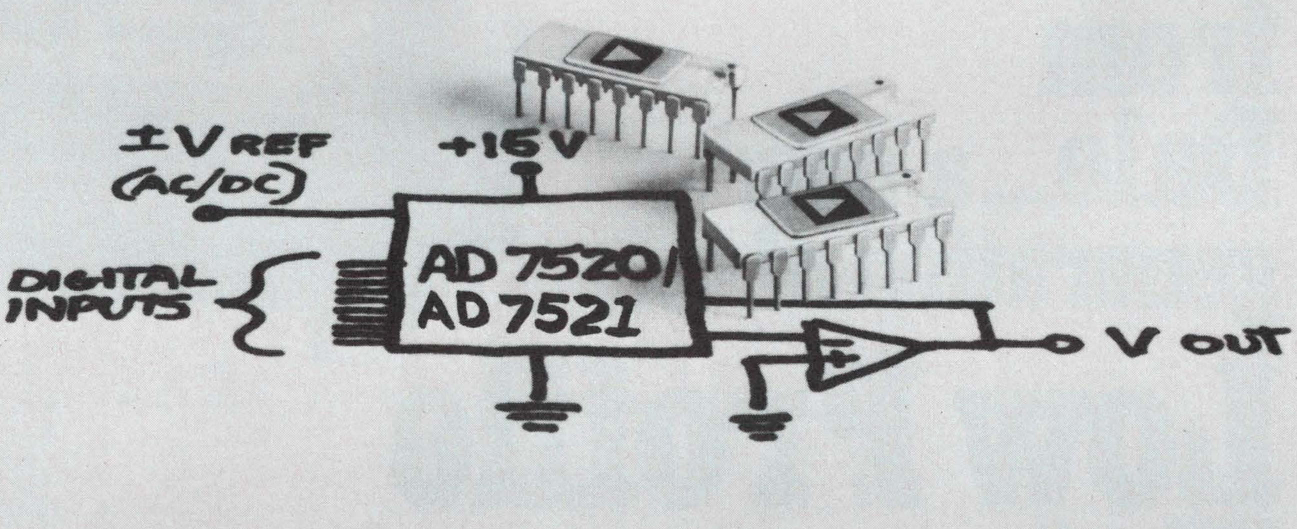
Both machines are compatible with existing Novas and will operate with 20% line voltage reductions.

Representative prices for the S100 with 32 kbytes are $11,900 (core) and $14,900 (semi). The S200 with 64 kybtes costs $21,700 (core) and $24,700 (semi). These prices do not include memory with error correction.

CIRCLE NO. 251

10-bit monolithic CMOS DAC.

And now with 12-bit resolution. AD7521.



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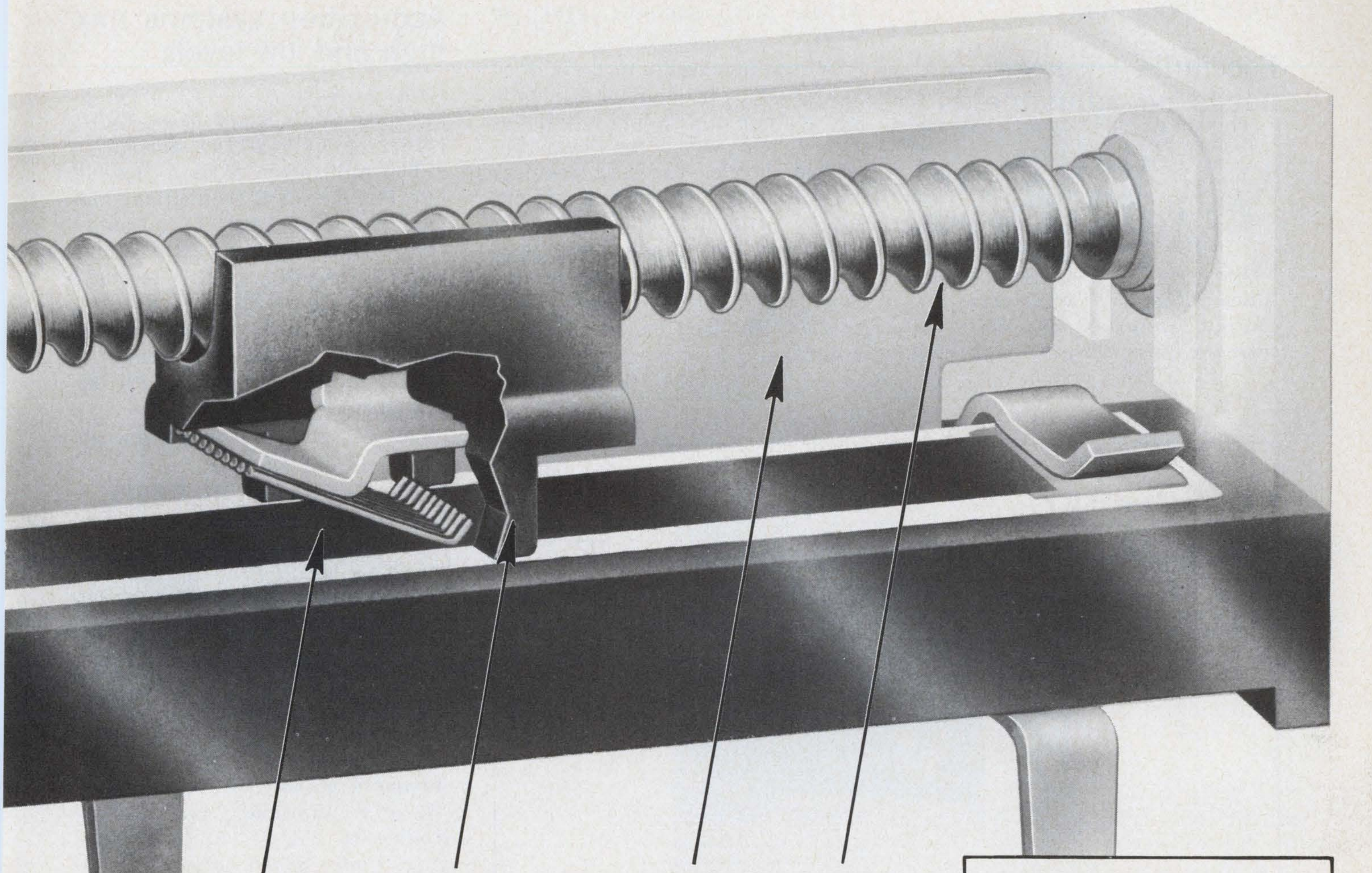
ANALOG DEVICES



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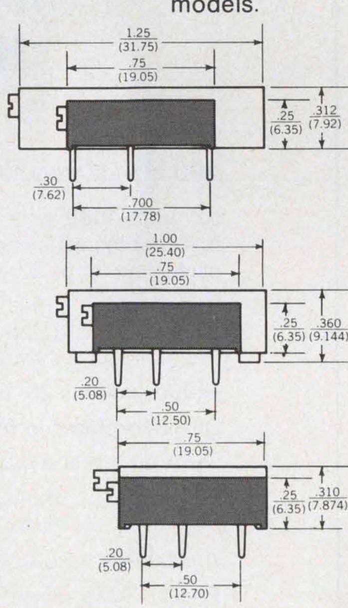
3 standard pin spacings allow fast interchange with many larger models.



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Facsimile receiver needs no adjustments

Alden Electronic & Impulse Recording Equipment Co., Alden Research Center, Westborough, MA 01581. (617) 366-8851. $951; 60 days.

A rack-mounted unit designated the Model 421C Radiofacsimile Converter converts audio FSK signals to corresponding linear amplitude levels. The unit requires no operating adjustments and operates with all 3-to-30 MHz HF receivers to monitor graphic communications. A 20-dB output wedge is obtained in the region of 1500 to 2300 Hz fixed by international standard.

CIRCLE NO. 262

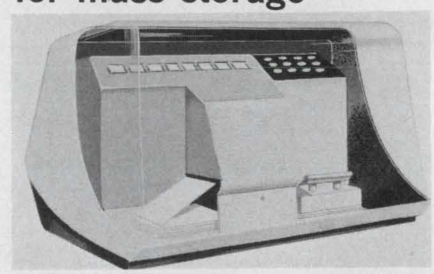
Acquisition systems mix high and low levels

Data Technology Corp., 2700 S. Fairview Rd., Santa Ana, Calif. 92704. (714) 546-7160. $3000.

The milliverter II is a flexible interface for data acquisition. The unit mates a PDP-11 to multiplexed high and low-level channels with a growth capacity to 1024 channels. Low-level signals of 5 to 500 mV can be handled as well as 5-V channels. Conversion is rapid—15-bit resolution with 40 kHz throughput.

CIRCLE NO. 263

Mag cards form basis for mass storage



Advanced Magnetic Products, Inc., 7067-1/2 Vineland Ave., North Hollywood, CA 91605. (213) 764-4712. Under $6000 (qty).

One magnetic card equals 162 punch cards. And the MCD-1000 magnetic-card drive reads them at a rate of 10/s. In addition the versatile unit can act as a random access mass storage. It can read, write, erase and protect data as well as select a card from a stack of 500. The firm indicates that random access to 200 cards takes 30 s.

CIRCLE NO. 264

Crosspoint switches can be set by mini

Cunningham Corp., Honeoye Falls, N.Y. 14472. (716) 624-2000.

The Model 1020 controller is the intermediary between minicomputer and a crosspoint switch. The unit controls 40-input-by-60-output crossbar switches at intervals as short as 40 ms. A connection pattern is set up with sequential 16-bit words. Fourteen bits are for address, and two for control. The controller generates a flag after a crosspoint has been latched or unlatched. With a reed matrix, the address interval is just 10 ms.

CIRCLE NO. 265

Fast and easy... MOSTEK's MK4102-6 static 1K RAM.

275 ns!

MOSTEK's MK4102P-6 is fast—275 ns access time! But speed is only one of its features. Just as important, it's easy to use, requiring only one +5 V power supply. All inputs are TTL compatible. And the processing technology is strictly state-of-the-art utilizing a combination of N-channel silicon gate plus ion implantation.

Also, you can accomplish large memory array construction with a minimum of additional circuitry because of the high impedance "off state" coupled with "chip select" input.

What else? Well, the MK4102P-6 is a pin - for - pin alternate for the 2102. But there's no comparison in access time. Check for yourself.

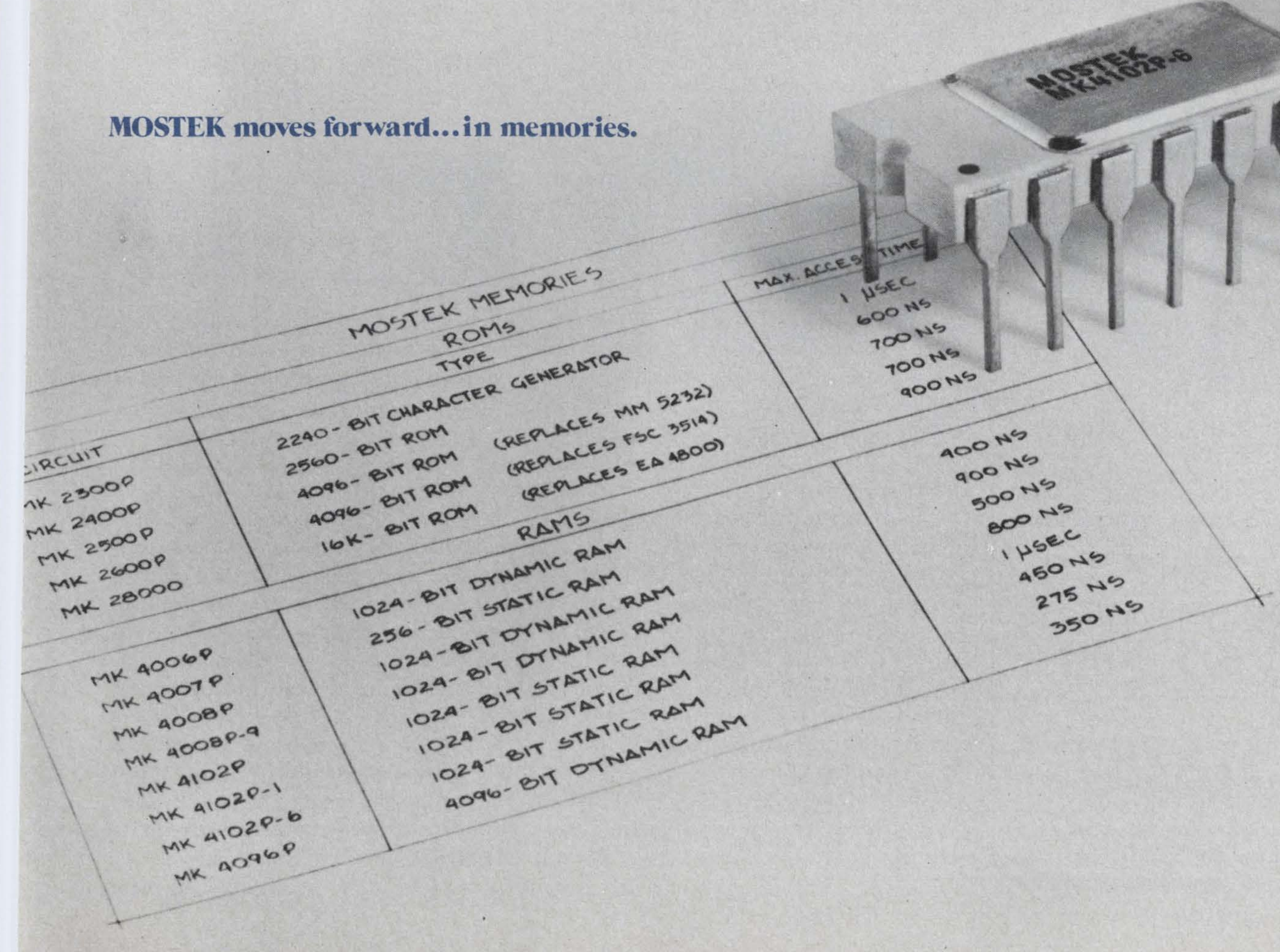
MOSTEK's line of 1K RAMs gives you plenty to select from, static or dynamic. They range from the MK4008-9 (at 800 ns) through two other versions of the MK-4102 (450 ns or 1 μ sec) up to the popular MK4006 (at 400 ns). Check the table below for the part number you need.

When your design requires an MOS memory, remember MOSTEK. Call your nearest MOSTEK distributor or representative or contact MOSTEK, 1215 W. Crosby Road, Carrollton, Texas 75006, (214) 242-0444. In Europe contact MOSTEK GmbH, TALSTR. 172, 7024 Bernhausen, West Germany, Tel. 798038.

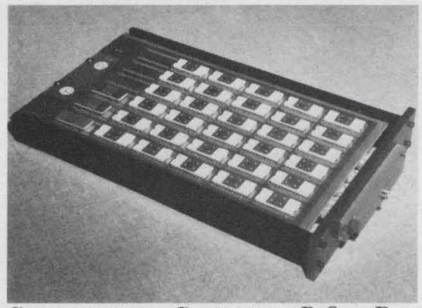
MOSTEK®

INFORMATION RETRIEVAL NUMBER 77

MOSTEK moves forward...in memories.



Electronic switch joins any pair of 256 channels

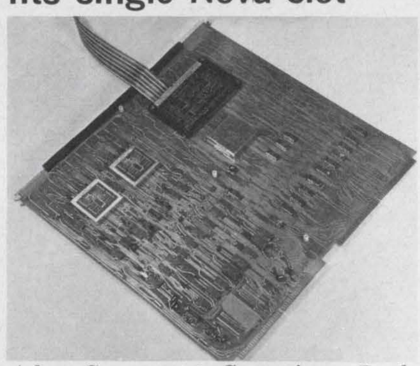


Counterscan Systems, P.O. Box 536, Sutton, NE 68979. (402) 773-3875. $2600.

An electronic switch, dubbed the Interconnect Switch, can connect any one of 256 lines to any other line. An eight-bit binary address, one for each of the 256 channels, selects the route. The transmission gates pass analog or digital data of up to 30 V pk-pk at 5-MHz rates. Usable channel selection rate is 2 MHz. Break-before-make operation minimizes channel interaction.

CIRCLE NO. 266

Data acquisition unit fits single Nova slot

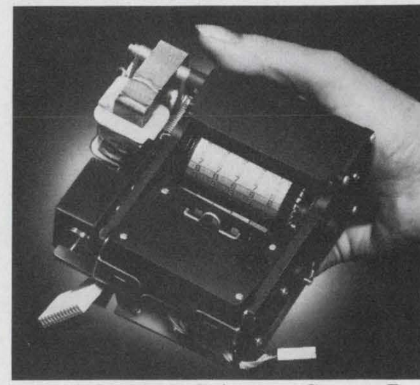


Adac Corp., 296 Cummings Park, Woburn, Mass. 01801. (617) 935-6668. 16ch $1800, 32ch $1990; stock.

A 15 × 15-in. board provides a Nova-compatible data-acquisition system. The plug-in unit can multiplex up to 32 analog channels into a 12-bit ADC. Two 12-bit DACs provide analog control outputs to the plant. Full range input scales are −10 to 10 V, down to 0 to 1 V with programmable gain. The acquisition portion operates at speeds to 100,000 samples/s. An interrupt type interface is used with the Nova.

CIRCLE NO. 267

Price slashed on compact printer



Mohawk Data Sciences Corp., Box 362, Utica, N.Y. 13503. (315) 792-2202. $50 (quan); 90 days.

The palm of your hand can hold this 15-column printer. Of simple design, the Model 2090 uses a single-print hammer for each three-column print. A disposable snap-in ribbon cartridge simplifies ribbon change. The standard 15 numeric columns (up to 3 line/s) are expandable on request to additional columns or numeric data. The unit measures 5.4 × 5.2 × 2.3-in and is suitable for point-of-sale terminals, ticket printers and instrumentation.

CIRCLE NO. 268

Multiplexer couples four devices to line

FX Systems Corp., 5070 Kings Highway, Saugerties, N.Y. 12477. (914) 246-9571.

Model BAC can couple up to four data sources to a serial TTY channel or provide eight-wire parallel ASCII code. The unit accepts parallel BCD data from up to four sources and converts it to serial ASCII. BCD data can be handled —with an option—in 1-2-2-4 or 1-2-4-2 form. Two control modes are available. Outputs can occur on first-come, first-served basis. In the second mode, each source is scanned sequentially. The first technique is recommended if one input device is slow compared to the others.

CIRCLE NO. 269

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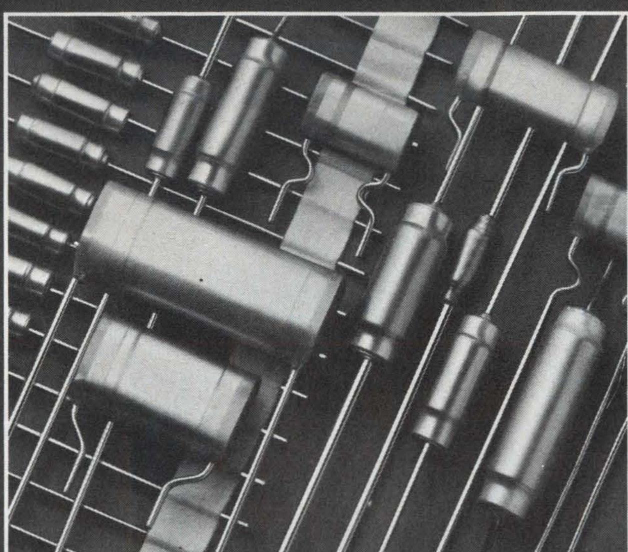

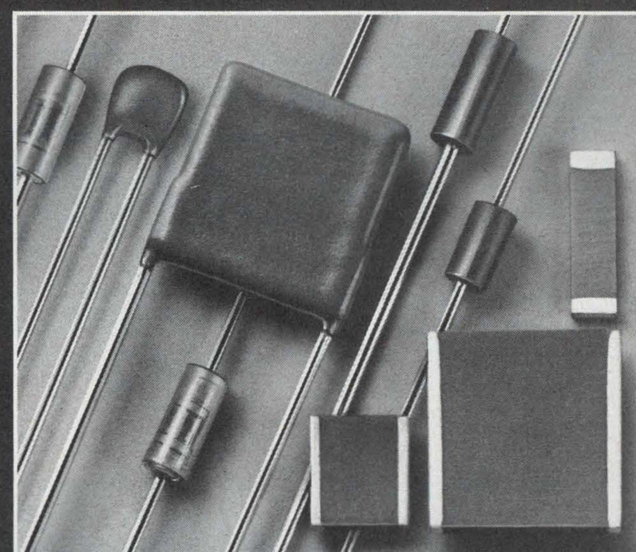

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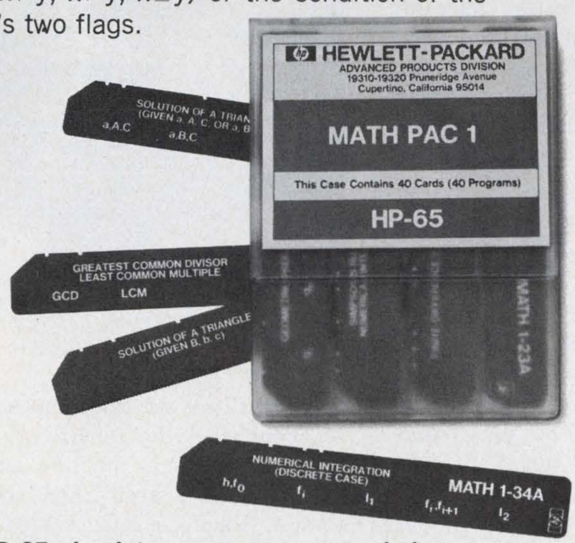
With an HP-65 you can write programs just by pressing the keys in sequence, without using a special "computer" language. You can edit programs, i.e. add or delete steps at will. And you can record your programs on magnetic cards for subsequent use anywhere.

The HP-65's 100-step program memory, in combination with its 51 pre-programmed arithmetic, logarithmic, trigonometric and exponential functions, its operational stack and its nine addressable memory registers, permits you to write exceedingly complex programs.

Its user definable keys let you program up to five routines using any of the machine's pre-programmed capabilities. You can also label portions of your program so the calculator can branch to a specific instruction or choose between alternate computational paths based on logical comparisons ($x=y$, $x \neq y$, $x>y$, $x \leq y$) or the condition of the HP-65's two flags.



The HP-65 also lets you use pre-recorded programs.

HP offers a series of pre-recorded program packages called Application Pacs at $45* each. Each Pac contains as many as 40 programs dedicated to a specific discipline. Our newest are Aviation, Marine Navigation and Finance. Also available are pacs for Electrical Engineering, Mathematics, Statistics and Medicine.

We also maintain a Users' Library of owner-contributed HP-65 programs which are itemized in catalogs distributed periodically to subscribing owners. Programs may be ordered from the Library for a small handling fee.

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INFORMATION RETRIEVAL NUMBER 80

Smart calculator now talks to computers

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 493-1501. $1000-1500; 8 wks.

The Model 11285A communications interface equips HP's Model 9830 calculator for data communications. The interface provides synchronous or asynchronous communications via an external modem that meets the EIA RS-232-C spec. The calculator acts as a terminal and can be equipped with the proper ROM for communication between calculators, calculator-to-IBM communication in remote batch mode, and time-share terminal communication. Two additional basic statements handle data transfer. Similar telecommunications capabilities have been available for some time with the System 2200 calculator from Wang Labs of Tewksbury, Mass.

CIRCLE NO. 270

Modem does 4800 bit/s on DDD with 50 ms start

Intertel, 6 Vine Brook Pk., Burlington, MA 01803. (617) 273-0950. $4700; 30 days.

A 4800 bit/s modem, the MCS 4800 operates on the direct-dial network or unconditional private lines. Features include a 50-ms adaptive equalizer split-stream operation of 1200 baud and 2400 bit/s and a low clear-to-send delay of 50 ms. In addition, the unit is claimed to provide error rates of one bit in 10^6 on simulated worst-case lines. The unit can also be commanded and tested from the central site while in operation.

CIRCLE NO. 271

Portable terminal has auto send/receive

Computer Devices, Inc., 9 Roy Ave., Burlington, Mass. 01803. (617) 273-1550. $3900.

Called the 1030 ASR Teleterm, this terminal uses a cartridge tape system, to enable it to perform most TTY ASR functions. The 1030 ASR contains two separate cartridges, Read and Write. Both cartridges may record or write information at speeds up to 30 char/s. Storage capacity per cartridge is 24,000 characters—enough for most applications. The portable terminal features a built-in acoustic coupler, noiseless thermal printing plus the parity check and full-duplex data transmission. Communication over voice grade telephone lines is at 110,150 or 300 baud.

CIRCLE NO. 272

Cassette data recorder has edit capability

Techtran Industries, 580 Jefferson Rd., Rochester, NY 14623. (716) 271-7953. From $889.

Capabilities of the 8400 cassette recorder include remote function control, character or line edit capability and search rates of 1000 char/s. Each cassette stores 145-k characters; transmit speed is switch selectable from 110 to 2400 baud. A MOS buffer permits partial rewind for editing and retransmission. The unit is plug compatible with most serial terminals or can be used with standard modems.

CIRCLE NO. 273

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for panel board and large equipment applications

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209 features

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Terminations: Solderless connector, screw or stud terminals.

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For more information about these compact, competitive Type 209 breakers, write for Airpax Bulletin 2012.

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Cambridge, Maryland 21613
Phone (301) 228-4600

INFORMATION RETRIEVAL NUMBER 83

40-column drum printer operates at 100 col/s

Practical Automation, Trop Falls Rd., Shelton, Conn. 06484. (203) 929-5381. $701.25 (100 quan); 4 wks.

With a 7 × 5 dot matrix, the DMTP-2 printer delivers 100 col/s with a 64-character ASCII set. A replaceable inked platen gives 200,000 print lines. Alternate options are use of pressure-sensitive paper or multiple copies. Interfaces for the DMTP-2 includes the bit-serial RS-232-C. The enclosed unit comes with print mechanism, power supply and interface electronics.

CIRCLE NO. 274

Interface puts BCD data to Tektronix calculator

Numonics Corp., Route 202 & Hancock St., North Wales, Pa. 19454. (215) 699-5762.

The Model 333 Interface inputs parallel BCD data to Tektronix TEK 21 or TEK 31 programmable calculators. Any instrument with parallel BCD TTL-compatible data output can be interfaced. The Model 333 enters data on the Display data bus of the calculator with up to 12 digits plus exponent and sign. The unit responds to the calculator's request for information. Two control signals are available for the inputting device: Flag indicates that valid data are ready on the data input lines; control indicates that the calculator has addressed the interface and is waiting for data. In addition, Model 533 interface is available for BCD calculator output.

CIRCLE NO. 275

Sideways printer has N-column capacity

Elec-Trol, Inc., 26477 N. Golden Valley Rd., Saugus, Calif. 91350. $428; stock.

Characters printed sideways give the Model PR1021 printer an N column by 26-line capacity. The throughput of this unit dubbed the sidewriter is 100 char/s. The unit measures 6 × 8 × 3-in. and weighs five lbs. Suggested uses include hardcopy for 80-column CRT terminals and digital instruments.

CIRCLE NO. 276

Accurate plotter uses internal processor

Glaser Data Co., 225 Forest Ave., Palo Alto, CA 94301. (415) 321-1348. $11,000. 60 to 90 days.

Built-in data-processing capabilities greatly reduce software and memory requirements for the DP-1500 plotter. Even programmable desk-top calculators can produce elaborate, precision drawings. The line-slope microprocessor in the plotter controls pen movements between two defined points. The DP-1500 offers an accuracy of 0.004 in. across the total 18 × 22.5-in. plotting table area, with speeds up to 2.8 in./s. The internal symbol generator can produce 55 different alphanumeric characters in response to standard ASCII codes. Size, position and direction of the symbols can also be selected at the same time. Four limit switches define allowable movements along the axes. The paper is held down by vacuum, and an optional paper advance is available for unattended drafting purposes. A wide variety of pens and papers can be used.

CIRCLE NO. 277

GIANT II

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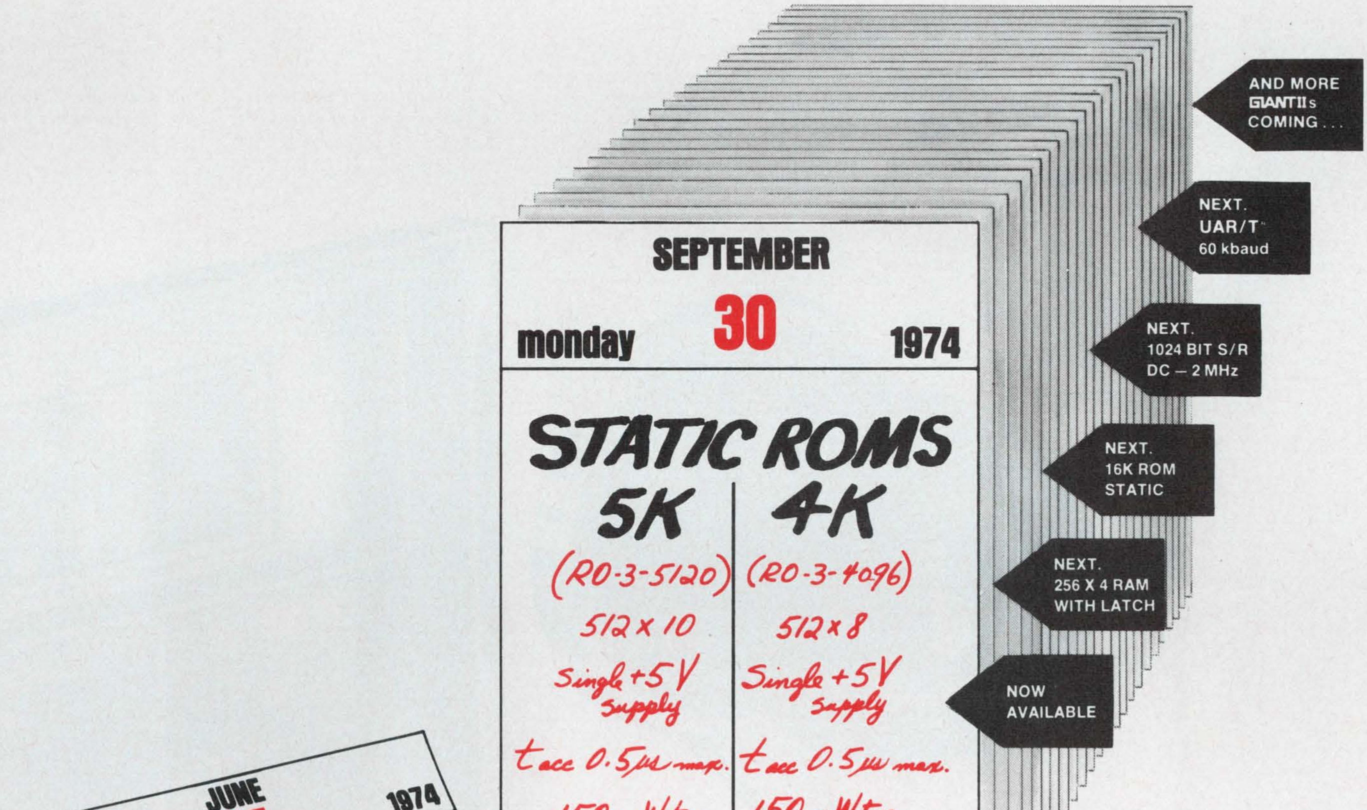
(CONT'D)



For complete information call toll-free 800-645-9247 (In New York State call 516-733-3107) or write, General Instrument Corporation, Microelectronics, 600 W. John St., Hicksville, N.Y. 11802

GENERAL INSTRUMENT CORPORATION MICROELECTRONICS

INFORMATION RETRIEVAL NUMBER 84

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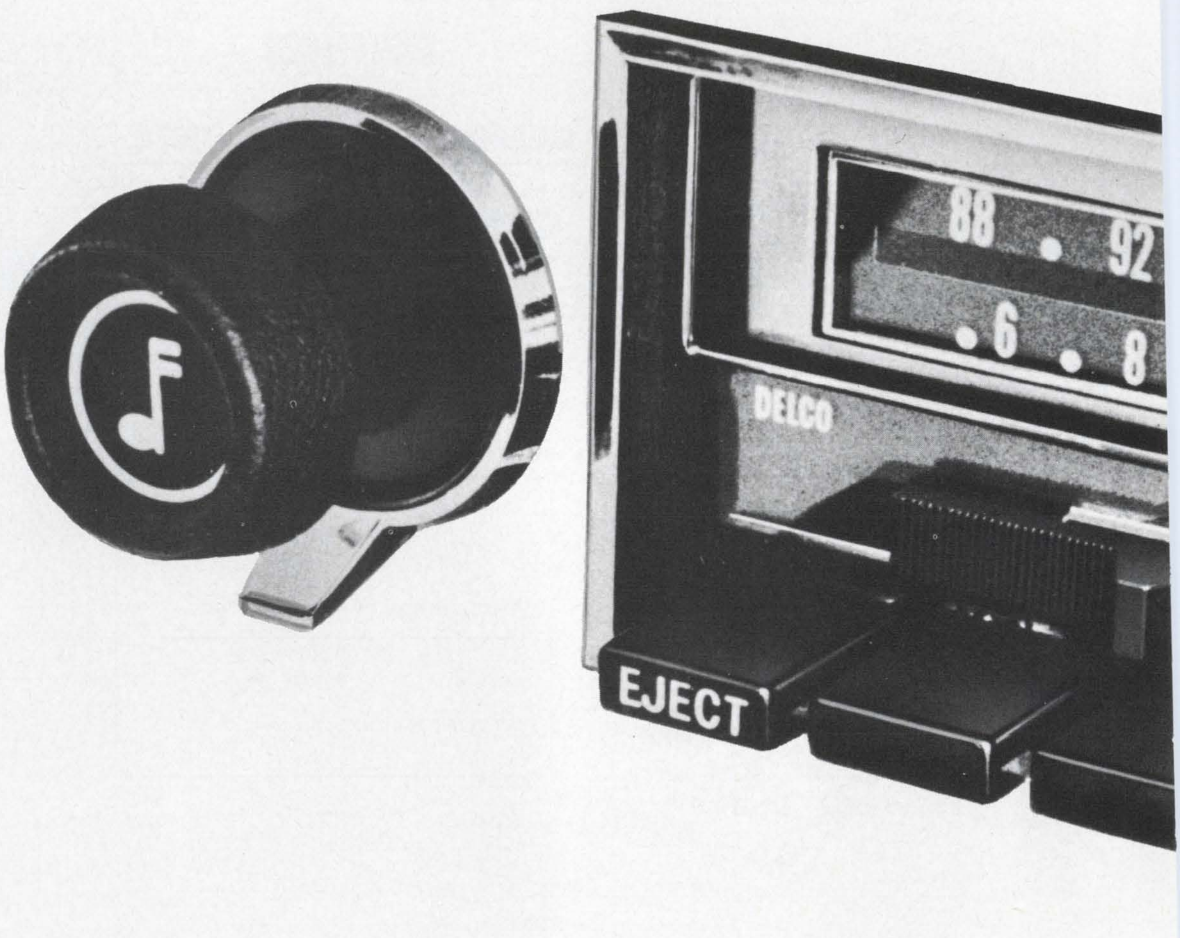

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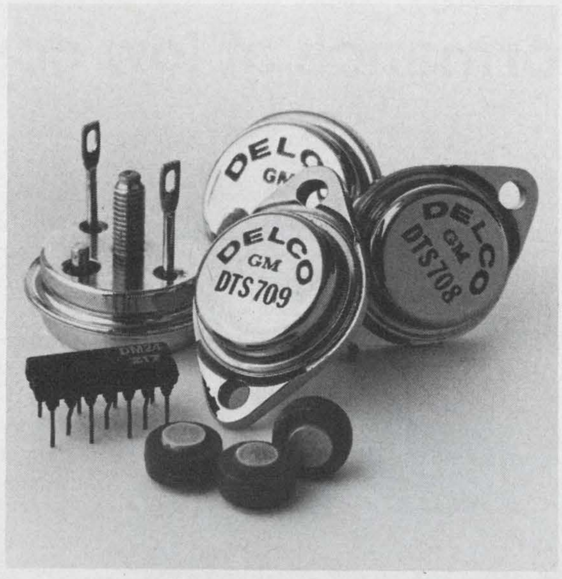

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DELCO ELECTRONICS

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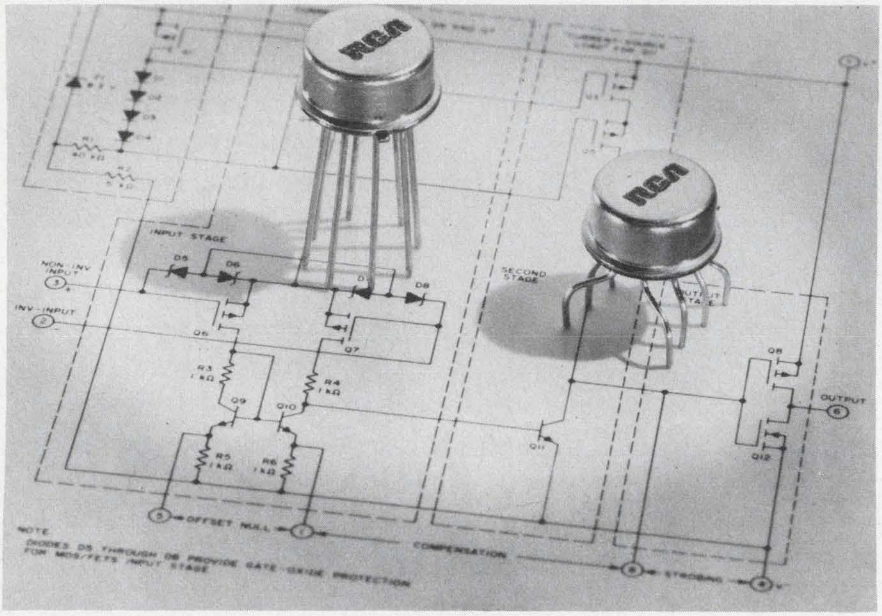
GM

INFORMATION RETRIEVAL NUMBER 86

MOS/bipolar monolithic op amp gives high performance at low cost



RCA Solid State Div., Route 202, Somerville, NJ 08876. (201) 722-3200. P&A: See text.

The first of a new series of linear ICs, the CA3130, comes one step closer to the ideal operational amplifier. RCA, the pioneer in CMOS circuits (trademarked as COS/MOS), has combined a high input impedance, wide bandwidth, high output current capability and high common-mode rejection by taking the best of MOS and bipolar technologies. All this at the attractive and unprecedented price of only $0.75 each in 1000-piece lots.

The CA3130 op amp has a MOSFET differential input stage with an impedance of $1.5 \times 10^{12}\ \Omega$—almost a million times higher than the 741 type op amp.

The output circuit is CMOS, which lets the output swing to within millivolts of ground or the power-supply levels. This feature lets you build accurate threshold detectors that are dependent only upon the supply voltage and the programming resistor. Standard op amps can't do this since their outputs reach only to within 1 V or so of the supply levels. The output can also sink or source a hefty current of 20 mA—about double that of ordinary IC op amps.

Input transistor matching has kept the input offset voltage to a super low 2 mV max on the premium version (3130B), and to a very reasonable 15 mV max on the commercial (3130). The low offset also means that the drift is low—only 15 μV/°C maximum and 10 μV/°C typical.

By using PMOS transistors instead of the usual lateral pnp bipolar transistors, engineers at RCA have given the 3130 a 15-MHz unity-gain crossover point. The main bipolar gain stage provides a slew rate of 10 V/μs—about the same as the new fast generation of 741 amplifiers.

Amplifier common-mode rejection—a spec most general-purpose op amps don't have—is a comfortable 90 dB typical. Furthermore, the 3130 can handle signal voltages that drop to below ground level—down to -0.5 V, even when operated from a single, positive power supply.

If rated input and power-supply voltage levels are observed, the amplifier is goof-proof. The CMOS output structure is inherently short-circuit protected. Active short circuit protection, used in most IC op amps deteriorates amplifier performance at high frequencies.

An additional feature of the output is a strobe capability which, for example, permits low power operation by letting you turn off the output transistors with a logic signal. And, since the CMOS output is operated in the Class-A mode, strobing can cut power consumption down to about 1 mA. The Class-A output also brings along another bonus—no crossover distortion at large signal levels. Most op amps available today use a form of Class-B output which creates some crossover distortion at large signal values.

A typical application of the op amp might be as a comparator; this is because of the low voltage capability on the output—voltages very close to ground can be measured with no interference from noise.

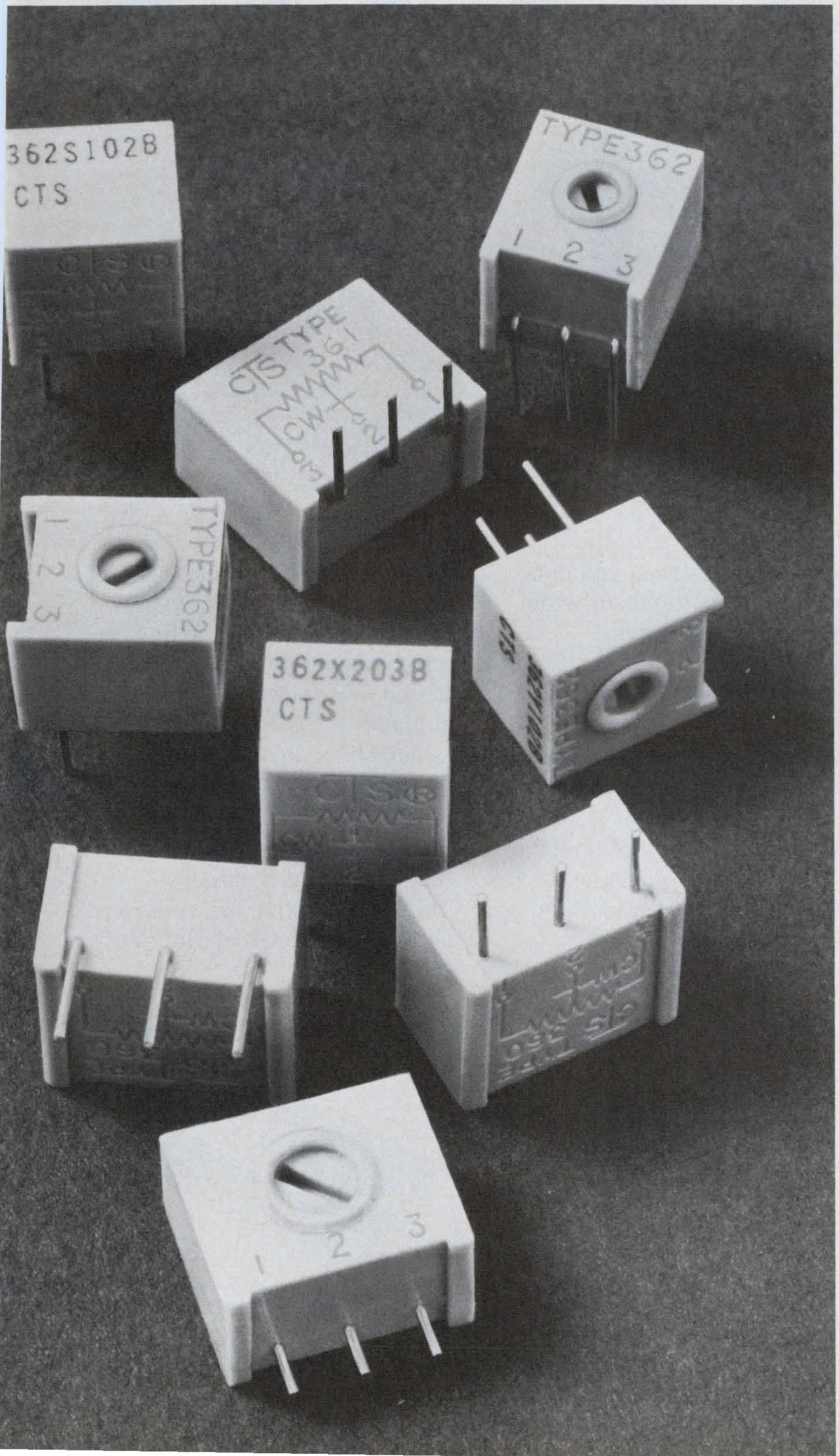
The output circuit of the CA3130 can be current boosted by use of additional linear CMOS arrays such as RCA's CA3600. These arrays can be paralleled almost indefinitely to get large current swings and still retain the strobing and short-proof features. There are three versions of the 3130 op amps available: the CA3130B, CA3130A and the CA3130. Prices for these units are $9.95, $2.95 and $0.75, respectively, in 1000-piece lots. All types are available from stock.

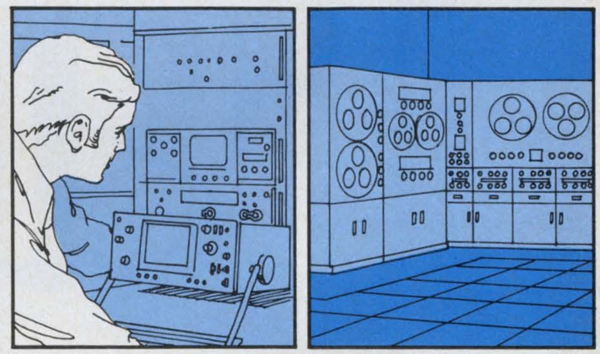
There are two package styles available, the standard TO-5 type case and the TO-5 with preformed DIP lead arrangement.

High reliability versions of the CA3130 series are also available for aeropsace, military and other critical applications. These units, noted with a slash (/), are supplied in any of six screening levels: /1N, /1R, /1, /2, /3 and /4—which correspond to MIL-STD-883 Classes A, B and C.

CIRCLE NO. 256

From instrumentation to computers, demanding OEMs turn to CTS for the best cermet trimmer values





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The SEMI 1217 offers two speed ranges: the basic 1217 accesses at 160 nsec, and the 1217A accesses at 135 nsec and cycles at 300. They also feature TTL compatible addresses and data, high impedance inputs, tri-state output, and a fully static memory cell.

The SEMI 1218 offers the highest speeds. The basic 1218 accesses at 120 nsec, and the 1218A accesses at 100 nsec, cycles at 225 nsec. They feature high-impedance TTL-compatible address and data inputs, and complementary outputs which may be wire OR'd.

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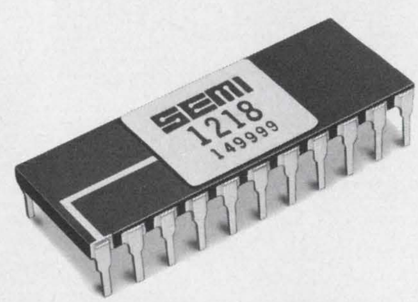
For full technical details, get in touch with your nearest EMM/SEMI office. Be sure to ask about our unique test procedures.



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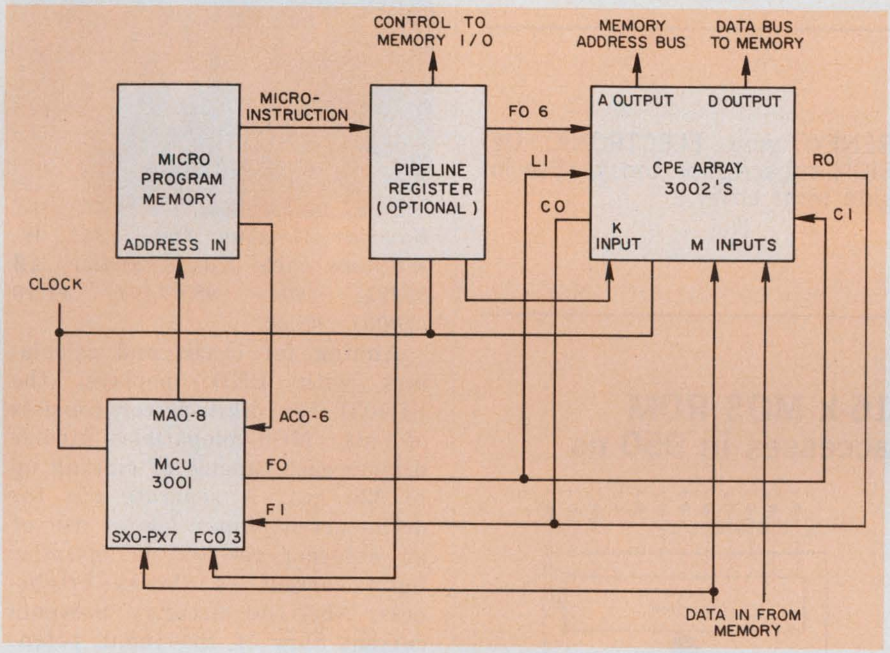
INFORMATION RETRIEVAL NUMBER 89

Bipolar microcomputer chips set the pace for flexibility



Intel, 3065 Bowers Ave., Santa Clara, CA 95051. (408) 246-7501. P&A: See text.

The newest microcomputer entry —Intel's 3000-Series LSI chip set —combines bipolar speeds with the exceptional flexibility provided by a 2-bit-slice configuration and LSI support circuits.

The improvements have been achieved at the expense of increased software development. Applications require microprogramming techniques, since Intel doesn't offer software support for the 3000 Series. However, various outside consulting organizations are expected to fill the software gap.

The LSI-chip set employs Schottky-TTL technology in a bit-slice configuration. Word lengths can be virtually any multiple of two bits, the length of the elemental processor slice. System cycle times, ranging from 120 to 300 ns, are comparable or higher than those of competing microprocessors, most of which use MOS technology.

Moreover, special ICs in the set can be used to obtain such benefits as simplified interfacing, improved interrupt handling and even increased processing speeds.

The only other bipolar/LSI processors that have been announced are the 6701 from Monolithic Memories (1165 E. Arques Ave., Sunnyvale, CA 94086) and the RP16 of Raytheon Semiconductor (350 Ellis St., Mountain View, CA 94042). The 6701 is a special-purpose processor for controller applications. It requires microprogramming techniques, as does the new Intel chip set. Raytheon's RP16, a seven-chip processor, doesn't require microprogramming, but it won't be available before the end of the year (see "FOCUS on Microprocessors," ED No. 18, Sept. 1, 1974, p. 52).

The Intel bipolar microcomputer includes these chips: the 3001 microprogrammable control unit (MCU), the 3002 central-processing element (CPE), the 3003 look-ahead carry generator and the 3214 interrupt-control unit. Also several mask and field-programmable ROMs are available for microprogram development and storage.

(continued on p. 186)

(continued from p. 185)

At the heart of the set is the 3002 CPE, a 2-bit processor slice with impressive features. Each CPE contains 11 general-purpose registers, an accumulator, bit-masking logic and main-memory "housekeeping" logic.

A microcomputer of any word length can be formed with the 3002 CPE, 3001 MCU and several memory circuits. For example, a 16-bit system entails the use of eight CPEs and an MCU, which selects microprogram words that operate the system.

With other circuits in the set, special features are available. For example, with the look-ahead carry generator, it is possible to overlap micro-instruction fetch and execution times to achieve a cycle time of about 120 ns. One 3003 generator can provide a fast carry over a complete 16-bit arithmetic section, or an array of eight CPEs.

Also each interrupt-control unit, interfaced with an MCU, provides eight levels of automatic priority interrupt. In a typical situation, the interrupted CPE array simply holds its register contents while the MCU controls processing of higher priority data in another CPE array. As a result this technique avoids both delays required to save interrupted data in memory and additional data-saving capacity.

Other chips in the set include the 3212 multimode latch buffer and the 3216 bidirectional bus driver. The buffer is an 8-bit-wide general-purpose I/O circuit, while the 4-bit-wide driver can be used to expand data busses.

The bipolar memories, with standard configurations, include a 4096-bit (512×8) pROM called the 3604. It has a typical access time of less than 70 ns. Other memories consist of a 1024-bit pROM (3601A) and ROM (3301A) and a 256-bit RAM with three-state output (3106).

All units are available from production, except for the 3003 carry generator, 3216 bus driver and 3604 4-k-bit pROM. The latter three ICs are expected shortly.

Total cost of the MCU and eight CPEs is less than $200 in hundred quantities. For system development, Intel supplies a kit containing design information along with the LSI building blocks and memory circuits. The kits cost $720 each.

Intel

CIRCLE NO. 252

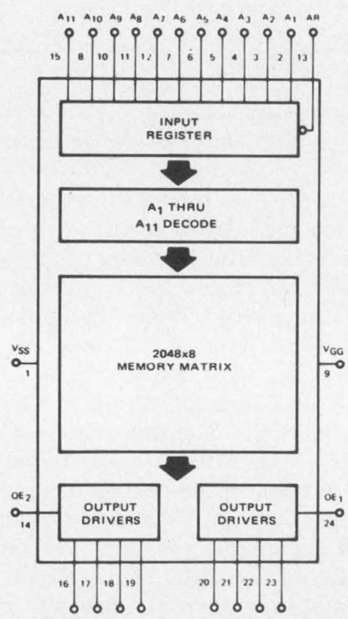
Monolithic Memories

CIRCLE NO. 253

Raytheon Semiconductor

CIRCLE NO. 254

16-k MOS ROM accesses in 950 ns

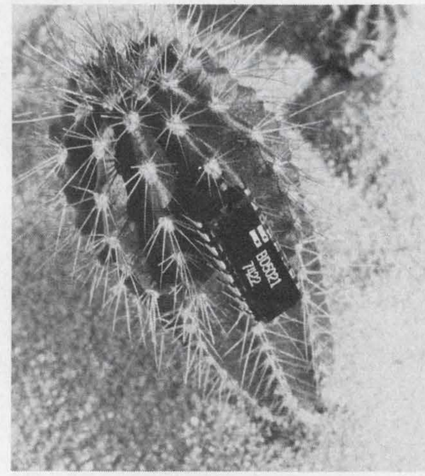


Electronic Arrays Inc., 550 E. Middlefield Rd., Mountain View, Calif. 94043. (415) 964-4321. $28 (100); 6 to 8 wks.

Maximum access times of 950 ns are guaranteed with a 16,384-bit MOS ROM called the EA 4900. The static ROM requires no clocks, includes decoding circuits on the chip and needs no external pull-up resistors for connection to TTL circuits. The ROM uses only two power supplies of +5 and −12 V. Power dissipation is 0.032 mW per bit.

CIRCLE NO. 278

LED driver sinks 320 mA per digit



Bowmar Arizona Inc., 2355 W. Williams Field Rd., Chandler, AZ 85224. (602) 963-7361. $1.20 (1000); stock.

Aiming for clocks and calculators with LED displays, the BD5021 hex digit driver consists of six MOS-compatible bipolar drivers each capable of sinking up to 320 mA. A separate pin for drive-current input allows use of an external resistor to optimize input current vs display brightness. Also the circuitry prevents current flow if the input potential becomes negative.

CIRCLE NO. 279

UART simplifies communication networks

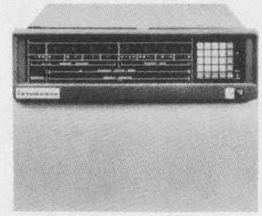
American Microsystems, Inc., 3800 Homestead Rd., Santa Clara, Calif. 95051. (408) 246-0330. $6.50 to $9 (100-999).

The S1883 universal asynchronous receiver/transmitter, or UART, totally replaces the interface between a word-parallel controller or data terminal and an asynchronous bit serial communication network. Packaged in a single 40-pin DIP, the S1883 can transmit and receive in a full duplex mode at data rates up to 12.5-k baud. Complete character framing is accomplished with a start bit; 1, 1.5, or 2 stop bits; and an odd or even parity bit if required, under program control. Both the transmitter and receiver are double buffered. Parity error, framing error and data overflow status conditions are available to ensure correct data transmission.

CIRCLE NO. 280

INTERDATA ANNOUNCES THE INDUSTRY'S FIRST 32-BIT MINICOMPUTER FOR UNDER $10,000.

WITH UP TO A MILLION BYTES OF DIRECTLY ADDRESSABLE MEMORY.



Performance	7/32	Nova 840	PDP-11/40
Word length	32	16	16
Memory speed (nanoseconds)	750	800	900
Maximum memory capacity (bytes)	1,048,576	262,144	262,144
Addressing range (bytes) Direct Relative Indexed Double indexed	1,048,576 ±16,384 1,048,576 1,048,576	512 ±256 65,536 No	65,536 ±32,768 65,536 No
General-purpose registers	32 32-bit	4 16-bit	8 16-bit
Index registers	30 32-bit	2 16-bit	8 16-bit
Vectored interrupt levels	Yes	No	Yes
Minimum interrupt overhead time (usec)	6.5	47.5	46.5

Price	7/32	Nova 840	PDP-11/40
32 KB processor 64 KB processor 128 KB processor 256 KB processor	$ 9,950 14,450 23,450 41,450	$12,930 19,330 35,630 61,230	$15,345 26,925 44,725 80,825
1 Megabyte processor	171,650	Not available	Not available

Source: Data General Price List, 5/15/73. DEC PDP-11/40 Price List, 6/73. DEC OEM & Product Services Catalog, 1972. Auerbach Minicomputer Characteristic Digest, June, 1973. "How to use Nova Computers", 1973.

Minicomputer myths you can live without:

1. There's no such thing as a 32-bit minicomputer.

2. Minicomputers have an absolute 64K addressing limit.

3. The only way to even access more is to resort to some sort of hardware kluge with a hairy software scheme that'll cost you an arm and a leg.

All wrong.

Because now there's the Interdata 7/32 – a powerful new 32-bit minicomputer with main memory expandable up to a million bytes and direct addressing up to 16 million bytes.

Big it is. But hairy it isn't.

Because it's simple, straightforward and efficient. And it's the industry's first uncomplicated extended-memory software environment.

Backed up by a lot of hardware muscle like thirty two, 32-bit registers, 1024 I/O interrupts with automatic vectoring, 239 instructions. And a lot more. All of which would lead you to expect to pay a lot more money, right? Well, that's also a myth.

The software muscle is all there, too. A new FORTRAN V compiler. An optimizing assembler called CAL. And the first extended operating system that's both powerful and simple – OS/32. Plus all the other field-proven Interdata software – it's all compatible.

The new Interdata 7/32.

We put our muscle where their myth is.

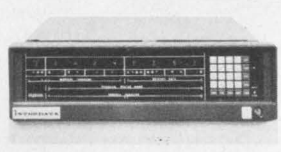
INTERDATA®

2 Crescent Place, Oceanport, New Jersey 07757 (201) 229-4040.
Boston – (617) 890-0557. Washington – (703) 525-4806. Philadelphia – (215) 436-5579.
Orlando – (305) 851-6962. Chicago – (312) 437-5120. Detroit – (313) 356-5515.
Dayton – (513) 434-4193. Kansas City – (913) 384-1606. Houston – (713) 783-3060.
Dallas – (214) 238-9656. Denver – (303) 758-0474. Los Angeles – (213) 640-0451.
Phoenix – (602) 968-2477. San Diego – (714) 565-0602. San Francisco – (415) 969-1180.
Seattle – (206) 455-0680. Toronto – (416) 677-8990. Tokyo – (270) 7711.
Sydney – 439-8400. London – Uxbridge 52441. Munich – 0811-8543887.

7/32 minicomputers scheduled for delivery July, 1974: On Time.

INTERDATA ANNOUNCES THE INDUSTRY'S FIRST $3200 MINICOMPUTER TO CHALLENGE THE NOVA.

PDP-11 PERFORMANCE AT A NOVA 2 PRICE.



Performance	7/16	Nova 2/4	PDP-11/05
Data word length (bits)	4, 8, 16	16	1, 8, 16
Instruction word length (bits)	16, 32	16	16, 32, 48
General-purpose registers	16	4	8
Hardware index registers	15	2	8
Maximum memory available (K-bytes)	64	64	64
Directly addressable memory (K-bytes)	64	2	64
Automatic interrupt vectoring	Standard	Not available	Standard
Parity	Optional	Not available	Special order
Cycle time (usec.)	1.0 or 0.75	1.0 or 0.8	0.9
Available I/O slots	4	2	2

Price	7/16	Nova 2/4	PDP-11/05
8 KB processor 16 KB processor 32 KB processor	$3,200 3,700 5,300	$3,200 3,700 5,300	$4,795 6,495 10,895
Multiply/Divide option	$950	$1,600	$1,800
Floating Point option	$4,900	$4,000 plus $1,000 for 2/10 configuration	Not available

Source: Data General Price List, Copyright 1973, and addendum dated 5/15/73. Nova 2/4 bulletin 012-000060, 1973. DEC OEM & Product Services Catalog, 1972. Auerbach Minicomputer Characteristic Digest, June, 1973. "How to use Nova Computers", 1973.

Minicomputer myths you can live without:

1. There is no such thing as a high-performance, low-cost minicomputer.

2. You have to choose between two extremes – pay a ton for a machine like the PDP-11 and save on software costs, or buy a cheapie like the Nova 2 and pay the price later.

All wrong.

Because now there's the Interdata 7/16 – an extremely flexible 16-bit OEM minicomputer that combines the best of both worlds.

It's easier to program than the PDP-11 because it has 16 hardware registers, up to 64K bytes of directly addressable main memory, 255 I/O interrupts with automatic vectoring to service routines and a comprehensive set of more than 100 instructions. That's a lot of muscle.

It's completely modular in design – plug-in options can be installed in the field to meet your specific application requirements.

Options like multiply/divide, programmers' console with hexidecimal display, power fail/auto restart, memory protect and a high-speed Arithmetic Logic Unit that includes floating point hardware. In fact, you can expand the low-cost 7/16 all the way up to the 32-bit Interdata 7/32.

Yet it costs as little as $3200. Just like the machines that give you the barest minimum. And quantity discounts can reduce that low price by as much as 40%.

So you no longer have to make the painful choice between good performance and good price. Or between hardware economy and software efficiency. Now you have a minicomputer that gives you both.

The Interdata 7/16.

We put our muscle where their myth is.

INTERDATA®

2 Crescent Place, Oceanport, New Jersey 07757 (201) 229-4040.
Boston – (617) 890-0557. Washington – (703) 525-4806. Philadelphia – (215) 436-5579.
Orlando – (305) 851-6962. Chicago – (312) 437-5120. Detroit – (313) 356-5515.
Dayton – (513) 434-4193. Kansas City – (913) 384-1606. Houston – (713) 783-3060.
Dallas – (214) 238-9656. Denver – (303) 758-0474. Los Angeles – (213) 640-0451.
Phoenix – (602) 968-2477. San Diego – (714) 565-0602. San Francisco – (415) 969-1180.
Seattle – (206) 455-0680. Toronto – (416) 677-8990. Tokyo – (270) 7711.
Sydney – 439-8400. London – Uxbridge 52441. Munich – 0811-8543887.

7/16 minicomputers scheduled for delivery February, 1974: On Time.

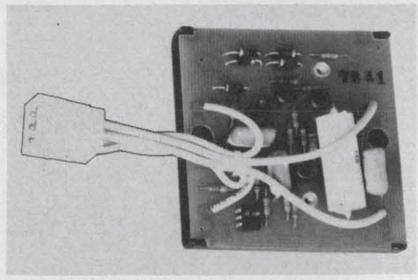
D/a converter operates over full MIL temp span

Hybrid Systems, 87 Second Ave., Burlington, MA 01803. (617) 272-1522. From $95 (unit qty); 4 to 6 wk.

The DAC365 series, a family of multiplying d/a converters, performs accurately over the full MIL temperature range of −55 to +125 C. The temperature coefficients of linearity and accuracy are 1 ppm/°C and 6 ppm/°C, respectively. These converters are available with linearities of 0.2%, 0.05% and 0.0125%, depending on model—but all versions provide 12-bit resolution. Some of the performance specifications include: Input codes, binary and offset binary; FS output, 0 to 10 V (unipolar), ±10 V (bipolar) and reference input, ±10 V, dc to 1 kHz. All models contain a stable internal reference to cover applications that do not require the multiplying feature.

CIRCLE NO. 281

Solid-state relay switches 6-A loads

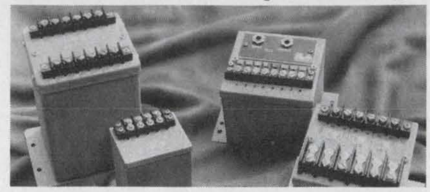


Sys-Tec, Inc., 877 Third St. S.W., New Brighton, MN 55112. (612) 636-6373. $24 (large qty).

The SR-151 zero-crossing solid-state relay/switch operates from 3-to-5-V-dc power supplies. It draws only 18 mA and can switch on a 6 A load of 10 to 120 V rms at a zero voltage cross-over point, and switches it off at a zero current cross-over point. Model SR-151s are currently being used in equipment that conforms with military specification #461-IIB. Typical applications include office machines, military equipment, computer peripherals, security areas and medical equipment.

CIRCLE NO. 282

Electrical transducers handle wide input range

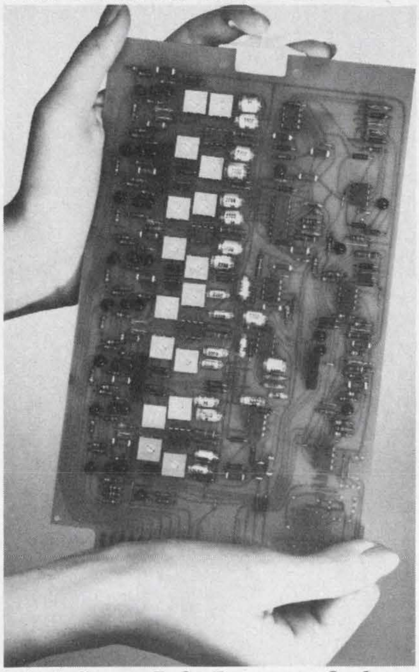


General Electric, 727 Lynnway, Lynn, MA 01910. (617) 594-0100. $78 to $425; 6 wk.

A line of small electrical transducers accepts a variety of ac inputs—including watts, vars, voltage, current, frequency, power factor/phase angle and temperature. The transducers convert these inputs, to a proportional 1-mA max dc output signal. Temperature influence on the transducers has been reduced to less than ±0.5% over a range of −20 to +65 C. Any load resistance from a short-circuit to 10 kΩ can be applied without affecting accuracy. Each unit also meets IEEE surge withstand capability (SWC) standards for reliable field performance.

CIRCLE NO. 283

Telephone-tone receiver has built-in checks

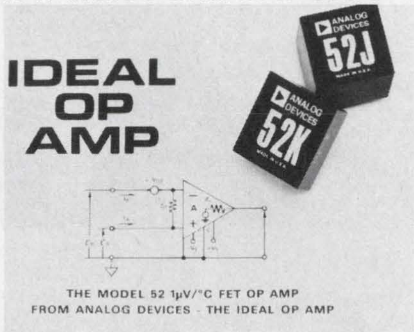


Mitel Corp., P.O. Box 704, Ogdensburg, N.Y. 13669. (613) 836-2118. $140 (1000-up).

The CM7208 telephone tone receiver is fully compatible with the accepted telephone industry tone signalling system. The CM7208 can be used in central offices, PBX's or for end-to-end signalling. It has ac-coupled balanced inputs of 50 kΩ, and operates from a 12 or 15 V supply. A low talk-off rate is assured through multiple signal quality checking circuitry and a frequency pre-emphasis circuit that detects the third formant frequency of voice signals.

CIRCLE NO. 284

FET op amp combines low noise and low drift

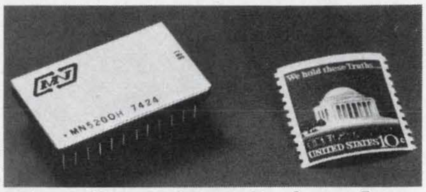


Analog Devices, P.O. Box 280, Rte. 1 Industrial Park, Norwood, Mass. 02062. (617) 329-4700. 52J: $42, 52K: $49; stock.

The Model 52K FET input op amp combines low noise (1.5 μV pk-pk from 0.01 to 1 Hz) with a low (±1 μV/°C max) offset drift. It has a high CMRR of 100 dB minimum, a guaranteed minimum open loop gain of 120 dB and ultra-low, −3 pA maximum, input bias current. The amplifier measures 1.12 × 1.12 × 0.4 in. and has a maximum noise current of 0.1 pA pk-pk. Unlike most low-drift amplifiers, the voltage drift of the Model 52K is not affected by the initial offset voltage (0.5 mV maximum is trimmed). The input bias current is held constant over the entire ±10 V common-mode voltage range. The amplifier is free from latch up when the common mode voltage range is exceeded. Warm-up drift of the amplifier after five minutes is 5 μV. Long term offset stability is 5 μV/month. Dynamic characteristics of the 52K include: 500 kHz bandwidth, ±5 mA minimum output current and 150 μs settling time to ±0.01%.

CIRCLE NO. 285

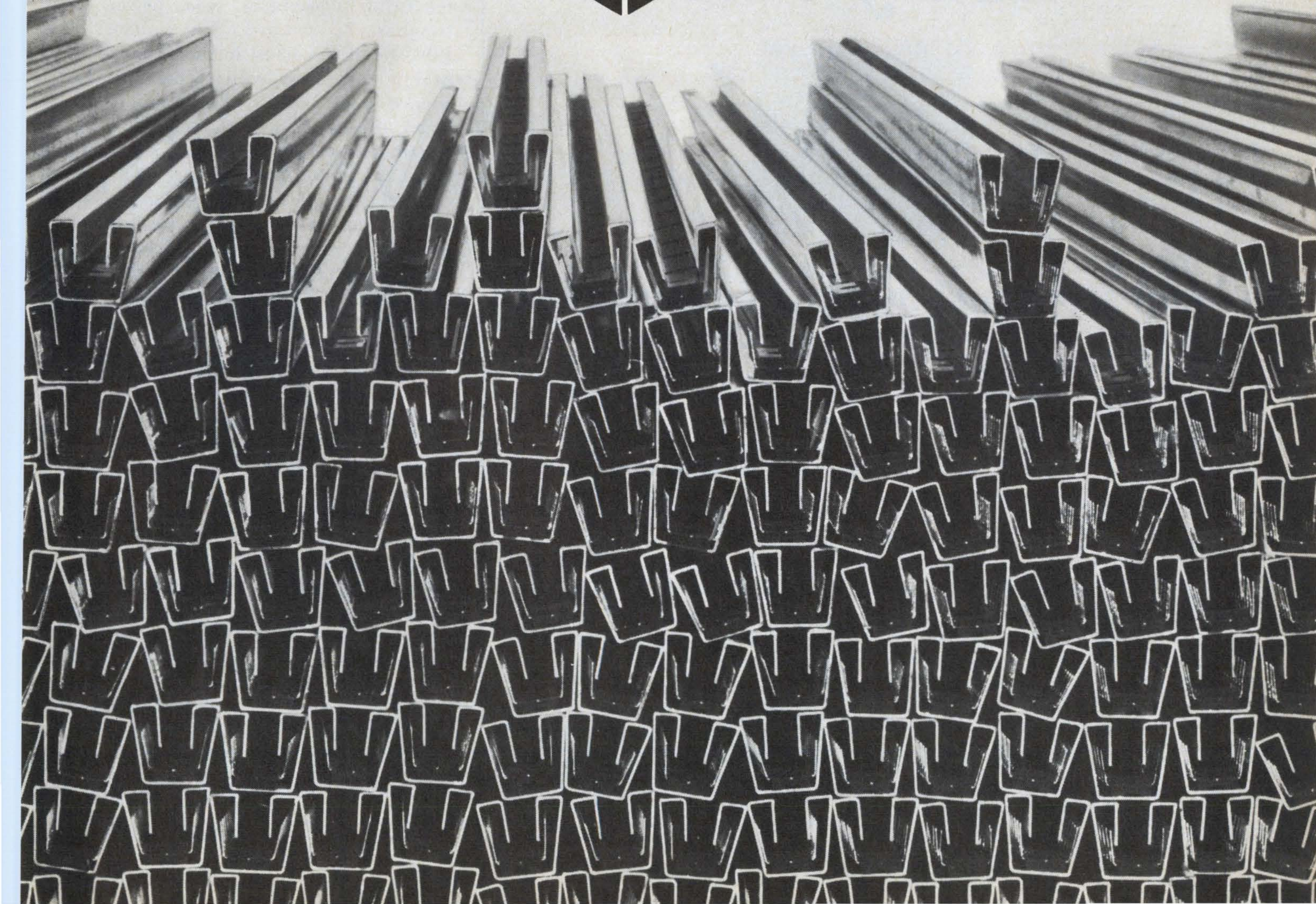
DIP sized a/d converters work over MIL temps



Micro Networks, 5 Barbara Lane, Worcester, Mass. 01604. (617) 753-4756. From $225 (unit qty.); 2 to 9 wk.

The MN5200H series 12-bit a/d converters are housed in 24-pin DIP sized cases and are rated for operation over the full military temperature range of −55 to +125 C. They are also guaranteed to hold ±1/2 LSB linearity over the full range. The DIP packaged units are available in three input voltage ranges: MN5200H, 0 to −10 V; MN5201H, −5 to +5 V; and MN-5202H, −10 to + 10 V. The units are housed in 24-pin hermetically sealed glass DIPs, 1.25 in. long and 0.79 in. wide. Pins are spaced in two rows, on 0.1 in. centers 600 mils apart and fit standard double-DIP IC sockets. The units have a maximum conversion time of 50 μs. the converters operate from ±15 to +5 M supplies, and consume 700 mW. The units provide both serial and parallel outputs and are complete with internal reference. They can operate either in a continuous conversion mode or on command by a "start" convert pulse. The MN5200H series is designed to meet the environmental and reliability requirements of military applications. It can be ordered to MIL-STD-883 Class B requirements.

CIRCLE NO. 286



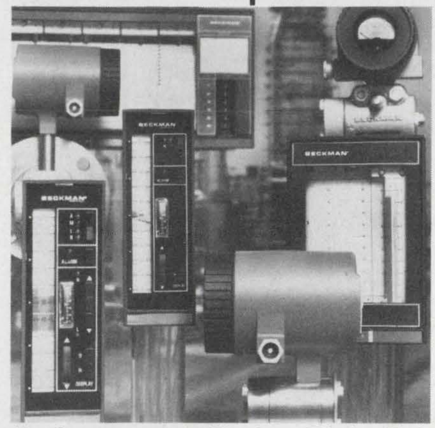
Chopper preamp has tempco of 0.03 $\mu V/°C$

Analogic, Audubon Rd., Wakefield, Mass. 01880. (617) 246-0300. $59 (unit qty); stock.

The MP221 chopper preamplifier is specifically designed for instrument and industrial applications with signals in the microvolt to millivolt region. The unit's specifications include a low drift offset tempco of 0.03 $\mu V/°C$ typical, a bias tempco of 2 pA/°C and low noise bandwidth (less than 0.1 μV pk-pk from dc to 1 Hz). The MP221 has a common-mode rejection ratio of 140 dB, a six-sided shield and a built-in current offset trimmer. It can be used with gains to 10,000 for signals as low as 1 mV full-scale. Physically, the unit measures 2 × 1 × 0.39 in.

CIRCLE NO. 287

Process controllers meet wide requirements



Beckman, 2500 Harbor Blvd., Fullerton, CA 92634. (714) 871-4848.

Three process controllers in the 8800 series include auto/manual, supervisory and direct digital control units. All use a combination of analog and digital circuits to give bumpless operation with any type of transfer. Augmenting the controllers are panel-mounted accessories for process indication, manual loading, auto/manual, auto/manual with bias, ratio, DDC manual backup and necessary mounting equipment and power supplies. To complete the control function, the series includes computing modules which perform square root, squaring, function-generation, integration, summing, multiplication and high/low selection functions. Four types of variable-reluctance transmitters measure differential pressure, absolute pressure, gauge pressure and level. Various diaphragm materials permit transmitters to accommodate a number of process fluids. The level transmitters come with various flange sizes, ratings, or material with extended diaphragms to match different wall thicknesses. The transmitters have 4 to 20 mA or 10 to 50 mA outputs. The process control instruments are designed to meet the intrinsic-safety requirements of the National Fire Protection Association. They have been submitted to Underwriters Laboratory for evaluation. The control room equipment meets Class I, Group D, Division 2 requirements. The transmitters meet Class I, Groups C-D, Division I requirements by enclosure design, and can be used with intrinsic barriers to meet Class I, Groups B, C or D, Division I requirements.

CIRCLE NO. 288

New Simpson 360 Digital VOM

Handy and rugged enough for the field — accurate and versatile enough for the lab. And its simplicity and readability make it perfect for production line testing.

- 3-1/2" digit, non-blinking, auto-polarity 0.33" LED display
- AC line or battery operation
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- Analog indicator for scanning nulls and peaks
- Analog output signal permits interfacing with recorders and other instruments
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Supplied with test leads, AC line cord, operator's manual, without batteries **$295**

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ORDER NOW FROM YOUR LOCAL ELECTRONICS DISTRIBUTOR OR WRITE FOR NEW CATALOG 4200

INFORMATION RETRIEVAL NUMBER 101

Bridge conditioner can automatically balance

Unholtz-Dickie, 3000 Whitney Ave., Hamden, Conn. 06518. (203) 288-3358.

Model D22PMB direct coupled bridge conditioner does automatic bridge balancing in less than 1 s, and simple gain normalization for calibration of outputs. It is designed for use with strain gauges, thermocouples and piezoresistive accelerometers. The conditioner provides internal bridge excitation, space for bridge completion and shunt calibration resistors and selectable low-pass filtering. Operation with piezoelectric accelerometers is possible when a remote preamplifier is used. Options include log dc output and computer-controlled ranging.

CIRCLE NO. 289

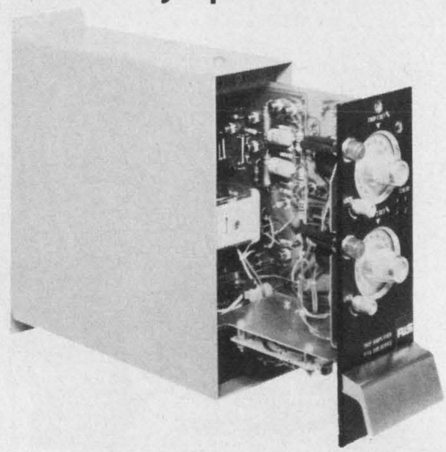
DACs offer choice of temperature coefficients

Datel Systems, Inc., 1020 Turnpike St., Canton, Mass. 02021. (617) 828-8000. -R: $69 to $79; -TR: $129 to $179; stock to 6 wk.

The DAC-R and DAC-TR series of d/a converters have 5 μs settling times. The converters are available in two different temperature stabilities: DAC-R units have 30 ppm/°C gain temperature coefficients with 10 μV/°C zero temperature coefficient; DAC-TR models have 5 ppm/°C gain tempcos and 10 μV/°C zero tempcos. All models have five programmable output voltage ranges set by external pin connection. Unipolar and bipolar output voltage ranges are 0 to +5, 0 to +10, ±2.5, ±5 and ±10 V. Input coding is complementary binary or complementary offset binary. Complementary BCD models are also available. Output voltage accuracy is externally adjustable to 0.01% of full scale ±1/2 LSB. Output current capability is 0 to ±5 mA at 0.02 Ω output impedance. The converters are encapsulated in a 2 × 2 × 0.375 in. module with DIP compatible 0.1 in. pin spacing. Input power requirement in ±15 V ds at 40-mA maximum and +5 V dc at 15-mA maximum.

CIRCLE NO. 290

Plug-in electronic alarm has many options



Rochester Instrument Systems, Inc., 275 N. Union St., Rochester, N.Y. 14605. (715) 325-5120.

The PTA-204 is a plug-in electronic alarm for direct thermocouple or millivolt inputs. The alarm provides a dpdt relay output as standard, and is furnished with a 1% fixed deadband. Variations include Model PTA-208, with a 1 to 100% variable deadband, and Model PTA-205, with dual set points and a fixed deadband. Contacts for all models are rated at 240 V ac, 3 A, resistive. Set point and deadband adjustment are made via front-mounted dials calibrated in divisions equivalent to the span of the input signal. The alarms are available with a choice of two power sources: 115/230 V ac or 24 V dc. Response time for the units is less than 200 ms. The units are available for wall, panel or standard rack mounting.

CIRCLE NO. 291

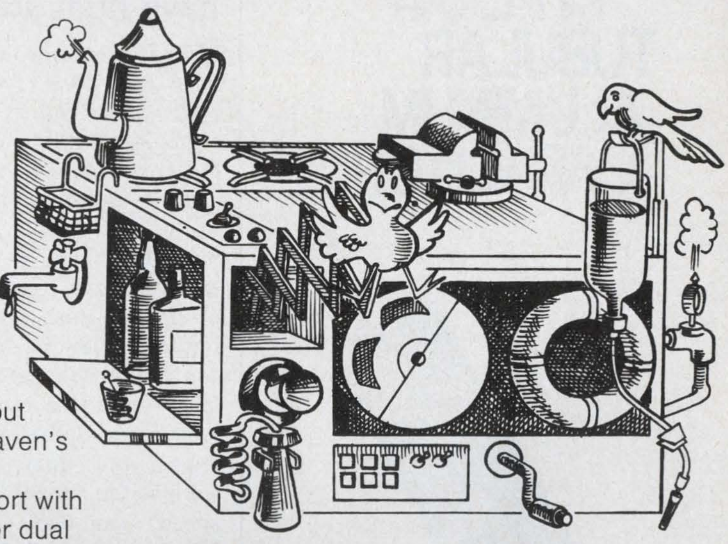
Remote ac power control handles up to 1500 W

Touch-Plate Electro Systems, 16530 Garfield Ave., Paramount, Calif. 90723. (213) 633-0701. From $29.-90; stock.

The Touch-Plate RC series units convert any standard 120-V-ac outlet into a remote power source. Two basic versions are available: a wired model that can be used up to 200 ft. away from the equipment it controls and a wireless radio-transmitted unit with a wider range. Both can control up to 1500 W. The units typically measure 6.25 × 3.75 × 2.25 in. and weigh 2 lb.

CIRCLE NO. 292

The No-Nonsense Vacuum Column Transport

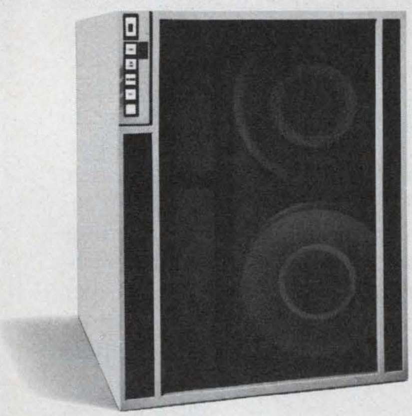


Introducing the T9000.
You can tell the difference just by listening.

A lot of manufacturers have a "run it up the flagpole and see if anybody salutes" kind of attitude about products. At Pertec, we ask customers what they want. Then we design to fill the gaps that our OEM customers feel will broaden *their* lines, increase *their* system marketability.

"What about a more basic vacuum column transport?" many asked. "Something with features we need but fewer bells and whistles, more cost effective, and for heaven's sake something quieter."

So we developed the T9000. A no-nonsense transport with Pertec design simplicity. It moves 25-75ips, with single or dual format electronics and a reel anti-twitch feature that not only minimizes tape wear, but keeps reels still when you expect them to be. With easy threading, editing and optional daisy-chaining. We've even succeeded in minimizing tape contamination by maintaining a positive pressure in the tape compartment area. And it's so quiet you won't believe it uses vacuum columns.



But the biggest benefit of the T9000 is that it's the kind of drive with the kind of reliability you expect from Pertec. It runs and runs and runs. And if it happens to run down, you can look to worldwide Pertec service, spares and support.

If your systems have to move tape, look to the company that moves more tape transports than any other independent manufacturer in the world.

Take a look at the non-nonsense T9000. There is a difference.

For more information, call us collect in the area nearest you: Boston (617) 890-6230; Chicago (312) 696-2460; Los Angeles (213) 996-1333; London (Reading) (734) 582115. Or write us at 9600 Irondale Avenue, Chatsworth, California 91311.

PERTEC

You can tell the difference just by looking.

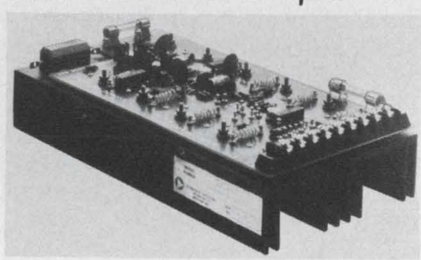
Clock oscillators have high stability

MF Electronics Corp., 118 East 25th St., New York, N.Y. 10010. (212) 674-5360.

Models 5420 and 5421 clock oscillator modules are hermetically sealed, and are intended for military applications. Frequencies are available from 4 to 50 MHz, and the units are IC-size, with a height of 0.3 in. Both operate at −55 C, but the 5420 is specified at 85 C for 0.005% stability, while the 5421 operates to +125 C for 0.0075%. Some units have rise times and duty cycles that are compatible with the 54H (high speed) and 54S (Schottky) series TTL (units with frequencies above 10 and 20 MHz, respectively).

CIRCLE NO. 293

Servo amplifier delivers 525 W within 40 μs

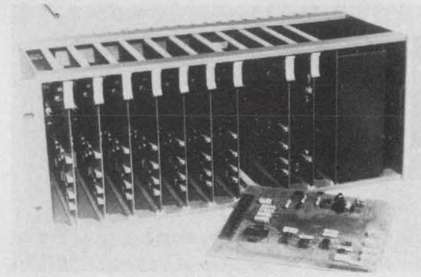


Torque Systems, 225 Crescent St., Waltham, Mass. 02154. (617) 891-0230.

The Model PA-601 dc servo amplifier provides 525 W of output. It consists of an op amp driving a class B power output stage. It features a high output slew rate capable of delivering full power within 40 μs after a step input command. In addition to providing its own heat sink and provision for optional fan and mounting bracket, the PA-601 has standoffs which allow the user to add components for current or voltage feedback as well as for servo compensation directly to the amplifier circuit board. Power requirements for the PA-601 are ±40 V at ±15 A. The unit provides a bipolar output with an output rating of 35 V minimum at 15 A. Both current limiting and thermal overload protection are built-in.

CIRCLE NO. 294

Multichannel servo uses plug-in modules



Moog Inc., Controls Div., Proner Airport, East Aurora, N.Y. 14052. (716) 652-2000.

The Model 127-101 motherboard servocontroller frame provides easy and compact servocontroller hookup. The motherboard servocontroller frame provides: convenient servoelectronics packaging, system flexibility and expandability—servocontrollers are tailored to the needs of specific systems, eliminates interconnections between control modules and easy installation, maintenance and replacement of circuit cards. Model 127-101 motherboard accepts up to 10 individual plug-in circuit cards to form a complete servocontroller. Commonality of power supplies, a wide choice of functions, convenient screw-type interconnections are additional features. The motherboard, with or without cover panel, fits into a standard 19 in. (48.06 cm) rack mount control console.

CIRCLE NO. 295

D/a converter has internal input register

Analog Devices, Rte. 1 Industrial Pk., P.O. Box 280, Norwood, Mass. 02062. (617) 329-4700. $80 (100-up); stock.

A 12-bit, 2× 4 × 0.4 in. d/a converter includes an input storage register and an output amplifier with five programmable voltage output ranges. The unit has a gain temperature coefficient of ±20 ppm/°C and settling time to 0.01% of 5 μs. The TTL/DTL compatible DAC1118 can be ordered with either binary, offset binary, BCD, or two's-complement input codes. The DAC1118 is specified for operation from 0 to 70 C. It has a ±1/2 LSB maximum linearity error and a ±2 ppm/°C differential linearity temperature coefficient.

CIRCLE NO. 296

INFORMATION RETRIEVAL NUMBER 105 ▶

Telephone coupler starts or stops recorders

Metro-Tech Electronics, 3338 Olive St., St. Louis, Mo. 63103. (314) 533-9970. $24.95; stock.

Model AID is a coupler that allows remote activation of any tape recorder—directly—at any point on the telephone line. The lifting of any telephone receiver on the connected line will activate the tape recorder. This allows automatic recording of all incoming and outgoing calls without unnecessary drain on batteries and tape waste. The unit is completely silent and does not change the clarity or volume of the conversation. Some states, though, prohibit recording of conversations without both parties' advance agreement. AID does not emit an audio beep. Its size is 1 × 1 × 1.25 in.

CIRCLE NO. 297

Sequence controller switches ac power

Libra Systems, 1055 W. Germantown Pike, Fairview Village, PA 19409. (215) 631-0900. $130 (1 to 4).

The Model 1033 sequence controller is designed to periodically connect the ac line voltage to as many as 16 different loads for controlled periods of time. The current requirements of each load can range up to 8 A. The period of time the load is energized and the rate each load is pulsed are set by appropriate controls on the circuit card. System operation and status are displayed by an array of neon lamps. The Model 1033 is covered with a polystyrene coating for protection from severe weather. The system is capable of withstanding temperatures from −55 to +125 C.

CIRCLE NO. 298

Multifunction module has wide dynamic range

Intronics, 57 Chapel St., Newton, Mass. 02158. (617) 332-7350. From $75 (1 to 9); 6 to 8 wk.

The MF433 series of analog function modules perform the very useful operation $Y(Z/X)^M$, where "M" is an exponent that can be continuously varied from 1/5 to 5. Log function techniques are used to keep total output errors below 10 mV (MF435) in multiplication mode over a 1000 to 1 dynamic range of input signals, and below 50 mV over the same range in division mode. A precision (±0.05%) internal 10 V reference can be used for either the X, Y or Z inputs. The value of "M" is selected by external resistors, with no external gain or offset adjustments required to meet rated specifications. Model MF433 is packaged in a 1.52-in.-square-by-0.62-in.-high encapsulated module. The MF434 and 435 are packaged in 1.75-in.-square-by-0.5-in.-high modules.

CIRCLE NO. 299

Solid-state timer works at half voltage

Syracuse Electronics, P.O. Box 566, Syracuse, N.Y. 13201. (315) 488-4915. $5 to $8; 8 wk.

The Series SBS timers can function at as little as half of its nominal operating voltage. The SBS is also immune to voltage transients as high as 400 V (for one full cycle, repetitive), current surges up to 15 A (for half a cycle, nonrepetitive), and inverse voltages (dc units). Other features include an output life expectancy of 100 million operations, a repeatability of ±2% (typical) and a reset time of 50 ms (during timing and after time out). This delay-on-make timer is available for input voltages of 24 to 230 V ac and 24 to 110 V dc, has a maximum power consumption of 3 W and will operate at 50/60 Hz. The SBS provides two terminals in a series connection with the load, is normally an open spst device, has an ac load rating of 1 A (rms) max./40 mA min., and a dc load rating of 1 A. The timer will operate at temperatures ranging from −10 to +60 C.

CIRCLE NO. 300

You'll be the second to know!

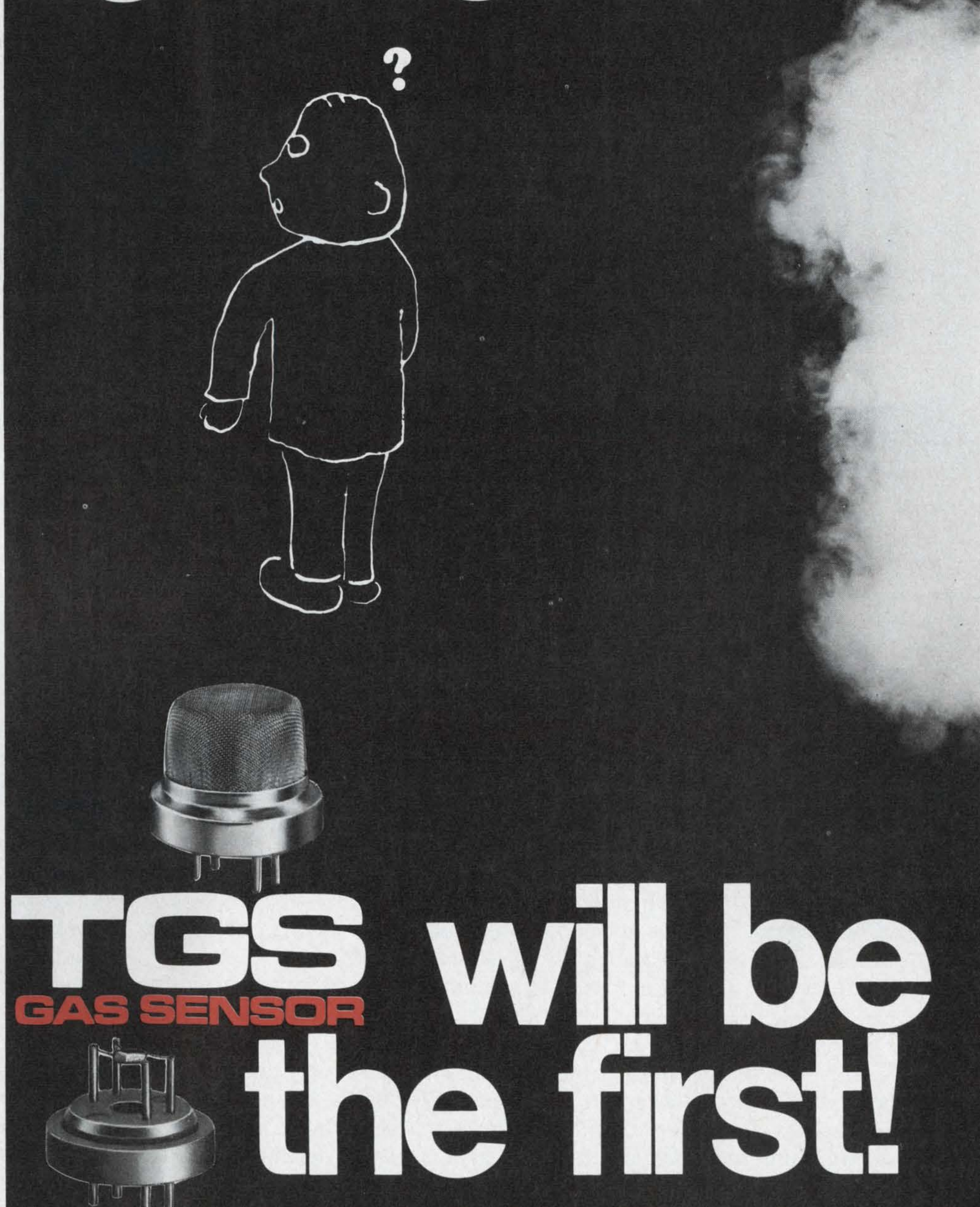
TGS is first of its kind.................
an internationally patented semi-conductor to convert deoxidizing gas or smoke to an electric signal.

TGS is first in safety...................
even a trace of exhaust gas, fire smoke, hydrocarbons, cigarette smoke or alcohol can't get past this sensitive sensor.

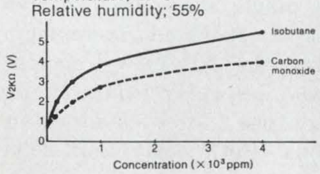
TGS is first in versatility.............
activates alarm or fire control systems, ventilating systems, or checks alcohol in drunken driver tests.

TGS is first in quality.................
remains stable after exposure to steam or even after 50,000 exposures to gas, and yet only the simplest circuitry is required.

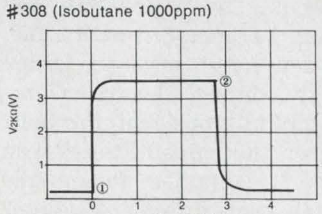
TGS is first in experience..........
more than four million units have been installed in Japan over the period of four years.



SENSITIVITY
Sample: #308
Test conditions:
V_C ; 10V A.C., V_H ; 1.2V A.C., R_L ; 2KΩ
Environmental conditions:
Temperature; 23°C
Relative humidity; 55%

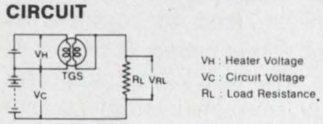


RESPONSE
#308 (Isobutane 1000ppm)



① Point at which sensor is exposed to gas/air mixture.
② Point at which sensor is removed from gas/air mixture.

CIRCUIT



For further information, please write to:

FIGARO ENGINEERING INC.

3-7-3, Higashitoyonaka, Toyonaka City, Osaka 560, Japan / Tel: (06) 849-2156 / Cable: FIGARO TOYONAKA

Applicants in U.K. & Ireland kindly requested to write to:

FIGARO ENGINEERING (IRELAND) LTD.

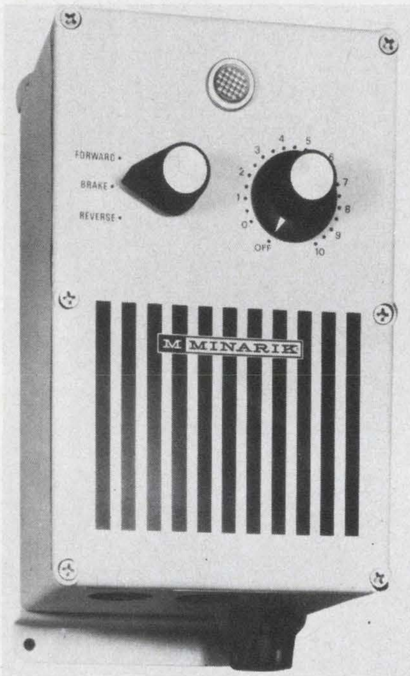
Shannon Airport Co., Clare, Ireland / Tel: Shannon (061) 61493 / Cable: FIGARO SHANNONAIRPORT / Telex: 6256

A Sample Shipment
10 pcs. (2 each of 5 types) set by air parcel post against US$ 32 ($3x10 plus $2 of airmailing charge). This contains 2 pcs. each of sockets and resistors (4 and 2kΩ) for user's convenience. Please send us a banker's check in advance.

INFORMATION RETRIEVAL NUMBER 107

RENEW your ELECTRONIC DESIGN subscription today! (See inside front cover.)

Motor speed control is moisture proof



Minarik Electric, 282 E. 4th St., Los Angeles, Calif. 90013. (213) 624-8876. $107 (single qty.); stock to 4 wk.

The WP series of speed controls, designed specifically for use in wet areas, is completely self-contained in a gasketed waterproof case that cannot be penetrated by splashes, spray or airborne water vapor. The units eliminate the need for a remote system when wet processes require speed variation. The control will operate shunt wound motors from 1/50 to 1/8 hp and provides stepless speed changes over a 25:1 range. Two simple knobs provide all functions. One is a forward-brake-reverse switch, and the other is a speed selector with a built-in on-off switch. Features include temperature, line voltage and IR compensation; choke/capacitor filtering; minimum and maximum speed adjustments; current limiting; plug-in circuit board and heat sink assembly; and an accessible fuse. The enclosure is cast aluminum with two 7/8-in. holes at the bottom for conduit entrance, so that wiring to motor and power source may also be watertight.

CIRCLE NO. 301

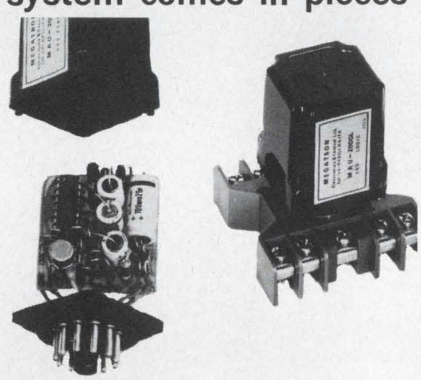
Signal conditioner made for short stroke LVDTs

Schaevitz Engineering, U.S. Rte. 130 and Union Ave., Pennsauken, N.J. 08110. (609) 662-8000. From $358.40; stock.

The CAS series of LVDT signal conditioners are particularly suited for use with short-stroke LVDT's (less than ±0.03 in.) and other low-output transducers. The conditioners are line powered, fully self-contained and are furnished with all necessary controls so connecting an LVDT and readout makes a complete measurement system. Typical specifications include a frequency response (−3 dB) of 1000 Hz with a ripple of 10 mV rms and nonlinearity and hysteresis less than ±0.05% full scale. Front panel gain and zero adjust facilitate matching the 3 to 5 V rms dc full scale output signal to the desired full stroke of the LVDT. Output is a low impedance, high level (±10 V dc full range) signal directly proportional to LVDT displacement.

CIRCLE NO. 302

Multichannel indicator system comes in pieces

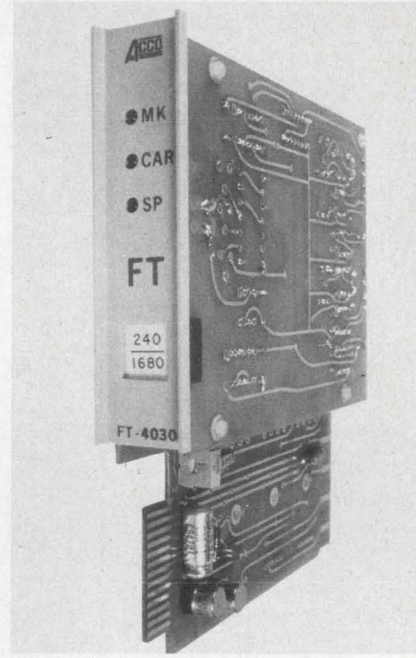


Megatron, 23 Ilanot St., 23, Haifa, Israel.

Annunciator modules in the MAU-2000 series let you put together your own alarm system. Each annunciator channel consists of a MAU-2000L logic module to operate a display lamp and horn as per ISA-1 guidelines. Each system contains a flashing module, a miniature horn and acknowledge and test pushbuttons. The module operates on 24 V dc or 110/220 V ac. Warning output contacts can be ordered for normally open, normally closed, existing or non-existing voltage.

CIRCLE NO. 303

FSK tone receivers and transmitters handle data

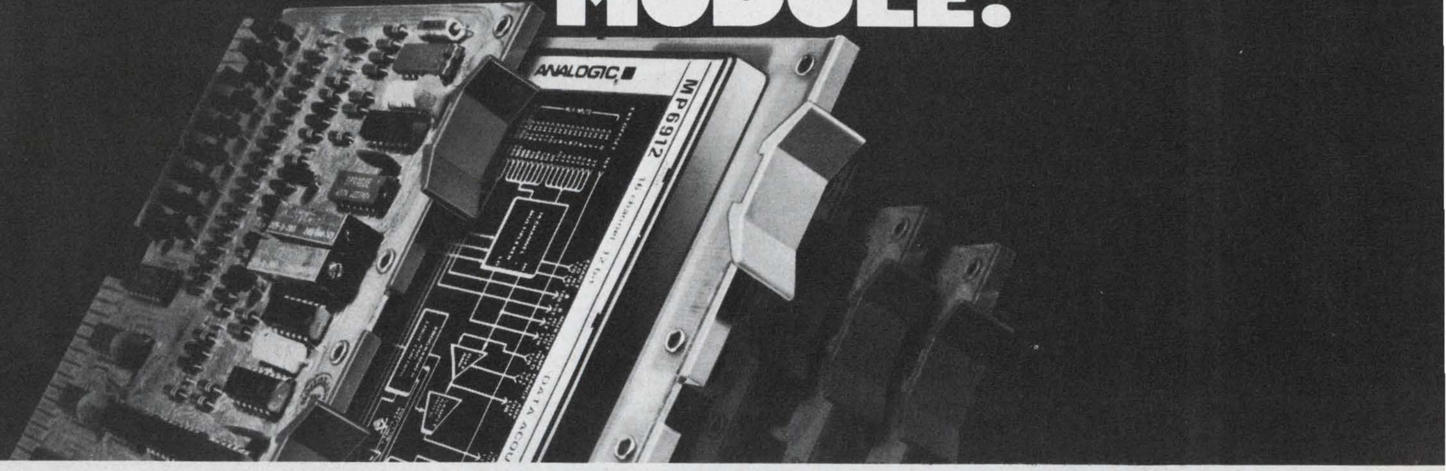


Acco Datamaster, 929 Connecticut Ave., Bridgeport, CT 06602. (203) 335-2511.

The FR-4030 tone receiver and FT-4030 tone transmitter are solid-state FSK units designed for telemetry data collection and supervisory control applications. The transmitter sends mark, space and carrier signal frequencies for conveyance of command and control information to an associated reception point, and the receiver accepts a mark, space and carrier signal at a specified frequency. Output for the FR-4030 tone receiver may be relay contacts or voltage output for telemetering applications. Both relay and voltage outputs are also available simultaneously so more than one device may be operated at a time. Transmitter input may be either voltage or contact closure. Opto-isolated input is optional for both the receiver and transmitter. These units can be supplied for operation at any center frequency from 350 to 2820 Hz over a telephone line or other transmission medium. Both can be used in conjunction with other receivers, each on a different frequency to perform many functions on a single transmission link. Design features of the units include plug-in filters, LEDs to provide visual indication of mark, center and space operation and wide temperature tolerances ranging from −30 to +70 C.

CIRCLE NO. 304

THE FIRST PRACTICAL DATA-ACQUISITION MODULE:



Complete 12-bit, 16-channel system fits 0.5″ card spacing-- anywhere. Better performance, at lower cost, than individual module combinations.

On a minicomputer motherboard, medical instrument or process control system . . . mounted on a single small card . . . plugged directly into a card-cage connector— there's always room for the 0.375″H x 4.6″W x 3.0″L Model MP6912: With space at a premium, this remarkable plug in, easily serviceable high-performance / low-cost system is your first really practical alternative to either in-house design or larger more costly systems. Particularly since you'd actually pay *more* to get comparable performance from individual modules that need.3-5 times the "real estate".

You get a 16-channel multiplexer (expandable to 256 channels), fast sample and hold, and a 12-bit A/D converter (accuracy ±0.025% at a 100kHz thruput rate), integrated with complete programming, control, and timing logic. (That's what we call the first *practical* data acquisition module.)

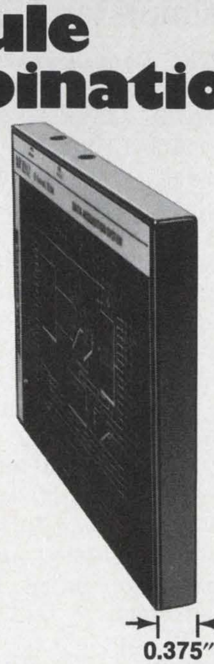
What you don't get is equally important: error accumulation; module interconnection costs and headache; redesign challenges every time the application changes; and testing, documenting, and quality-controlling at the module level.

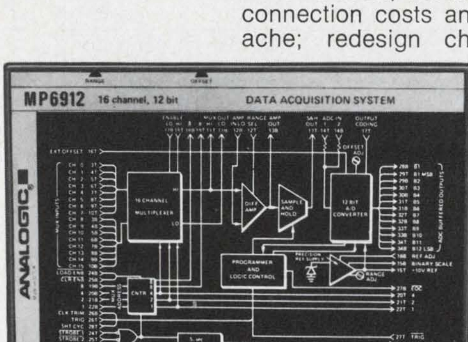
The MP6912 is an optimized design: 100% shielding on all six sides to minimize interference; minimum parts count for inherently high reliability; an exceptional 100kHz basic throughput rate that can be "short cycled" up to 450kHz; buffered outputs for trouble-free digital interconnection.

A companion D.C. to D.C. converter, the MP3020, which is powered by the +5V logic supply is also available to provide all the power needed for the MP6912 in a compatible 0.375″ thin package.

Write for our 16-page designer's guide to the MP6912 —applications and timing diagrams, set-up and calibration procedures, etc. and see why the Analogic alternative makes sense. Analogic, Audubon Rd., Wakefield, Mass. 01880; phone (617) 246-0300.

Northeast, 617-235-2330, 203-966-2580, 315-466-0220, 201-652-7055, 212-947-0379
Mid Atlantic, 215-272-1444, 215-687-3535, 703-790-5666, 301-252-8494
Midwest, 314-895-4100, 913-362-0919, 216-267-0445, 513-434-7500, 313-892-2500, 412-892-2953, 312-283-0713, 414-476-1500, 317-844-0114
South, 713-785-0581, 214-620-1551, 305-894-4401, 919-227-3639, 205-534-9771, 305-773-3411, 813-867-7820
West, 303-744-3301, 505-523-0601, 602-946-4215, 505-292-1212, 714-540-7160, 415-398-2211, 206-762-7664, 503-643-5754,
Canada, 613-836-4411, 604-688-2619, 416-499-5544, 514-636-0525, 902-434-3402



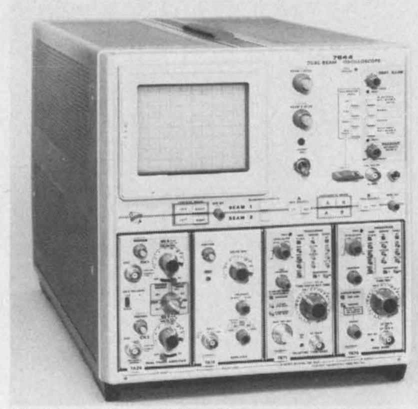


ANALOGIC®
. . . The Digitizers

INFORMATION RETRIEVAL NUMBER 108

INSTRUMENTATION

400-MHz scope also gives dual beam



Tektronix, P.O. Box 500, Beaverton, Ore. 97005. (503) 644-0161. Mainframe, $5900.

Model 7844 400-MHz dual-beam scope—said to be the fastest dual-beam—can analyze simultaneous, fast, single-shot events or fast events occurring at very slow repetition rates. The unit is essentially two scopes in one, in which both independently and simultaneously use the same CRT display area. The unit has four compartments that accept over 30 different plug-ins. For example, with a 7A24 amplifier, bw is 300 MHz at 5 mV/div sensitivity. Or, with a 7A21N direct access plug-in, the bw is 1 GHz at less than 4 V/div.

CIRCLE NO. 305

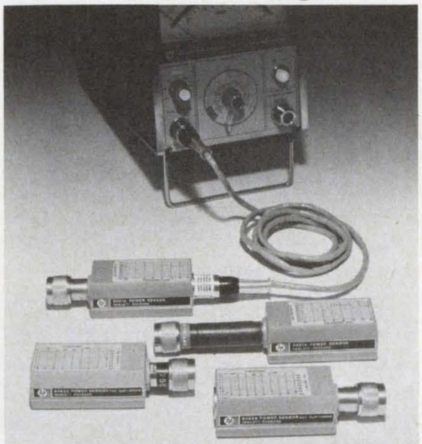
Programmable unit simulates synchros

ILC Data Device Corp., Airport International Plaza, Bohemia, NY 11716. (516) 567-5600. $2450.

Model SR400 is a fully programmable, synchro/resolver angle simulator that provides accuracy to ±0.01° for laboratory or ATE applications. The all-solid-state unit can also be used as a remotely programmed stimuli device. It features high resolution (five-decade BCD input with storage register), and bright LED seven-segment display in either manual or remote mode. Other features include synchro or resolver output at 11.8, 26, or 90 V L-L; transformer isolation of signal outputs and reference input; lever action five-decade manual input; DTL/TTL-compatible BCD inputs with storage register for computer interface.

CIRCLE NO. 306

Thermocouple sensors stretch meter range



Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 493-1501. 8482A/8483A: $400 ea.; 8481A Option H01: $495; 4 wks.

Three new thermocouple power sensors extend both the frequency and the power range of the HP 435A power meter. Model 8482A is a 50-Ω sensor operating from 100 kHz to 4 GHz with SWR below 1.1 in the range 1 to 2000 MHz. 8483A is for 75-Ω systems, from 100 kHz to 2000 MHz (SWR 1.18 from 0.6 to 2000 MHz). For input power up to 3 W, Model 8481A Option H01 provides coverage from 10 MHz to 18 GHz.

CIRCLE NO. 307

Bench DMM gives lab accuracy for $325

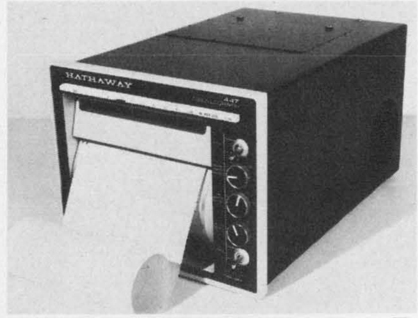
Data Precision, Audubon Rd., Wakefield, MA 01880. (617) 246-1600. $325.

Model 1450 is a 4-1/2-digit bench-model multimeter featuring 1/2-in. high, seven-segment planar display, 100% overranging and 21 function range operation. Dc volts are measured from 100 μV to 1000 V; ac volts from 100 μV to 500 V rms; resistance from 100 mΩ to 20 MΩ; and current, both ac and dc, from 1 μA to 2 A. Frequency response for ac current and voltage is from 30 Hz to 50 kHz. Basic accuracy on dc V is ±0.02% of reading ±0.01% fs, ±1 digit.

CIRCLE NO. 308

INSTRUMENTATION

Oscillograph records up to 42 traces



Hathaway Industries, 11616 E. 51 St., Tulsa, Oklahoma 74101. (918) 663-0110. $3240; 90 days.

The Model 447 oscillograph can record up to 42 traces, has 12-speeds and comes in a bench-mount configuration. The basic unit includes one 14-channel magnet bank, resistor mounting board, and a remote control and record-intensity control. The 12 standard recording speeds range from 0.1 to 100 in/s. With a frequency response of 5000 Hz, the 447 has a full 8-in. pk-pk deflection, continuously adjustable recording intensity, and convenient drop-in paper loading. Paper capacity of 475 feet is said to be double that of most high-frequency oscillagraphs.

CIRCLE NO. 309

DVM holds 0.01% for six months

Datron Electronics Ltd., Meteor Close, Norwich Airport, Industrial Estate, Norwich, NOR 17B, England.

Long-term accuracy coupled with dc capability down to 1 μV are advantages claimed for the Datron 1041 digital voltmeter. It is a 4-1/2-digit multifunction voltmeter which automatically encompasses seven resistance ranges between 10 Ω and 100 MΩ, and six voltage ranges between 10 mV and 1000 V. The dc accuracy specification of 0.01% of reading ±0.005% of full scale holds for six months over a temperature range of ±5 C without recalibration.

CIRCLE NO. 310

Spectrum analyzer can be used with any scope

Kay Elemetrics, 12 Maple Ave., Pine Brook, N.J. 07058. (201) 227-2000. $2390 (plug in).

Model 9040 spectrum analyzer covers 1 to 300 MHz. This new unit, with its 72-dB dynamic range, comes in two versions; as a self-contained unit with vertical and horizontal outputs for use with any scope, or as a plug-in module for the company's 9000 series. Tuning range, which is digitally displayed on the front panel, provides continuously variable frequency spans in eight steps, over the 30 MHz/div to 10 kHz/div range. Display flatness is held to ±1.0 dB over-all.

CIRCLE NO. 320

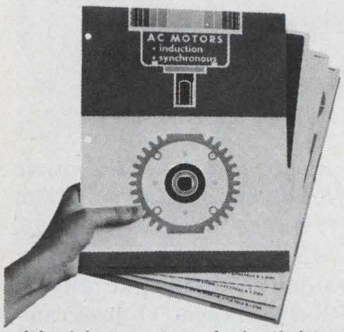
40 ranges given by compact multimeter

James G. Biddle Co., Township Line & Jolly Rds., Plymouth Meeting, Pa. 19462. (215) MI-6-9200. $99; stock.

This pocket-sized, solid-state V-I-Ω multimeter, Model EM-272, features sensitivity of 316 kΩ/V ac, up to 10 MΩ. The instrument has just two simple controls to measure 20 voltage ranges, 14 current ranges, including seven ac ranges, five resistance ranges, plus a decibel range. Battery life is in excess of 1000 h in normal operation.

CIRCLE NO. 321

Everything you always wanted to know about Drive Motors.



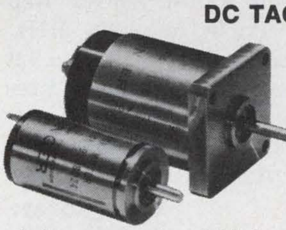
Into these five booklets we've crammed 156 pages of the latest information on Kearfott's line of Drive Motors.

Kearfott, as you probably already know, is a primary supplier of drive motors. And has a reputation for quality, service and on-time delivery.

We can furnish you with drive motors in individual units or in packages to fit any of your aerospace or industrial applications. From counters to computers. From business machines to printers and tape readers.

Let's take a look at the type and range of motors we're talking about.

DC TACHOMETERS



Kearfott Tachometers are designed specifically for precision speed sensing and as rate generators to help velocity servos achieve fast response.

Features include: outputs to 100V dc/1000rpm; minimum ripple at high commutation frequency; high linearity; low friction torque.

These are ideal for computer tape transports where efficient data retrieval is a must. And for business machine and numerical control machine tools.

DC TORQUERS

You can get sizes 12 through 42, uncased for gimbal mount applications and cased for direct drive torque motor positioning.

Kearfott can also supply them with a variety of integral feedback elements such as potentiometers, synchros and tachometers—in a single housing.

You've a choice of standard design, inverted construction (inner member is magnetic and transfers power to an outer armature) and brushless Limited Rotation design.

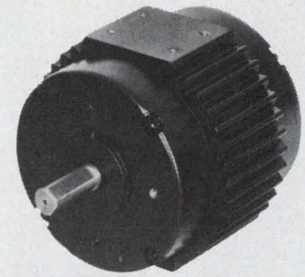
DC MOTORS

These are Moving Coil Motors used for high-response DC servos such as High-Speed Printer and Capstan drives.

One of their unique features is that they need less cooling than equivalent competitive units. The reason: low internal impedance which allows a high cooling flow rate at low developed pressures.

Permanent magnet and wound-field types are available for standard aerospace and industrial applications, including high acceleration motors with integral tachometers for terminal printers.

AC MOTORS



Kearfott induction or synchronous motors of the nysterisis or reluctance type come in a broad range of frame sizes. And from sub-fractional power to 1.5 HP.

We can furnish motors that run on up to 440 volts ac, single, 2 or 3 phase. Induction motors that operate on 2, 4, 6, 8 or 12 pole design. And dual speed motors such as needed for driving memory discs in large computers.

You can also get: high-slip motors for aircraft requirements at 400 cps; synchronous motors for constant rotating speeds with varying loads; gear motors for extremely low speeds or speeds incompatible with the power supply frequency.

STEPPER MOTORS

If you want precision control—for example for small peripheral devices, small line printers and tape readers—Kearfott Steppers provide it via discrete steps and high slew rates. And in a wide choice of stepping rates and torque levels.

Typical Kearfott units have 15° stepping angles, compatible with all 24-tooth sprockets. They give high holding torque, high stepping speed and fast response.

Units with other step angles, such as 1.8°, 7.5°, 10°, 30°, 45° and 90° are readily available in frame sizes through 50.

But why not get all the details? Mail the coupon for our new booklets now. The Singer Company, Kearfott Division, 1150 McBride Avenue, Little Falls, N.J. 07424.

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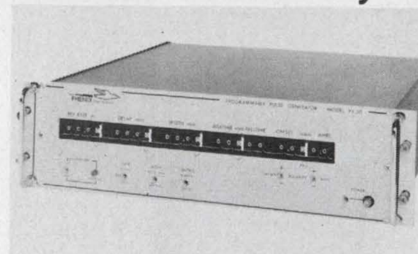
INFORMATION RETRIEVAL NUMBER 112

Pulse gen shows less than 2% nonlinearity

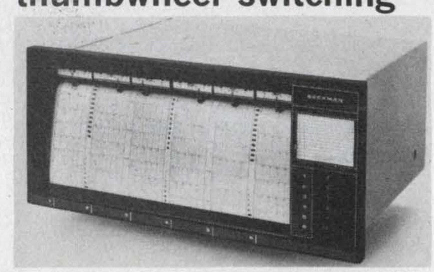


Phenix Electronics, 13724 Prairie Ave., Hawthorne, Calif. 90250. (213) 772-4765. PX-30: $3750, PX-31 (ASCII): $4500; 4-8 wks.

General-purpose pulse generator, Model PX-30/31, has 11 programmable parameters controlled by serial or parallel BCD inputs. The instrument features less than 2% nonlinearity of pulse rise and fall. Pulse amplitude is 0 to 10 V into 50 Ω from a 50-Ω source. Rep rate range is 0 to 9.99 MHz. Dc-offset range is 0 to ±9.9 V independent of amplitude. Preshoot, overshoot, undershoot, droop, ringing and other anomalies are all less than 5% combined.

CIRCLE NO. 322

Trend recorder offers thumbwheel switching



Beckman Instruments, 2500 Harbor Blvd., Fullerton, CA 92634. (714) 871-4848.

Model 8750 six-channel trend recorder offers thumbwheel switching to permit selection of any 6 or 12 input signals or two calibration sources. Input switching permits the operator to view trends among interrelated process variables without wiring changes, while internal 1-V and 3-V signals allow independent calibration of any channel. The unit exhibits an over-all accuracy of less than 2% full-scale; hysteresis is less than 0.5% including a deadband of less than 20 mV.

CIRCLE NO. 323,

5-1/2-digit DPM offers four counting modes

Digilin Inc., 3521 W. Pacific, Burbank, CA 91505. (213) 846-1800. $602.

Model 2552, a compact 5-1/2-digit panel meter, offers 0.01% accuracy, four counting modes and 100% overranging. The unit permits count by 10s, 5s, 2s and 1s. Maximum readout in the "count by 10s mode," including overrange, is 199,990, with the least-significant digit a "dummy" zero. Full-scale readout for count by 5s, 2s and 1s is 50,000, 20,000 or 10,000, respectively, plus 100% overrange. A Beckman display is used.

CIRCLE NO. 324

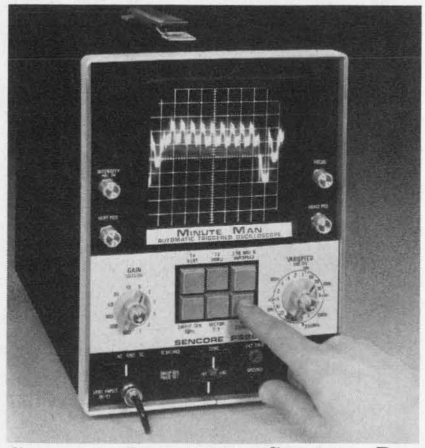
Polymeter replaces seven other instruments

Dranetz Engineering Labs., 2385 South Clinton Ave., South Plainfield, N.J. 07080. (201) 755-7080. $1250; 4-6 wks.

Model 325 Digital Power-System Polymeter, a portable, digital voltage-current-time meter simultaneously measures two ac voltages, two currents, voltage or current, or time and voltage or current. It thus replaces, in a single ten-pound package, the assembly of voltmeters, ammeters, and timer/counters normally required for precision field measurements in power systems. And it requires but a single operator for the whole procedure. The unit measures time either in seconds or in cycles of the power line frequency.

CIRCLE NO. 325

Scope features automatic triggering



Sencore, Inc., 3200 Sencore Dr., Sioux Falls, S. D. 57107. (605) 339-0100. $495.

This completely automatic-triggered pushbutton scope, the PS29 Minute Man, enables any technician or engineer to display any color TV or video waveform by simply pushing a button. Pushbutton displays include TV vertical, TV horizontal, 3.58 MHz, five-times expand, and a vector display. The sixth button sets the scope for 60-Hz line sweep. The Minute Man triggers internally on any signal down to 20 mV. External trigger allows you to sync on any signal above a dc voltage. Absence of input signal is indicated by a continuous running baseline.

CIRCLE NO. 326

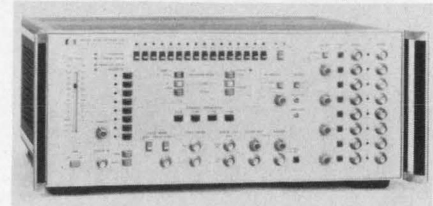
Digital wattmeter is only 9/16-in. thick

Nationwide Electronic Systems, 1536 Brandy Pkwy., Streamwood, Ill. 60103. (312) 289-8820. Start at approx $300.

The Slimline digital wattmeter provides a 3-1/2-digit LED readout of true wattage. It is not an averaging instrument; it takes pinpoint readings of voltage and current simultaneously and performs a mathematical calculation to derive the wattage. One of the unique features of Slimline instruments is the very thin case: the entire unit is only 9/16 in. thick. No large panel cutouts are required, and no space is used up behind the panel. The wattmeter is available in a number of ranges, covering ac up to 20 kHz and dc.

CIRCLE NO. 327

Word generator offers 8 synchronized outputs

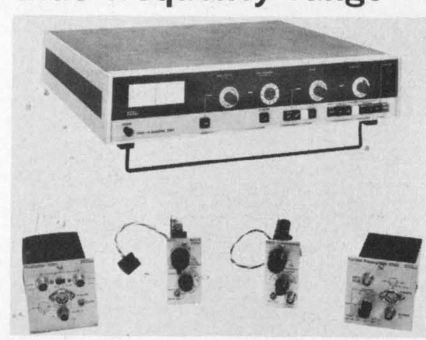


Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 493-1501. $7560.

Model 8016A, a word generator with eight synchronized outputs, can deliver test data in parallel—32 bytes each 8-bits wide—or in serial, eight words simultaneously, each 32 bits long, at rates up to 50 megabits/second. The eight channels can be serialized to form a single word 256 bits long. For synchronization, the generator has first and last-bit outputs and a clock output. And a strobe channel functions as a ninth data channel. The bit pattern delivered by the 8016A is programmed with front-panel buttons.

CIRCLE NO. 328

Lock-in amplifier offers wide frequency range



Ortec Inc., 203 Midland Rd., Oak Ridge, Tenn. 37830. (615) 482-4411. $1050.

The 9501 lock-in amplifier has auto-tracking reference circuitry and a frequency range of 0.5 Hz to 150 kHz, said to be wider than the range of some costlier instruments. Full-scale sensitivity is 10 μV without preamp. Dynamic reserve is 60 dB (1000 X), and can be increased with built-in high and low-pass filters. Featured are a phase control that includes negative settings to facilitate accurate phase adjustment; and time constants as small as 250 μs can be selected to measure rapidly changing signals.

CIRCLE NO. 329

We can deliver add-on memories to every PDP-11 user in the next 10 days.

Wherever you are.

We've stocked up on PDP-11 add-on memories, because we know you don't want to wait a month — or longer — when you need more memory. They're thoroughly tested. Operational. Ready for delivery. That's why we can guarantee that you'll receive your memory 10 days after we receive your order. Prices? You might pay less for somebody else's. And you can pay a lot more. We're competitive. But we deliver. Call the daring young men in our Memory Products department today, place a verbal order, confirm it with a written P.O. and 10 days after we receive your order, you'll receive your memory. Call (305) 974-1700. Ask for Gen Fortin. Or write Harris Corporation, Computer Systems Division, 1200 Gateway Drive, Fort Lauderdale, Florida 33309.

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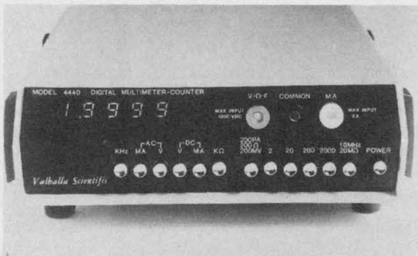
INSTRUMENTATION

DMM/counter combo sells for $299



Valhalla Scientific, 7707 Convoy Ct., San Diego, CA 92111. (714) 234-3685. $299.

Model 4440 digital multimeter-counter measures ac and dc volts, ac and dc current, resistance and frequency to 10 MHz. The unit will operate for approximately six months from disposable alkaline batteries. Ac line operation and rechargeable batteries are optional. The full-scale resolution is 1 part in 20,000, with a dc volts accuracy of ±0.05%. The crystal-controlled frequency counter resolves to 1 part in 100,000, with an accuracy of 0.01%.

CIRCLE NO. 330

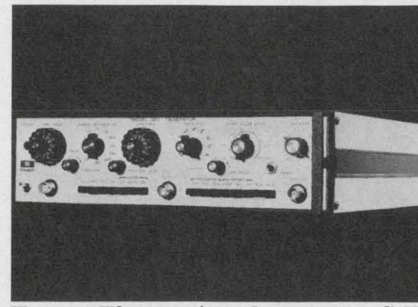
Low-frequency analyzer resolves to 0.1 Hz

Quan-Tech, Randolph Park W., Route #10, Randolph Township, N.J. 07801. (201) 366-3663. $2475.

Model 304-A low-frequency wave and spectrum analyzer covers the frequency range of 1 Hz to 5 kHz in one continuous range with three selectable bandwidths of 1, 10 and 100 Hz. Resolution is 0.1 Hz from 1 Hz to 5 kHz. The Model 304-A features electronic tuning and automatic electronic sweep. Readout is a 5-digit LED display at actual tuned frequency. The instrument has selectable time constants of 0.1, 1.0, 10 and 100 s, input voltage range of 30 μV to 100 V fs, and a dynamic amplitude range of better than 70 dB.

CIRCLE NO. 331

Unit gives linear/log sweep and 5 waveshapes



Exact Electronics Inc., 455 S.E. 2nd Ave., P. O. Box 160, Hillsboro, OR 97123. (503) 648-6661. $1145.

Model 7271 contains two complete generators in one package and is a precision source of sine, square, triangle, pulse and ramp waveforms over the range of 0.0001 Hz to 20 MHz. Sweep width is accurately set by two Kelvin Varley controls; one for start frequency and one for stop frequency over a (1000:1) three-decade range. The operator may select linear or logarithmic sweep. A 20-kHz range enables the entire audio band to be swept without range changes.

CIRCLE NO. 332

INFORMATION RETRIEVAL NUMBER 118 ►

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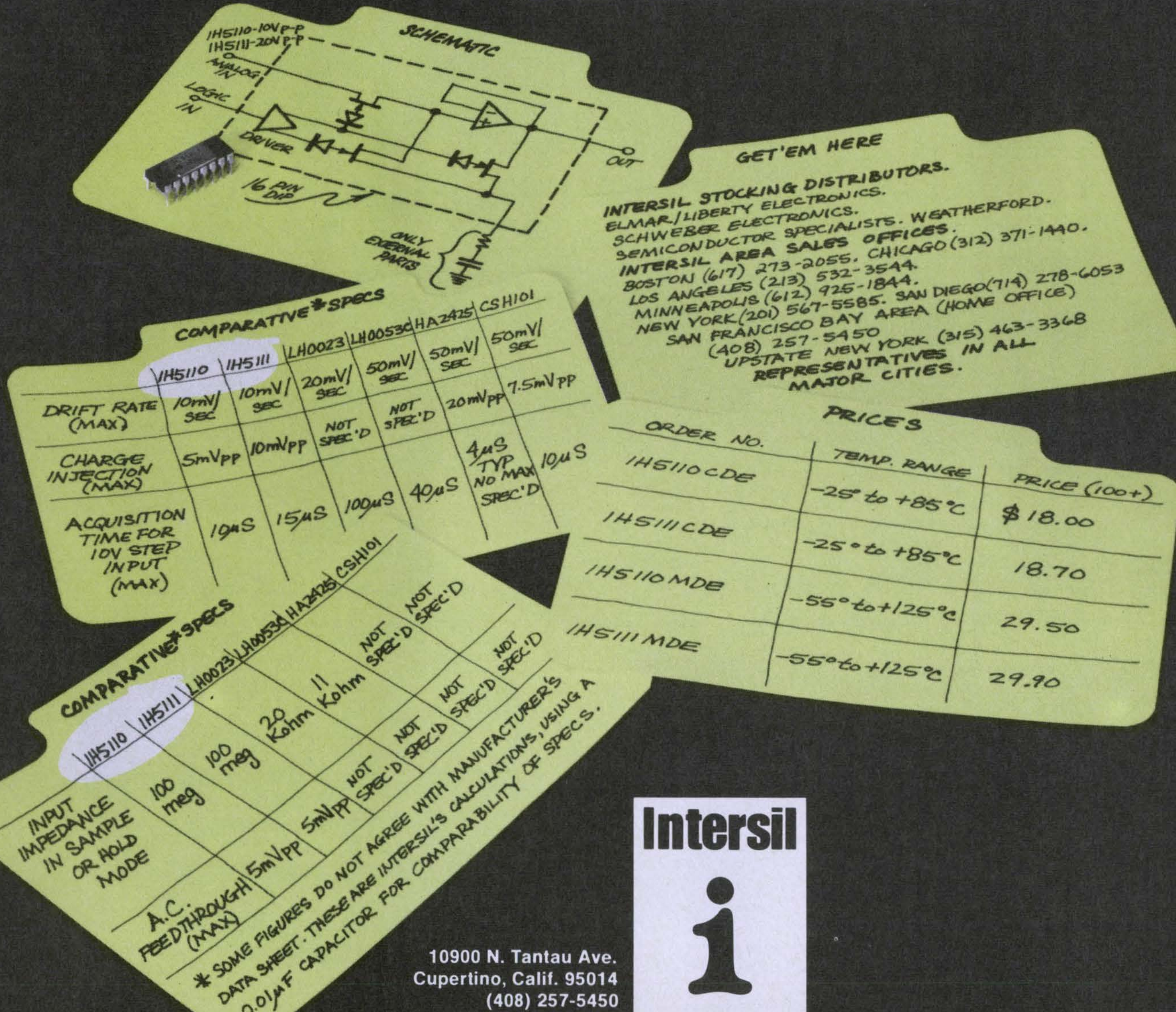

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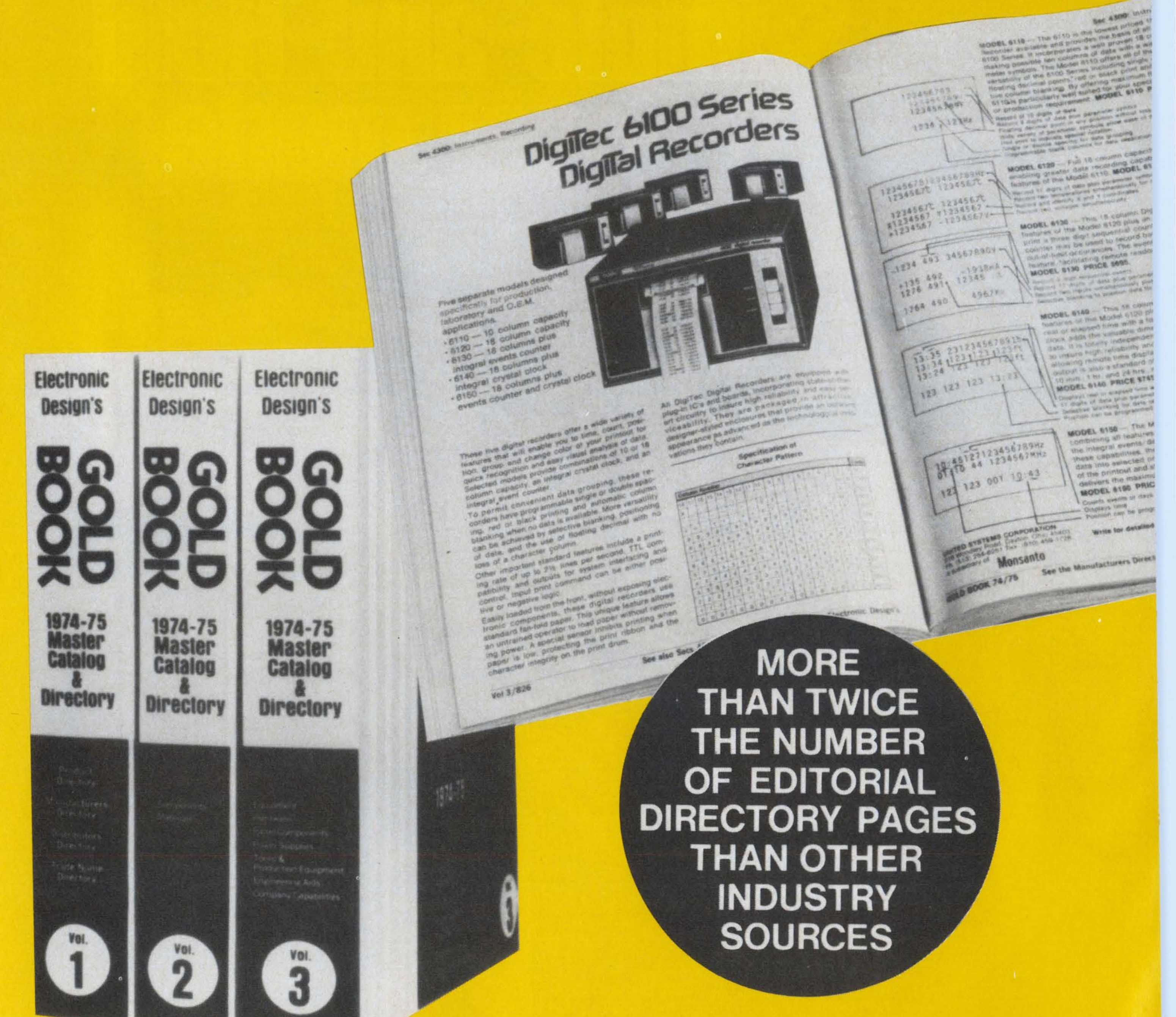

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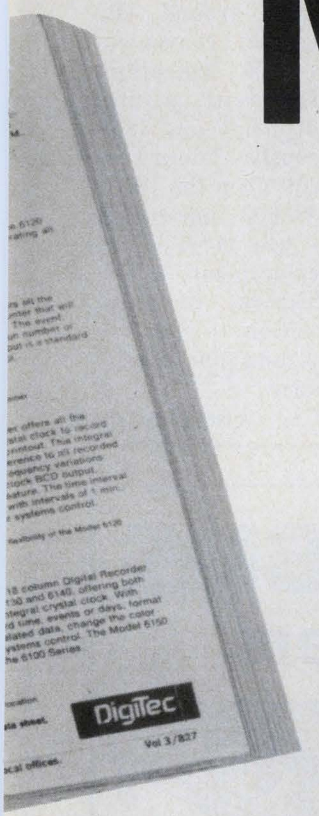
EVERY MEASURE



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DISTRIBUTORS	–Alpha	14	39	+ 25
	–Geo	15	40	+ 25
	Total Editorial	443	917	+474
ADVERTISING		2752	2820	+ 68

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ELECTRONIC DESIGN'S
GOLD BOOK

Unit senses and counts ac line overvoltages

Transtector Systems, 532 Monterey Pass Rd., Monterey Park, CA 91754. (213) 283-9278. $449.

TCD-640 helps predict and prevent electrical failures by simultaneously sensing over and undervoltages on ac lines, recording overvoltage transients on a digital LED display, and low line conditions on a light indicator. It permits continuous or periodic monitoring of 120-V lines. Featuring a simplified control panel, the counter is designed for monitoring 120-V-rms, single phase, 50-to-400-Hz ac lines. When connected to an ac power source, it records a continuous, cumulative count of overvoltages above 200, 300, 400 or 500-V, depending upon the level selected. Undervoltages are indicated when the line falls below 94 or 104 V rms.

CIRCLE NO. 333

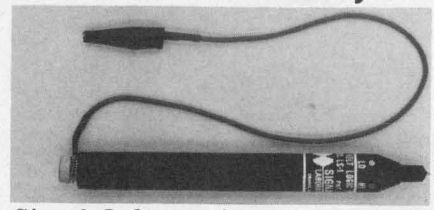
Rf probe stretches DMM capability

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 493-1501. $85.

This new rf probe adds 100-kHz-to-500-MHz ac measurement range to the company's Model 970A DMM. Accuracy within this frequency range is greater than 1 dB. Voltages from 0.25 to 30 V full scale are measured with this Model 97003A rf adapter. Maximum ac input is 30 V rms plus 200 V dc. The basic, pocket-sized 3-1/2-digit multimeter measures ac and dc volts and ohms. Its ac voltage range is from 100 μV to 500 V, 45 Hz to 3.5 kHz. Input resistance on the ac range is 10 MΩ.

CIRCLE NO. 334

Logic probe works from internal battery



Signal Laboratories, 187 N. State College Blvd., Orange, CA 92668. (714) 538-7280. $77.

Model LC-1 battery-operated logic probe can be used on all 5-V logic circuits: TTL, DTL, RTL, Schottky-TTL, low-power TTL and CMOS. No external power clips are required. The ground clip may be placed on any convenient system ground. LED indications on the probe trip permit operator to look at circuit point and indication simultaneously. There's no power drain except when the LEDs are lit. Over 70,000 one-second logic indications are possible before battery replacement is required. Other features are input overvoltage protection to ±200 V dc or 125 V rms, and 100 kΩ, 10-pF input impedance.

CIRCLE NO. 335

Some of the best things about our new Digivac® 1000 are what you can't see.

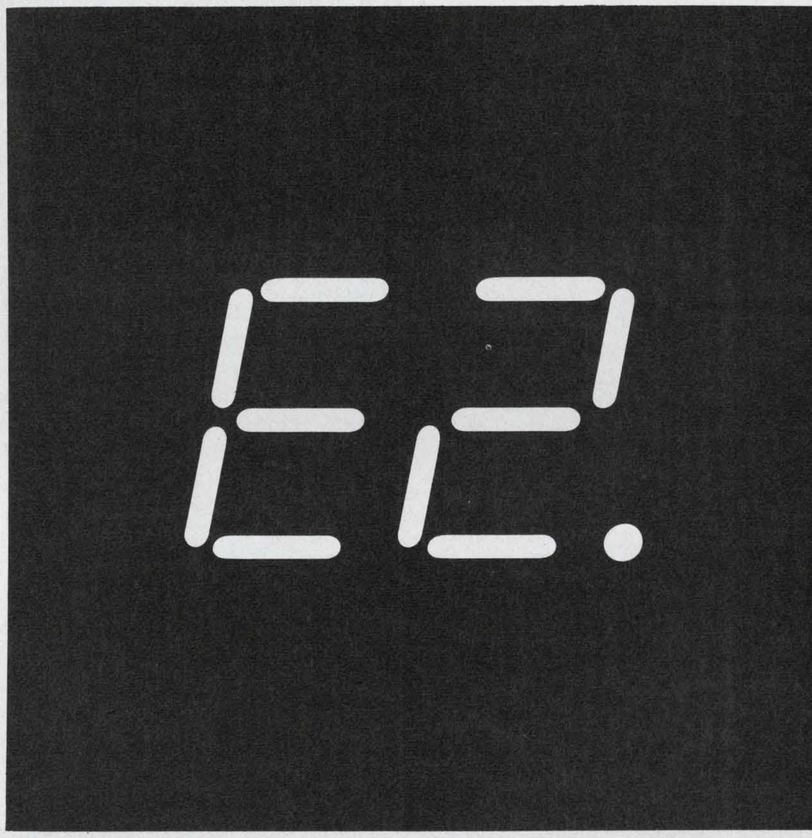
When you look at our vacuum fluorescent readout, you won't see the low voltage requirements making it directly compatible with available MOS IC logic packages.

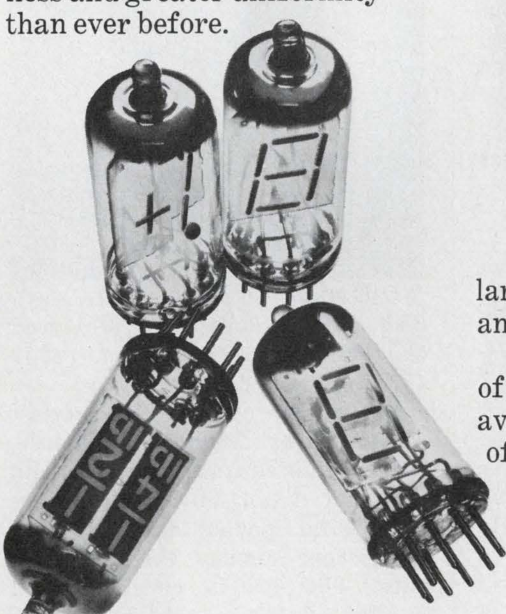
You won't see the exclusive mica substrate which supplies mechanical strength and helps emphasize lighted segments through a desirable halo effect.

You won't see the low cost, lower than competing readouts with fewer customer advantages.

Of course, there are things about our Tung-Sol® Digivac 1000 you can see.

Like the Digivac 1000's brightness. 50% more brightness and greater uniformity than ever before.





You can see the flexible language with alpha, numerical and symbolic figures.

You can see the wide range of colors, including white, available with common types of filters.

And because of the unique construction, you can see the accurate viewing assured from virtually any angle.

With the Digivac 1000 readout, whether you see it or you don't . . . it's still nice to know it's all there.

For additional information on the Digivac 1000, write to: Wagner Electric Corporation, 1 Summer Avenue, Newark, New Jersey 07104.

Wagner makes other quality products in volume for the electronics industry, including bridges, power supplies and subsystems, silicon rectifiers, resistors, miniature lamps and status indicators. And Wagner offers contract manufacturing.

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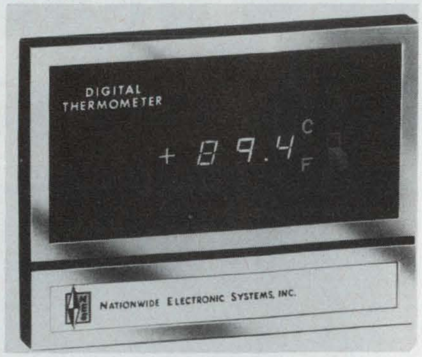
INFORMATION RETRIEVAL NUMBER 121

Thin thermometer reads °C or °F



Nationwide Electronic Systems, 1536 Brandy Pkwy., Streamwood, IL 60103. (312) 289-8820. Start at $350.

The new dual-range SLIMLINE digital thermometer displays temperature in either Celsius or Fahrenheit: Just flip the front-panel switch to the desired position. There is no need to change probes, re-calibrate, or make conversion calculations. The unit is only 9-1/6-in. thick. The LED display is easy to read, and parallel BCD-data outputs are provided. The thermometer accepts a precision platinum-wire probe input. There are several models available, including one that covers from −58 to +1112 F and −50 to +600 C. The unit operates from +5-V-dc and ±12-V-dc power.

CIRCLE NO. 336

Five counters added to company's line

Philips Test & Measuring Instruments, 400 Crossways Park Dr., Woodbury, N. Y. 11797. (516) 921-8880. PM 6611: $790, PM 6615; $1750.

Four new universal counters and one universal counter/timer offer frequency ranges from 10 Hz up to 80 MHz, 200 MHz, 520 MHz and 1 GHz. Each counter has a nine-digit "mini planar Pandicon" gas discharge display. LSI/CMOS circuitry allows each counter to have 100-ns time resolution, low power consumption and small size. The PM 6610 family can do frequency, single period average, totalizing and multiple ratio measurements. The PM 6612 counter/timer can also make time interval measurements.

CIRCLE NO. 337

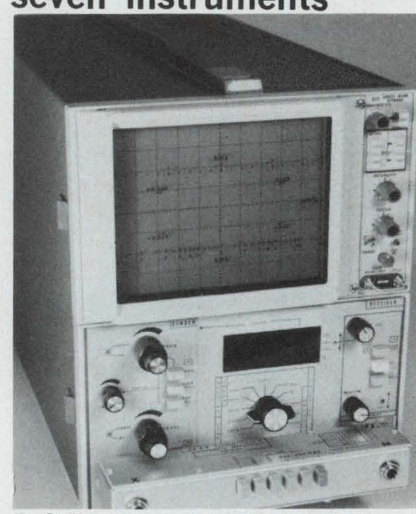
Ac/dc voltmeter measures true rms

Ballantine Labs, P.O. Box 97, Boonton, N. J. 07005. (201) 335-0900. $1395.

Model 3620A is a new ac/dc, true-rms, digital voltmeter that is said to be capable of measuring ac voltages, dc voltages and mixtures of the two with resolution and accuracy unavailable from similar class instruments. The unit offers 1-μV resolution and spans the range from 10 mV to 1 kV full scale. Featured are a 4-1/2-digit (19999 count), back-lighted, liquid-crystal display; a four-terminal, guarded and floating input; overload protection up to 1 kV on all ranges; and a typical accuracy of ± (0.1% of full scale).

CIRCLE NO. 338

Test set replaces seven instruments



R-O-R Associates Ltd., 3300 Cavendish Blvd., Suite 150, Montreal, Quebec H4B 2M8 Canada. (514) 482-8432.

System 300 channel sweeper test set measures frequency response, level, weighted and flat noise and harmonic distortion. An autoranging digital readout and a storage oscilloscope display the measured data. The system consists of a number of plug-ins that fit a standard storage-scope mainframe. The plug-ins include an audio generator, level, noise and distortion meter; return loss and impedance bridge, and a stereo phase and level difference meter. A unique accessory is a remote controlled test generator for end-to-end circuit tests.

CIRCLE NO. 339

Add AC measure power with this fully programmable wide band AC calibrator.

Put the Fluke 5200A AC calibrator to work in your lab or factory for "state-of-the-art" voltage calibrations from 10 Hz to 1.2 MHz. It's the one reasonably priced calibrator ($3995) that's fully and easily programmable.

High output, high accuracy.

Here's a calibrator to give you up to 50 ma from 100 μv to 120 volts. External sensing maintains accuracy under varying load condition. Accuracies are excellent over the entire bandwidth. Typical midband (30 Hz to 20 KHz) accuracy is ± (0.02% of setting + 0.002% of range) on 1, 10, and 100 volt ranges; and ± (0.02% of setting + 10 μv) on 1, 10, and 100 millivolt ranges. Resolution is 0.0001% of range. Extremely fast response time, 0.5 seconds from 100 Hz to 1.2 MHz avoids the delays of conventional AC calibrators. Output is protected by current limiting. The instrument is fully guarded.

Phase lock and quadrature output.

The oscillator of the 5200A can be phase locked to an external source to produce synchronous signals of precision amplitude and stability. The user can slave a current source for wattmeter calibration or synchronous operation to line or system frequencies.

A quadrature output 90° out of phase with the fundamental is also available. This feature simplifies servo-amplifier testing and synchronous detection.

Remote control is field installable. Circuit boards are field replaceable.

Low distortion.

Distortion is extremely low. From 10 Hz to 100 KHz, harmonic distortion and noise are 0.04% of setting + 10 μv rms.

For production and voltmeter calibration applications, the Fluke 5200A provides an error measurement feature to read amplitude error in percent, speeding reading substantially.

Send for data.

A new bulletin is yours on request or arrange a demonstration through your local Fluke sales engineer.

For data out today, dial our toll-free hotline, 800-426-0361.

In the continental U.S., dial our toll free number 800-426-0361 for the name and address of your nearest local source. Abroad and in Canada, call or write the office nearest you listed below, John Fluke Mfg. Co., Inc., P.O. Box 7428, Seattle, Washington 98133. Phone (206) 774-2211. TWX: 910-449-2850. In Europe, address Fluke Nederland (B.V.), P.O. Box 5053, Tilburg, The Netherlands. Phone 013-67-3973. Telex: 844-52237. In the U.K., address Fluke International Corp., Garnett Close, Watford, WD2 4TT. Phone, Watford, 33066. Telex: 934583. In Canada, address ACA, Ltd., 6427 Northam Drive, Mississauga, Ontario. Phone 416-678-1500. TWX: 610-492-2119.

FLUKE®

Memory power source outputs a variety of bias voltages

Reliability, Inc., P.O. Box 35733, Houston, TX 77035. (713) 729-4444. See text.

Designed especially to provide power to 4k RAMs, the Reliability, Inc., RP12 "RAM-PAC" source takes 5 V dc and converts it to +12 V, plus a choice of negative voltages needed for the memory's substrate bias.

Depending on the model, −3, −5, or −9 V is available; where a clock-driver boost is needed, +15 V is also offered as an option. Thus the "RAM-PAC" offers up to three output levels.

Current outputs of the RP12 source are 550 mA from the +12, 10 mA from the negative level and 25 mA from the optional +15-V output. However, the total power delivered is limited to 6 W.

Size of the RP12 is 2.8 × 2.8 × 0.4 in. Another series, the V12R, comes in a DIP-like package (0.1-in. pin spacing) that measures 1.25 × 0.6 × 0.4 in. The V12R series offers single or dual output from a +12-V input (instead of +5 V), and can provide up to 0.5-W out. Still another series, the V12A, offers unregulated outputs in the same DIP-like package.

With a 5-V line and with 6-W output, the RP12 shows a nominal efficiency of 70%. Temperature range of the units covers 0 to 70 C, and tempco is listed as ±3 mV/°C, typically.

Note that the RP12 Series is not isolated from the source; the V12R series is, but the preliminary spec sheet doesn't give figures for input/output impedance.

Line regulation of the RP12 is ±150 mV for the negative levels, and ±50 mV for the +12 output. The optional +15 V isn't regulated.

Load regulation (full load to a 1-mA load) is a maximum of 100 mV for the negative outputs and 175 mV for the +12 V. Line and load regulation for the V12R source are ±0.2% and 1%, respectively.

Typical single-quantity prices of the memory sources range from $27.75 for the smaller V12R, to $65 for the larger RP12. Delivery is stock to 8 weeks.

CIRCLE NO. 250

Hybrid converters power gas displays

LRC Inc., 11 Hazelwood Rd., Hudson, N. H. 03051. (603) 883-8001. $50.

These new hybrid IC dc-to-dc conversion supplies are powered by standard logic supply voltages. They produce from such inputs the high dc voltages (180 to 270 V dc) needed to operate gas-discharge, digital and bar-graph display devices. Three models are available in miniature (0.6 cubic inch) packages. Model PS1510D operates from a 5-V TTL supply and produces 200 V at 1 mA. Model PS-1515D operates from 5 V and produces 180 V at 15 mA. Model PS1520D operates from 12 to 16 V and produces 200 to 270 V at 10 to 14 mA.

CIRCLE NO. 340

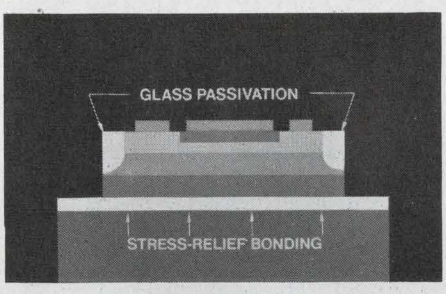
IR's new glass passivated, high voltage Power Transistors and Darlingtons...

Better performance where it really counts.*

The three other largest selling high voltage power transistor lines of today offer you good characteristics. But while a specific device may excel in specs for one parameter, it may be marginal in other equally important characteristics. Not so with IR's new high voltage power transistors. They easily meet or exceed all established specifications. Now you can design a better, more efficient circuit without compromising.

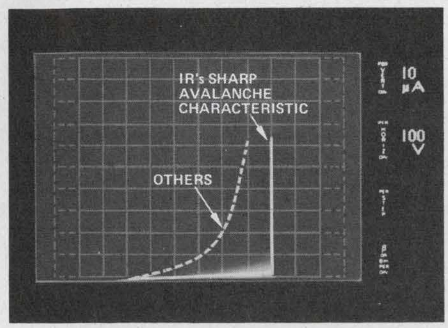
*** High Voltage and High Gain in the same transistor.**

Most others offer you either high voltage or high gain. They can't give you both in the same device. We can. For example: rated to 700V_{CBO} with an I_C from 7 to 10 Amps (pulse), we provide a gain of 30 - 90 at 1 Amp.



*** Glass Passivation for longer life, better stability.**

IR triple-diffused, NPN mesa structures are the first and only high voltage power transistors with glass passivated junctions. You'll get longer life and a stability unequalled by the other brands.



The avalanche curve pictured shows our "sharp" curve and the "soft" curve of the others. Convincing evidence of better junctions that you can operate at full rated specs without a worry.

*** Lower Saturation Voltage for better efficiency.**

IR saturation voltage is lower than the others. Higher efficiency, less power loss, reduced power consumption and system operation at lower power levels are your new advantages. And you won't have to sacrifice switching speeds or voltage capability.

*** "Stress-Relief" Bonding for better resistance to temperature cycling.**

IR's "Stress-Relief" bonding between the chip and mounting surface gives better protection from thermal cycling, gives you an extra margin of safety in thermal design considerations, with a broad safe-area that is more than adequate for any application.

Competitively Priced and Cross-Referenced to the 3 major lines.

IR high voltage power transistors are available in 12 models rated from 300 to 700V_{CBO} with an I_C from 7 to 10 Amps (pulse). Monolithic Darlingtons in 15 models are rated to 600V_{CBO} with an I_C from 15 to 25 Amps (pulse). All are in the standard TO-3 package.

Find IR's equivalent to the devices you're now using, then ask your local IR salesman, Rep or Distributor for complete specs and a test evaluation sample. When you've put it to the test, we think you'll agree. It's better — everywhere that counts.

IR P/N	Delco P/N	RCA P/N	Motorola P/N
IR401	DTS 401		MJ3026 MJ3027
IR402	DTS 402 2N3902		MJ3028 MJ3030 2N3788 2N3902
IR403	DTS 403		
IR409	DTS 409		
IR410	DTS 410	RCA410	MJ410
IR411	DTS 411	RCA411 2N5838 2N5839	MJ411 MJ1800 MJ3029 MJ3430
IR413	DTS 413	RCA413 2N5840	MJ413
IR423	DTS 423	RCA423	MJ423
IR424	DTS 424		MJ424
IR425	DTS 425		MJ425
IR430	DTS 430	2N5239 2N5240	MJ430
IR431	DTS 431	RCA431 2N5240	MJ431 2N5241

Monolithic Power Darlingtons

IR P/N	Delco P/N	
IR4040	DTS 4040	Ask for data on IR's 11 additional types.
IR4045	DTS 4045	
IR4060	DTS 4060	
IR4065	DTS 4065	

Prove our point on your curve tracer...

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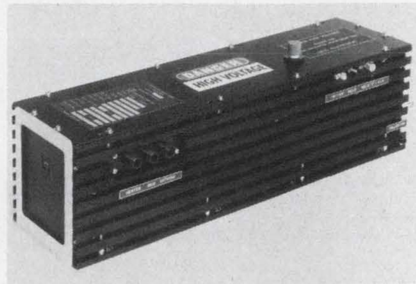
INFORMATION RETRIEVAL NUMBER 124

Airborne supply powers TWTs



Litton Industries, 960 Industrial Rd., San Carlos, CA 94070. (415) 591-8411. $12,000.

Model 636 traveling-wave-tube supply is designed for airborne use to drive the company's family of depressed-collector, kilowatt, pulsed traveling-wave tubes operating in the 1-to-18-GHz range. The unit provides a pulse width range of 0.25 to 40.0 μs and has a typical operating efficiency of 85%. Total time delay from trigger input to rf output from the TWT is typically 35 ns; duty cycle is 4%, maximum. The Model 636 measures 5 × 5.5 × 19.5 in. and weighs 36 lbs.

CIRCLE NO. 341

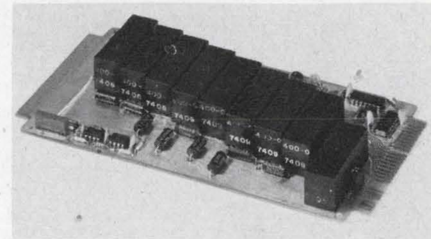
OEM supply features 0.1% dual tracking

Power-One Inc., 531 Dawson Dr., Camarillo, Calif. 93010. (805) 484-2806. $91.95.

This triple-output model features 0.1% dual tracking of the ±15-V, said to be a 10 times improvement over competitive models. The unit has a 5-V, 6-A output for logic circuitry and dual tracking, ±15-V, 1.5-A outputs for op amps, MOS, etc. The ±15 V is adjustable to ±12 V and has the same accuracy at that setting. Other features are ±0.01% line regulation, ±0.02% load regulation and 0.01%/°C temperature coefficient. Current limit/foldback protection is built-in, and full power is available from 0 to 50 C.

CIRCLE NO. 342

Unit calibrates data-acquisition systems

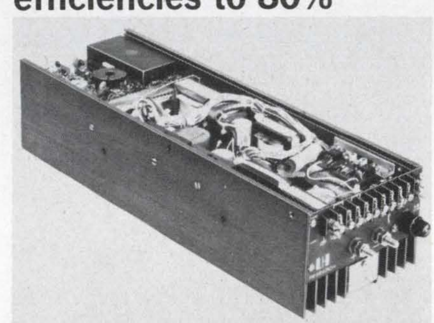


Computer Products, 1400 N.W. 70 St., P.O. Box 23849, Fort Lauderdale, Fla. 33307. (305) 974-5500. $700.

RTP7481/30 programmable voltage calibrator is for use with the company's RTP7480 Series wide-range analog input controller, and provides eight program selectable precision input voltages for on-line calibration of computer directed data-acquisition systems. The eight available calibration voltages are 0.0 V, ±1 μV; 2.0 mV, ±0.03% ±1 μV; 8.0 mV, ±0.03% ±1 μV; 32.0 mV, ±0.025%; 128.0 mV, ±0.02%; 512.0 mV, ±0.02%; 2.048 V, ±0.02%; and 8.192 V, ±0.02%.

CIRCLE NO. 343

Switchers yield 300 W, efficiencies to 80%



LH Research, 2052 S. Grand Ave., Santa Ana, Calif. 92705. (714) 546-5279. $460 to $485.

Designated the LH 300 Series, these new switchers supply 300 W in dual or triple outputs, measure 3.65 × 5.05 × 16.25 in. and weigh 9 to 9.5 lbs. Primary output efficiency is over 80%; outputs of dual or triple models average 75%. The complete LH line includes 85 standard models in six wattages—250, 300, 500, 600, and 1000, plus a 1500-W series. All have externally selectable input voltages, 115 or 230 V ac, 47 to 440 Hz. All models have fully regulated primary outputs.

CIRCLE NO. 344

DO IT FOR ME

I'm Miss *Electronic Design* (some of us have met before). I can be *very* friendly . . . but when things don't go right I can be mean as a hippo.

You know you're going to renew your FREE subscription to *Electronic Design* . . . so why keep me waiting?

Turn back to the first page of this issue *right now*. Then fill in your free renewal application form and mail it *today*.

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Encapsulated supply offers triple outputs

Calex, P. O. Box 555, Alamo, Calif. 94507. (415) 932-3911. $79.

Model 3.15 triple-output power supply is a dual regulated unit (±15 V dc at 100 mA) and a single regulated supply (+5 V dc at 500 mA) both in an encapsulated unit of standard size (0.5 × 3.5 × 1.25 in.) and pin configuration. Designed specifically to power small hybrid systems using op amps and 5-V logic, the unit is a direct replacement for most popular competitive models. Other specs of importance are: 0.02% load and line regulation, 1.5-mV rms ripple and noise; ±100-mV output voltage tolerance; −25 C to +71 C operating temperature; and short-circuit protection through foldback current limiting.

CIRCLE NO. 345

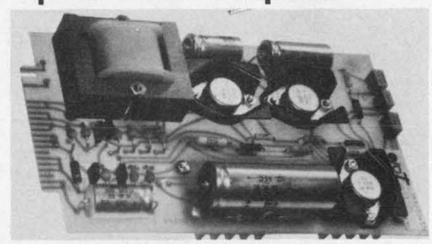
14 models added to open-frame series

Lambda Electronics, 515 Broad Hollow Rd., Melville, N.Y. 11746. E size: $190, EE size: $275.

The company has just added 14 new open-frame power supplies to its LT series. The new models are available in "E" and "EE" single output package sizes. Package size "E" is 4-15/16 × 7-1/2 × 11-3/4 in. and package size "EE" is 4-15/16 × 7-1/2 × 16-1/2 in. Models are available in 5, 6, 12, 15, 20, 24 and 28 V in currents to 32 A. The 5-V package has fixed overvoltage protection. These fixed-voltage power supplies have a maximum of 13 components and include the company's 100,000 MTBF power hybrid voltage regulator.

CIRCLE NO. 346

Card cage supply gives up to four outputs



OPT Industries, 300 Red School Lane, Phillipsburg, N.J. 08865. (201) 454-2600. $168.

Series 4000 power supplies, with up to four outputs on a single PC board, are designed to plug directly into the customer's card cage. Operation is from 115 V ±10%, 60-Hz input, 0 to 55 C without derating. and includes complete overload short-circuit and overtemperature protection. A typical unit, Model 4200-10, offers ±12 V at 120 mA for op amps, 5 V at 1100 mA for digital logic and 24 V at 100 mA for high-level buffers, etc. All models are constructed on a 7-13/16 × 4-1/2-in. circuit card, under 3 in. thick, with a 22-pin card-edge connector on 1/8-in. centers.

CIRCLE NO. 347

High-voltage units insert in NIM bins

Bertan Assoc., 180 Miller Pl., Hicksville, N.Y. 11801. (516) 433-3110. Start at $350.

Series NIM high-voltage power supplies are designed for sensitive nuclear instrumentation with photomultipliers, solid-state detectors and proportional chambers. Models are available with outputs variable from zero to 1, 3, 5 and 10 kV. Features include digital voltage readout, reversible polarity with LED polarity indicators, and remote programming. Regulation and ripple are 0.001% and tempco is 50 ppm/°C. All modules are arc protected, short-circuit proof and self-restoring.

CIRCLE NO. 348

FOR NEW STANDARDS IN SPECTRUM ANALYZERS, THINK HP

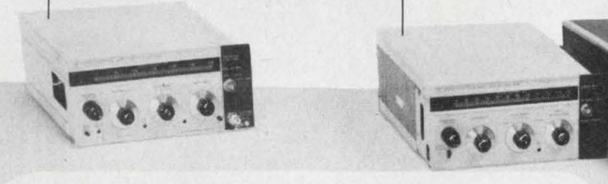
Tracking generators for wide dynamic range, swept frequency response measurements.

8556A Tuning Section, 20 Hz—300 KHz, with built-in tracking generator, $1975

8553B Tuning Section, 1 KHz—110 MHz, $2650.

8443A 110 MHz Tracking Generator/Counter, $3925.

8444A 1300 MHz Tracking Generator, $3150.



The Widest Choice in Spectrum Analyzers.

With HP's neatly-interrelated spectrum analyzers, you choose tuning sections, displays and companion instruments to tailor a system for your measurement needs all the way from 20 Hz to 40 GHz. Then, as your requirements expand, re-configure your system simply by adding the related piece of equipment. For example, when you need to cover a new frequency range simply add that tuning section.

By themselves, any of the 4 spectrum analyzers give you tremendous signal analysis capability made possible by absolute amplitude calibration, low distortion, high resolution, and wide frequency scans coupled with the ability to zoom down to a narrow scan.

Value really multiplies when you add the companion instruments. For example, the tracking generators combined with the analyzers make swept measurements over a 120 dB range thus forming precision swept frequency test systems.

And our automatic preselector for the microwave tuning unit does away with virtually all image, multiple and spurious responses.

All in all, HP's family of spectrum analyzers gives you the greatest depth and breadth of performance and the best value in signal analysis equipment available anywhere.
For more information, call your local HP field engineer or write.

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8554B Tuning Section, 0.1—1250 MHz, $3700.

8555A Tuning Section, 10 MHz—40 GHz, $6750.

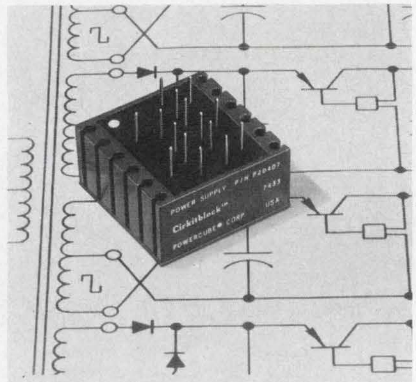
8445B, 18 GHz Automatic Preselector, for wide scans, free from unwanted responses, $2370. ($3040 with LED frequency readout option.)

8552B High Resolution IF Section has 10 Hz bandwidth, manual scan, two log plus linear scales, $3275. Lower cost unit (8552A, $2575) also available.

141T Variable Persistence and Storage Display Section. Gives bright, high-resolution traces at slow scans, $2035. Also available: economical normal persistence and large screen displays.

04315B (U.S. Domestic Prices Only.)

Dc/dc converters offer up to four outputs

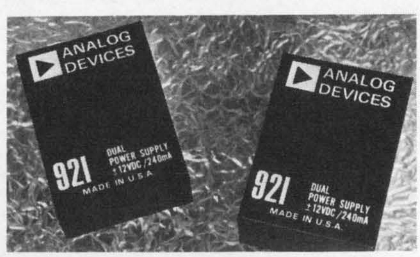


Powercube Corp., 214 Calvary St., Waltham, MA 02154. (617) 891-1830. Start at $145.

A new series of modular, multiple-output dc/dc converters offers up to four independent regulated outputs. Each output is transformer isolated and short-circuit protected. Total output power is up to 15 W for any combination. Dc inputs range from 11 through 54 V and operating temperature is from −25 to +85 C (base plate). Size is 2 × 2 × 1 in. and weight is 6 oz.

CIRCLE NO. 349

12-V modular unit regulates to 0.02%

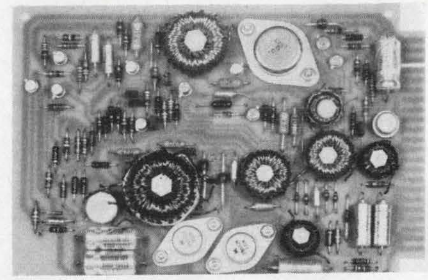


Analog Devices, Rt. 1 Industrial Pk., P. O. Box 280, Norwood, MA 02062. (617) 329-4700. $69.

Model 921 is a dual, ±12-V dc, 240-mA modular power supply with 0.02% maximum line and load regulation. The unit offers short-circuit protection by use of current limiting. Rms ripple and noise is a maximum of 0.5 mV and tempco is 0.015%/°C max. The Model 921 accepts a 105 to 125 V ac, 50 to 400-Hz input. The epoxy-encapsulated unit is specified from 0 to 70 C, measures 3.50 × 2.50 × 1.25-in. and weighs only 18 oz.

CIRCLE NO. 350

Dc/dc converters deliver 15 W

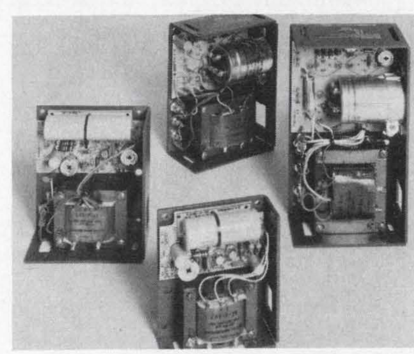


MIL Electronics, 176 Walker St., Lowell, MA 01854. (617) 453-4142. $220.

The C series of dc/dc card converters contains over 100 different standard models in single, dual, and triple outputs, with quadruple outputs available with power levels of 15 W. Features include inputs from 11 to 60 V and outputs from 5 to 500 V at currents up to 3 A. The supplies are designed for standard rack mounting with 4.5-in. card spacing and only 0.75-in. depth. The MBTF of 60,000 hours holds for board temperatures from −20 to +90 C. Typical efficiency is 65%.

CIRCLE NO. 351

52 models added to open-frame series



Lambda Electronics, 515 Broad Hollow Rd., Melville, NY 11746. (516) 694-4200. $32 to $165.

This new LO series is said to be the lowest cost job-rated OEM dc power supply offered by the industry. The open-frame series contains 52 models in single and dual-output voltages. Included in the single-output fixed voltages are: 2, 5, 6, 12, 15, 20, 24, and 28 V. The dual models are ±15 to ±12 V. Currents range from 0.8 to 25 A. Line and load regulation for the LO series is 0.15%, and ripple is 1.5 mV.

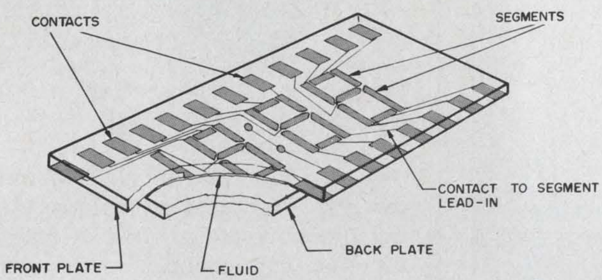
CIRCLE NO. 352

The case for Liquid Crystal Displays

Dynamic Scattering or Field Effect

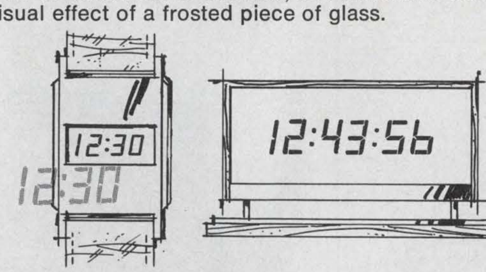
Liquid Crystal Displays; light emitting diodes; incandescent and fluorescent displays and "Nixie" tubes are becoming solidly established in circuit design as the trend to digital readout continues. The design engineer faces an unusually formidable task in determining the type of display most suitable and practical for his product. We make liquid crystal displays — dynamic scattering **and** field effect.

The display of the future? Our displays are as sandwiches of two glass plates, spaced typically about .0005″ apart with a nematic liquid crystal solution between them and hermetically sealed at the perimeters.



How they work. When the liquid is not electrically excited, its long cigar-shaped molecules are parallel to one another in a position perpendicular to the plates. The liquid appears transparent. When an electric current is applied, ion activity of the molecules leads to turbulence causing the liquid to scatter incident light. Depending on the type of nematic liquid used, either a dynamic scattering or field effect display results.

Dynamic scattering. We use a nematic liquid crystal solution in our dynamic scattering displays. This nematic liquid crystal is conductive, has negative dielectric anisotropy, and is oriented in either a homeotropic or homogeneous alignment. In either case the liquid is clear in the absence of an electric field. When an electric field is induced, the molecules scatter, giving the visual effect of a frosted piece of glass.



Field effect. These displays also utilize a nematic liquid crystal but with a different molecular orientation. The molecules are arranged in a helical stack, like a spiral staircase. The liquid is also sandwiched between two polarizers which are at right angles with each other. When current is applied the molecules rotate 90° so that they become perpendicular to the front polarizer. Light that passes through them is not rotated and therefore is absorbed by the rear polarizer. The result is a dark image on a light background. The image also can be reversed — light on dark.

Producing an image — digital or other — simply requires a conductive surface the shape of the desired image on the front glass plate. Current flowing from the conductive image through the liquid crystal to the common ground back plate causes the liquid to change from clear to a frosted appearance in the current-carrying areas.

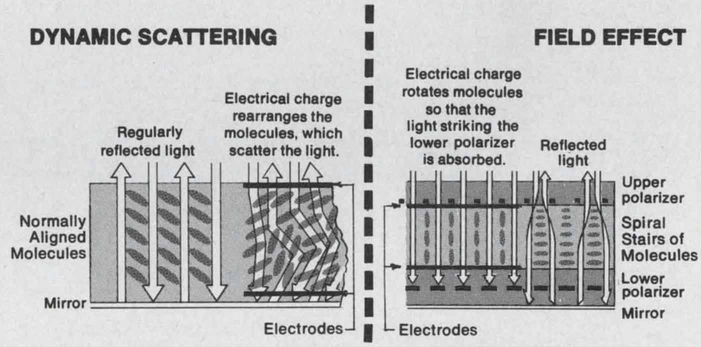
The images almost always are in the form of seven segments formed on the front glass with transparent oxide and each with its own electrical lead. Energizing the proper segments produces the desired numerals. Lead-ins connect the segments to external contacts on the sandwich (display).

Consider the advantages. Liquid crystal displays have a number of distinct advantages. Simplicity is the reason for several of these. The elements are few and passive — very little can go wrong with an LCD and this means reliability and long life.

Simplicity means low cost too — lower than that of most similar displays. Packaging costs are low because LCD's can be driven directly by MOS and C/MOS circuits. Very narrow character widths are possible and still provide a good viewing angle — 60 degrees in many cases.

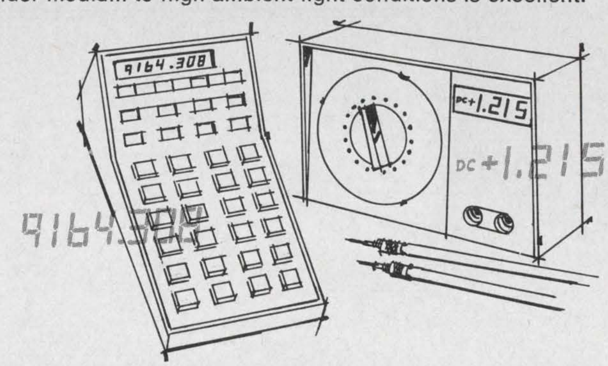
Low power consumption makes LCD's a logical choice where power limitations rule other displays out. They do not generate light as do other displays so use no power for that purpose. Watch type field effect LCD's use only 3μW. for example with all segments energized at 7 Volts.

LCD's offer the greatest flexibility of any display type. Several standard displays, dynamic scattering or field effect, are immediately available from Hamlin's stock. Special displays with virtually any type of image can be produced with surprisingly low preparation or "tooling" cost. Because of the LCD's simplicity, lead time on specials is only a matter of weeks.



A few limitations. LCD's have limitations too. Operating temperature range is one. Liquid crystals slow down and may even cease to function at temperatures below 0°C. Above 50-60°C, crystals go into solution and will not function properly. But extremes do not damage LCD's. Once the temperature returns to normal, operation is automatically resumed.

LCD's are somewhat difficult to read under low ambient light conditions. (Side or back lighting can remedy this.) Visibility under medium to high ambient light conditions is excellent.



Conclusion. In the majority of display applications, MOS and C/MOS compatibility, reliability, flexibility and low power requirements are important considerations. No other display can match the liquid crystal display on these jobs. They could be the display of the future.

And that's the case for the LCD. For specifications, and application data, write Hamlin, Inc., Lake Mills, WI 53551 • 414/648-2361. Or dial toll-free 800-645-9200 for name of nearest representative. (Evaluation samples are available at moderate cost.)

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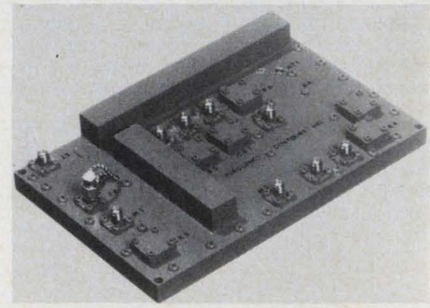
INFORMATION RETRIEVAL NUMBER 130

Assembly combines front-end functions



Frequency Contours, 3140 Alfred St., Santa Clara, Calif. 95050. (408) 984-7820.

A stripline assembly combines receiver front-end signal-processing functions at Ku band. A major function, for example, is the generation of single-sideband signals to simulate transmitter signals. The unit's selectivity is said to be comparable to waveguide-filter performance.

CIRCLE NO. 353

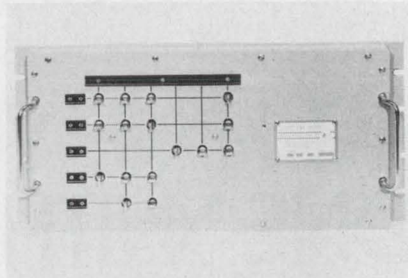
Signal gen covers 1-18 GHz in one sweep

Narda Microwave Corp., Plainview, L.I., N.Y. 11803. (516) 433-9000.

Octave-band limitations are eliminated by the 9535 broadband sweeper/signal generator. It provides full sweep coverage of L, S, C, X, and Ku frequency bands—from 1 to 18 GHz—in a single range, self-contained instrument. The sweeper can be proprammed for amplitude and frequency. The programmable frequency input is directly correlated as one volt per GHz—18 V corresponds to 18 GHz. The unit's rf power capability provides a 30-dB dynamic range for a zero to 2-V input. An analog source or BCD-type power supply may be used.

CIRCLE NO. 354

Switching matrix eases transmitter traffic



Delta Electronics, Inc., 5534 Port Royal Rd., Springfield, Va. 22151. (703) 321-9845.

The Model SLS-5 antenna switching matrix is a 50-Ω switching system for the interconnection of a number of transmitters to antennas or loads in any combination. The SLS-5 uses a compact, rack-mount design with spacing of only 1-1/4-in. between matrix points. It has a power handling capability of 4 kW average (20 kW peak) to 32 MHz, and 1 kW average (10 kW peak) to 400 MHz. The switching matrix comes as a manually operated matrix (Model SLS-5), or as a remotely controlled unit equipped with actuators for automated operation (Model SLS-5M).

CIRCLE NO. 355

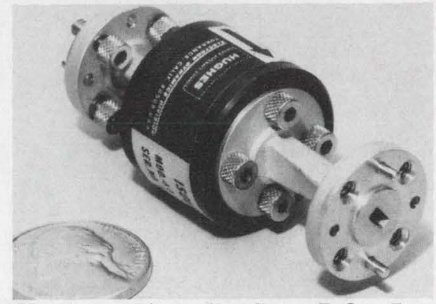
500-mW red laser comes in small housing

Lexel Corp., 928 E. Meadow Dr., Palo Alto, Calif. 94303. (415) 326-2000. P: See Below.

The company's Little Red is a small Krypton laser that delivers a guaranteed 50 mW of red power at 647.1 nm. The compact unit has a head weight of 36 lbs and a head size of 2 ft-4 in. × 5 in. × 7-in. System price is $4995.

CIRCLE NO. 356

Mm isolators have 25-dB separation

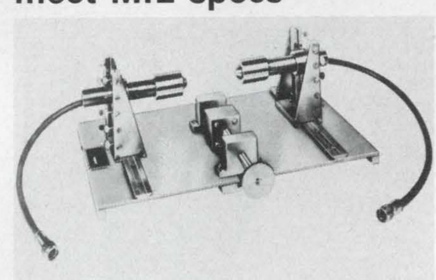


Hughes Aircraft Co., P.O. Box 90515, Los Angeles, Calif. 90009. (213) 670-1515. $1175 to $1295.

Each of two mm-wave isolators, the 44610H (33-50 GHz) and the 44606H (75-110 GHz), covers a full waveguide bandwidth and features isolations of 25 dB or greater and maximum input/output VSWR of 1.5. The isolators are of the Faraday-rotation type and consist of low-loss ferrite material and resistive elements. An external magnetic bias field is supplied by a permanent magnet.

CIRCLE NO. 357

Coupling adapter helps meet MIL specs



Filtron Co., 200 Shames Dr., Westbury, N.Y. 11590. (516) 997-3500.

The M-240B coupling adapter, for frequencies ranging from dc to 10 GHz, can be used to measure filter insertion loss as specified in MIL-STD-220A. It also permits a check of filter circuitry for RFI/EMI compatibility. Accessories to meet MIL specs include an isolation attenuator (M240-lb), a buffer network assembly (M240-3B) and 50-Ω, six-position coaxial switches (M-240-4B).

CIRCLE NO. 358

TAKE IT OFF!

Peel off the label on this magazine, then affix it to your renewal card inside the front cover of this issue. Fill in and mail the form. In return we'll send you ELECTRONIC DESIGN for another full year. Fair enough?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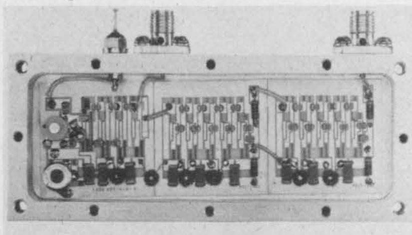
I-f limiters have low phase shift

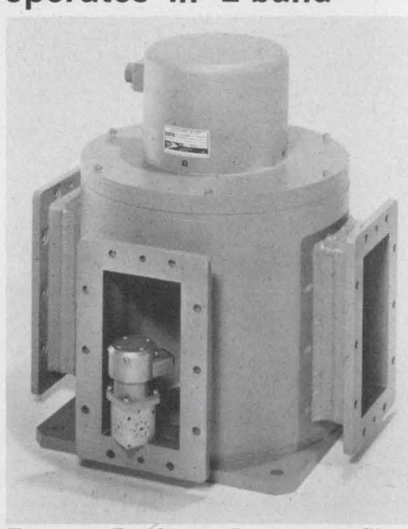


RHG Electronics Laboratory, 161 E. Industry Ct., Deer Park, N.Y. 11729. (516) 242-1100. $675 (45 days).

IC limiting i-f amps have less than 5° phase shift over a 65-dB dynamic range. The new ICSL series employs hybrid IC construction on alumina substrates, and it is available with center frequencies from 30 to 160 MHz and bandwidths to 20 MHz. Typical specs are an output-power variation of less than 0.5 dB, noise figure of less than 10 dB and input/output VSWR of less than 1.5.

CIRCLE NO. 359

Waveguide switch operates in L-band



Transco Products, Inc., 4241 Glencoe Ave., Venice, Calif. 90291. (213) 821-7911.

An L-Band, WR-650, 1.2-to-1.4-GHz waveguide switch features a pressurized E-plane design using interlock and position-indicator switches. The unit has an insertion loss of 0.1 dB max, VSWR of 1.05 max and an isolation of 50 dB max. Switching time is less than 1 second.

CIRCLE NO. 360

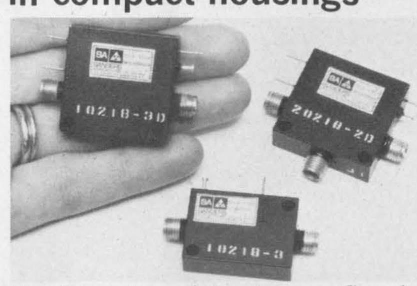
Communications amp features 2.5-dB NF

Frequency West, 3140 Alfred St., Santa Clara, Calif. 95050. (408) 249-2850.

A transistor amplifier (FW-0811N) provides a maximum noise figure of 2.5 dB and a minimum gain of 20 dB over the 0.8-to-1.1-GHz range. As an add-on to an existing system the amplifier can provide improved signal-to-noise ratio—an initial system noise figure of 7.6 dB receives a 5-dB improvement in S/N ratio. As a retrofit for tunnel-diode amplifiers, the FW-0811N provides increased dynamic range—up to 30 dB—together with decreased sensitivity to supply variations—only 0.08 dB/V. Also the unit has a group-delay variation of ±20 pS and group-delay slope of 5.5 pS per 20 MHz.

CIRCLE NO. 361

Diode switches come in compact housings

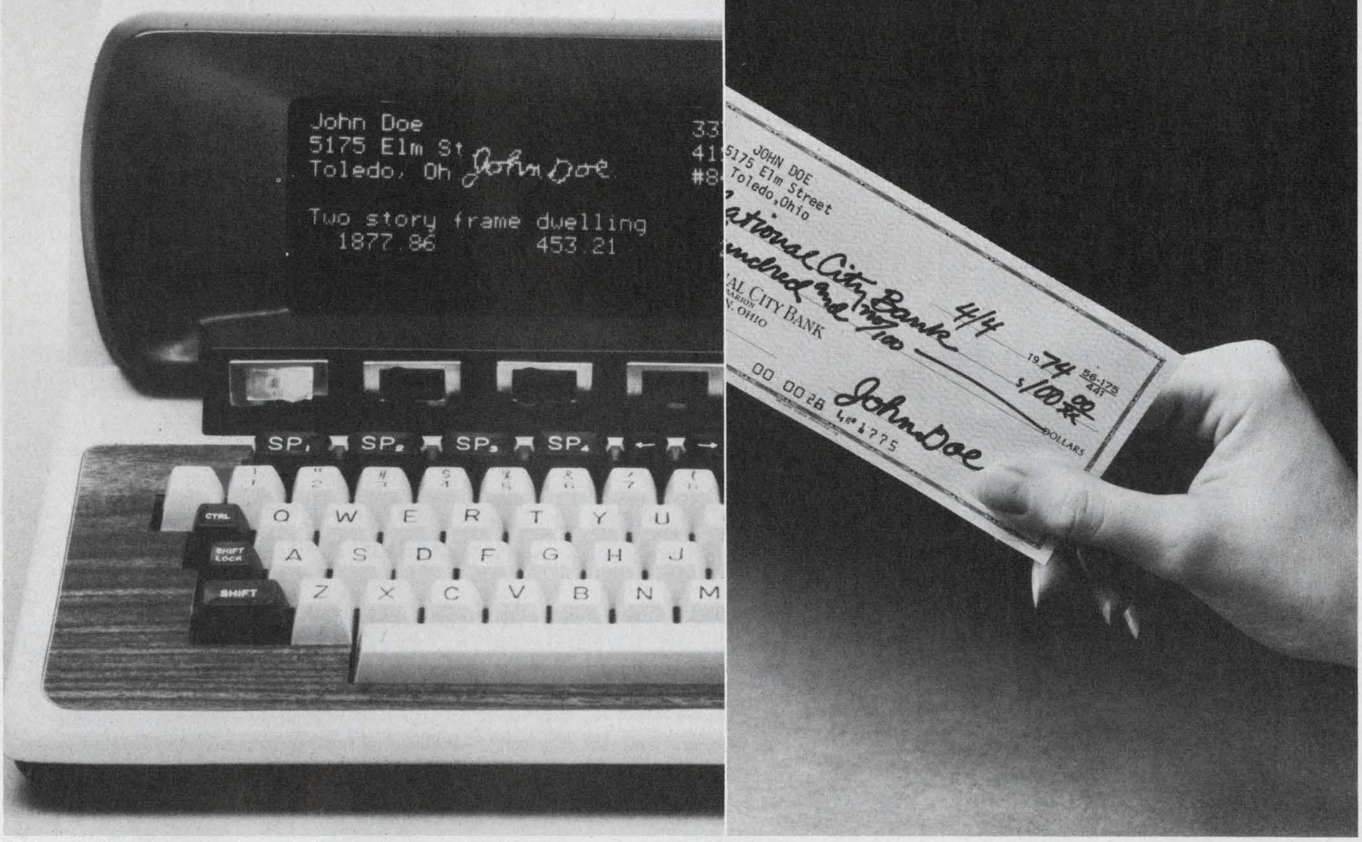


Sanders Associates, Inc., Grenier Field, Manchester, N.H. 03101. (603) 669-4615. P&A: See below.

A series of miniature octave and multi-octave switches range from SPST to SP4T with optional integrated drivers. A typical SPDT model, operating from 2-to-18 GHz, yields greater than 50-dB isolation with 2.5-dB maximum loss and switches in less than 25 ns (50% TTL to 90% rf). Standard units handle up to 5 W cw and come in a 1.1 × 1 × 0.38-in. package with SMA connectors. Called the DS10000 and DS20000 series, the new diode-switch units are priced as low as $195 each, with 30-day delivery.

CIRCLE NO. 362

Digivue®- a better way to look at it.



Digivue 80-33 in demonstration unit, showing high-contrast display for use in signature verification.

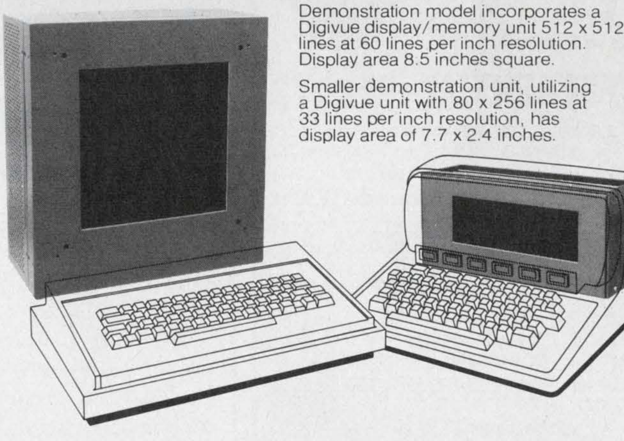
Because computer time is valuable to your customers, Digivue display/memory units offer an unforgettable advantage.

The advantage is inherent memory and it's an inherent part of every Digivue unit. This makes Digivue units especially useful for graphic presentations like signature verification since refresh is not required.

And Digivue units offer a high-contrast, flicker free display for precise readings with less chance of eye fatigue for people who spend long periods referring to data displays and computer terminals.

There's a lot more to Digivue, too. Our 512-60 models have hard copy and rear projection capabilities. And Digivue panels are flat and thin, allowing precise display and broad equipment design parameters.

As you may have guessed, Digivue display/memory units currently cost more than CRT's. But then, they offer a lot more. For a booklet that explains Digivue more fully, call (419) 242-6543, Ext. 66-415. Or write Electro/Optical Display Business Operations, Owens-Illinois, Inc., P.O.Box 1035, Toledo,Ohio 43666.



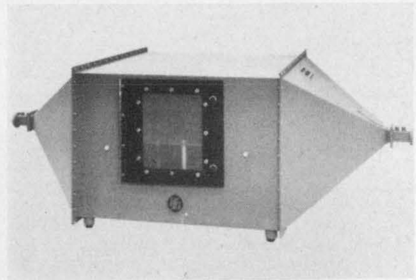
Demonstration model incorporates a Digivue display/memory unit 512 x 512 lines at 60 lines per inch resolution. Display area 8.5 inches square.

Smaller demonstration unit, utilizing a Digivue unit with 80 x 256 lines at 33 lines per inch resolution, has display area of 7.7 x 2.4 inches.

OWENS-ILLINOIS

Toledo, Ohio

Radiation tests eased with enclosed unit

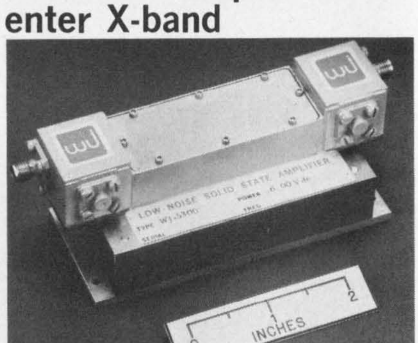


Instruments for Industry Inc., 151 Toledo St., Farmingdale, N.Y. 11735. (516) 694-1414.

Test cells—known as Crawford Cells—offer a broad-band method of measuring both emitted radiation from, and the susceptibility of, equipment placed within the cell. Consisting of an enclosed waveguide environment, the cell eliminates the need for cumbersome antennas and the uncertainties of their use in shielded rooms. A typical unit, the Model CC-103, measures 53-in. long, 24-in. wide and 16-in. high. It has a standing wave ratio of less than 1.05:1 up to a frequency of 300 MHz. A 100-W amplifier produces a field strength of over 200 V/m.

CIRCLE NO. 363

GaAs FET amps enter X-band

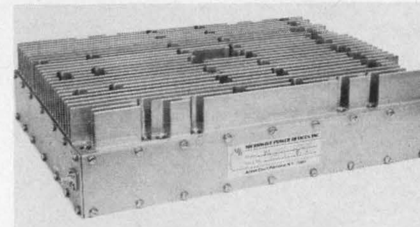


Watkins-Johnson Co., 3333 Hillview Ave., Palo Alto, Calif. 94304. (415) 493-4141.

A family of GaAs FET low-noise amplifiers are offered for the X-band frequency range. Typical specifications of the WJ-5300 Series include a 6-dB noise figure and a 30-dB small-signal gain for the 7.25-to-8.4-GHz unit. Also, the model has a +5-dBm output power and a ±0.5-dB gain flatness. Group-delay distortion is 0.5 ns per 40 MHz, and VSWR (in and out) is 1.25:1.

CIRCLE NO. 364

100-W class C amp specs 1.6-1.7-MHz range

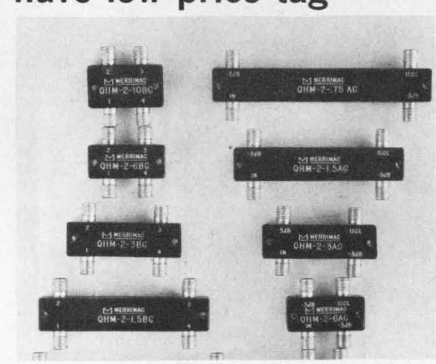


Microwave Power Devices, Adams Ct., Plainview, L.I., N.Y. 11803. (516) 433-1400.

The Model PWA1617-12 cw solid-state class-C amplifier delivers 100-W saturated power over the frequency band of 1600 to 1700 MHz. The unit also features 50-dB gain, output circulator for protection against load mismatches and MIC construction. Harmonics are at least 30 dB below the fundamental.

CIRCLE NO. 365

Small 3-dB couplers have low price tag



Merrimac Industries Inc., 41 Fairfield Place, West Caldwell, N.J. 07006. (201) 228-3890. P: See below. Stock to 30 days.

Lightweight 3-dB couplers reportedly provide increased reliability at a price that is one-half that of competitive units. The new quadrature couplers cover the 500-MHz-to-12.4-GHz range with five models, each covering a different octave bandwidth. The units weigh 0.9 oz or less and cost $40 in quantities of one hundred. Typical specs for the QHM-2 series are 20-dB isolation and 0.3-dB insertion loss. Mid-frequency coupling is 3 ±0.2 dB, and output-to-output phase quadrature is 90 ±1.5 degrees. Output-to-output amplitude equality is ±0.5 dB. The couplers have a peak power rating exceeding 250 W, and an average capability of 50 W.

CIRCLE NO. 366

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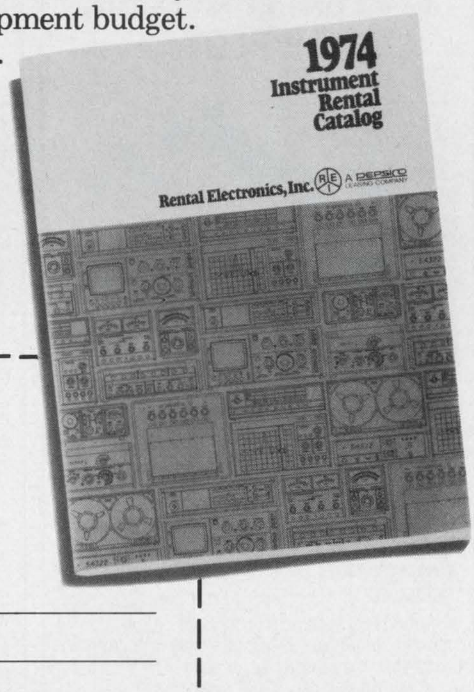

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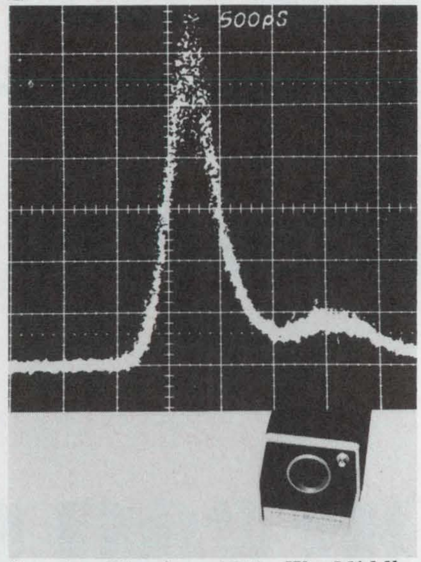
INFORMATION RETRIEVAL NUMBER 139

Power laser gives short pulses

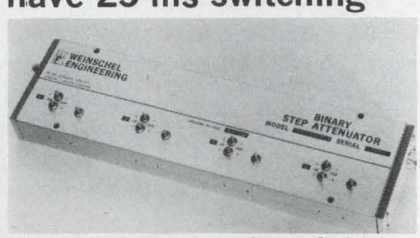


Spectra-Physics, 1250 W. Middlefield Rd., Mountain View, Calif. 94042. (415) 961-2550.

The Model 166/366 Combo mode-locked cavity-dumped laser operates at maximum peak power levels of about 50 to 200 W, at any rate from single shot to 5 MHz with internal triggering. Selection of any sub-multiple frequency of 100 MHz is provided with external triggering.

CIRCLE NO. 367

Dc-18-GHz attenuators have 25-ms switching

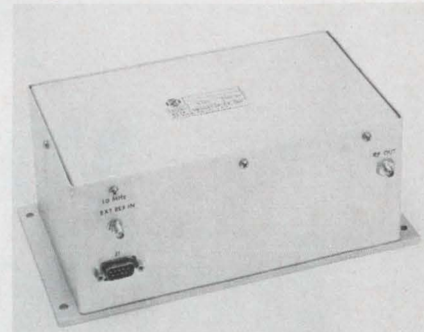


Weinschel Engineering, Gaithersburg, Md. 20760. (301) 948-3434. $485 to $1125; 150 days.

In addition to the dc-to-18 GHz frequency range, each model in the 132 through 134 series of binary step attenuators is available in these ranges: dc-to-1 GHz, dc-to-4 GHz, dc-to-8 GHz and dc-to-12.4 GHz. They reach a settled condition in only 25 ms or less. And they have an operational life time of 2 million steps per cell. The units have a repeatability of typically 0.04 dB to 18.0 GHz and a choice of Type N, SMA, TNC, and 7-mm connectors.

CIRCLE NO. 368

Synthesizer specs high stability



Zelta Laboratories, Inc., 616 National Ave., Mountain View, Calif. 94043. (415) 961-9050.

A stable S-band frequency synthesizer, Model 6550, operates in the 2830-to-2990-MHz frequency range. The frequency stability is better than 1 part per million over the 0 to 50 C temperature range and the option exists for an external reference at 5 or 10 MHz. The 6550, housed in a 8.25 × 3.69 × 5-in. module, provides 10-MHz steps in 10 ms/step across the band with a minimum of 100-mW power output.

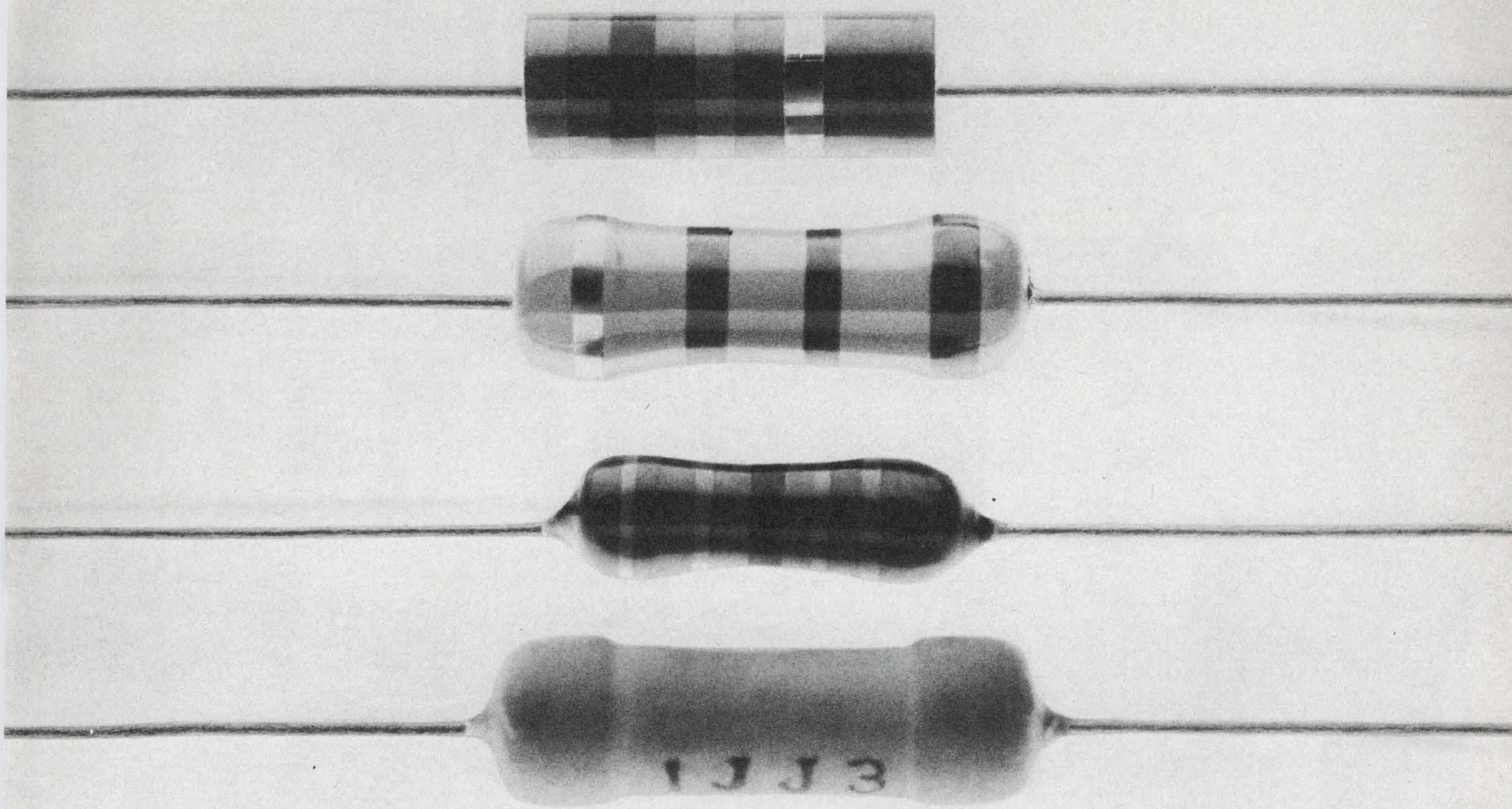
CIRCLE NO. 369

Rugged TWT outputs 10 W at 6 GHz

The M-O Valve Company, Ltd., Brook Green Works, Hammersmith, London W67PE, England.

A new travelling-wave tube—the TWC37—reportedly represents a new generation of TWTs for which reliability is measured in years rather than hours. The TWC37 is designed for 10-W operation in 6-GHz radio links, and it can handle 1800 channels. The new unit requires a total input power of less than 50 W, for a power conversion efficiency of over 20%. The TWC37 employs a low-temperature, low-emission-density cathode. Compared with earlier units, the tube construction reduces thermal dissipation and minimizes internal gas pressure.

CIRCLE NO. 370



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Matsushita Electric Corp. of America, ED-1
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INFORMATION RETRIEVAL NUMBER 142

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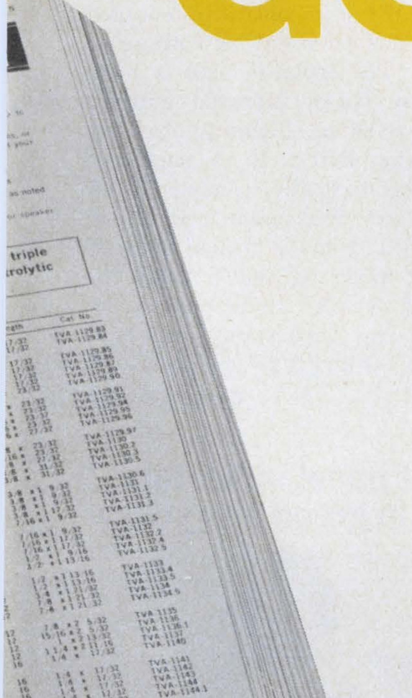

IT'S ALL THERE Under CAPACITORS, for example, you'll find source information listed in the following categories in the PRODUCT DIRECTORY (each listing gives *complete* manufacturer's name, street address, city, state, zip and phone for your convenience in contacting suppliers): • CHIP CAPACITORS • FIXED CAPACITORS — AC&AC MOTOR; AIR; CERAMIC; CERAMIC CHIP, CERAMIC TEMPERATURE COMPENSATED; ELECTROLYTIC — ALUMINUM, (TANTALUM FOIL, SOLID, & WET-SLUG); FEEDTHROUGH; FILM, TEMPERATURE COMPENSATED; GAS FILLED; GLASS; HIGH TEMPERATURE; LABORATORY STANDARD; METALIZED PAPER; MICA; MICA PAPER; OIL-FILLED; PAPER; POLYCARBONATE; POLYESTER; POLYPROPYLENE; SOLYSTYRENE; PRECISION; TFE; HIGH ENERGY • VARIABLE CAPACITORS — AIR, (INCLUDES TRIMMER); CERAMIC; FILM; GAS; GLASS OR QUARTZ TRIMMER; HIGH TEMPERATURE; LAB TYPE; MICA; MOTOR-DRIVEN; TEMPERATURE COMPENSATED, AND VACUUM.

YOU'LL FIND 235 CATALOG PAGES ON RESISTORS AND CAPACITORS

Volume 2 of *Electronic Design's* GOLD BOOK provides page after page of catalog information and specs for resistors and capacitors. Twenty-five capacitor manufacturers are represented, including 24 pages from Sprague, 20 pages from Corning, 12 pages from USCC Centralab and so on. Twenty-three manufacturers are represented for fixed or variable resistors. Scan these pages before you contact a supplier. You can nearly always save valuable time, perhaps locate the exact item you need — and that goes for each one of the 52 product categories cataloged in two full volumes of *Electronic Design's* GOLD BOOK. These pages are READY WHEN YOU ARE, 2,820 of them, right at your fingertips for immediate reference.

FOR FURTHER INFORMATION SEE OUR TECH PAGES IN Electronic Design's GOLD BOOK

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If your company has catalog pages in *Electronic Design's* GOLD BOOK, don't forget that 91,000 copies are in circulation with 13,200 overseas (11,000 in Europe). Your advertising manager should refer engineers to your pages at every opportunity, especially in current advertising campaigns.

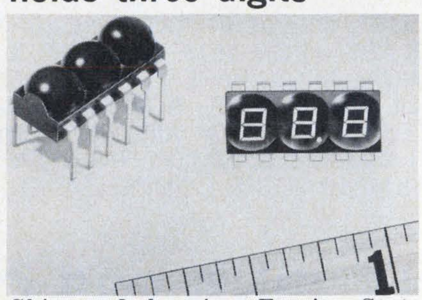
GaP LEDs have a beam spread of 150°

Opcoa, 330 Talmadge Rd., Edison, NJ 08817. (201) 287-0355. From $0.28 (1000-up); stock to 4 wks.

A series of 0.12 in. diameter GaP LED lamps offers a rugged lead frame construction with both flange and flangeless lenses. Standard lead lengths are 0.5 in. minimum and cathode indentification is by means of both a flatted flange and lead length differential. The diodes have a beam spread of 150° for wide angle viewing. All three colors—red, green and yellow—are characterized for the same luminous intensity, 1 mcd typical, at 20 mA. Lenses on standard devices are diffused and tinted.

CIRCLE NO. 371

DIP sized LED display holds three digits

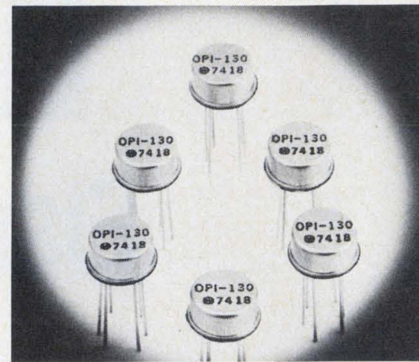


Shigoto Industries, Empire State Bldg., 350 Fifth Ave., N.Y., N.Y. 10001. (212) 695-0200.

The GL-930 AR triple seven-segment red LED display is designed into a standard 12-pin DIP with integrally molded bubble lenses. The lenses provide a magnified digit height of 2.55 mm and a wide viewing angle of ±30° from the center line of the digit. Brightness is rated at 200 ft-lamberts at $I_F = 5$ mA. The three-digit display is only 15.24 mm wide and is end stackable for compact and easy-to-read multiple unit arrays. The monolithic GaAsP common-cathode chip for each digit is interconnected for strobed operation. The multiple digit numeric display is rated at 80 mW maximum power dissipation per digit and 30 mA continuous forward current per digit. The shock resistant unit offers a wide operating and storage temperature range of −25 to +85 C.

CIRCLE NO. 372

Optocouplers provide up to 1500 V of isolation



Optron, 1201 Tappan Circle, Carrollton, Tex. 75006. (214) 242-6571. $3.35 (1000-up); stock.

The OPI 130 optically coupled isolator has an isolation voltage of 1500 V. The isolator uses a high efficiency GaAs infrared emitter coupled with a silicon photo-Darlington amplifier. It is packaged in a hermetically sealed TO-5 package for maximum reliability. The OPI 130 has a typical current transfer ratio of 500% with an input of 5 mA. Input-output resistance and capacitance are typically 10^{12} Ω and 3 pF, respectively.

CIRCLE NO. 373

Preset panel indicators come in green and yellow

Dialight, 203 Harrison Pl., Brooklyn, N.Y. 11237. (212) 371-8800. $1.71 (1000-up); stock.

The 249 series of green and yellow permanent mount panel lamps is available in voltages from 3.6 to 28 V dc with a maximum current of 20 mA. Tolerances on the dc voltage should be within 5% of that specified. Both short cylindrical and short stovepipe lens shapes are available. The indicator is supplied in a black anodized finish case that produces a high contrast ratio. Polarity is marked on the mounting bushing terminals to assure proper installation. All indicators operate at temperatures between −55 and +71 C.

CIRCLE NO. 374

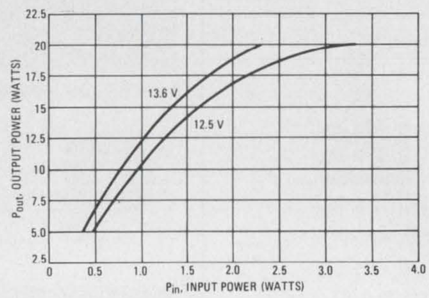
Program optocoupler with a single resistor

General Electric, Electronic Park, Bldg. 7, Mail Drop 49, Syracuse, NY 13201. (315) 456-2021. $1 (large qty); stock.

The H11A10 programmable photocoupler turns on a transistor, electrically remote from the input, when the input current exceeds a specified threshold. This threshold can be programmed over a 10:1 range, from 4 to 40 mA by changing a single external resistor. The H11A10 is characterized and specified with two resistors, one in the input and one in the output. The coupler provides an isolation voltage of 1500 V and a minimum current transfer ratio of 10% in the "on" state. Operation is over a −55 to +100 C temperature range.

CIRCLE NO. 375

Rf power transistors deliver 10 W at 225 MHz



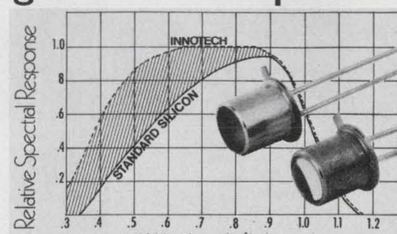
MRF226 – OUTPUT POWER versus INPUT POWER

Motorola, P.O. Box 20924, Phoenix, Ariz. 85035. (602) 244-6900. 100-up lots: 225 ($1.95), 226 ($9); stock.

The MRF225 and MRF226 rf power transistors are characterized for operation at 225 MHz. The MRF226 has been specified for 13 W output. The MRF225/226 driver/power amplifier pair provides the design with an anticipated 3 W power margin over the operated 10 W limit on Class E citizens band transmissions. The MRF226 can withstand a 20:1 VSWR at any phase angle; both devices provide a power gain of 9 dB, minimum, with collector efficiencies of 50%. The MRF225 driver has a 1.5 W output capability; both devices are characterized at 12.5 V dc collector supply.

CIRCLE NO. 376

Photodiodes offer a guaranteed response

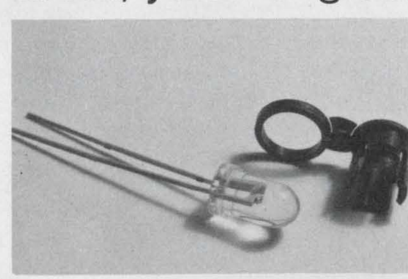


Innotech, 181 Main St., Norwalk, Conn. 06851. (203) 846-2041. $17 (25-up); 2 wk.

The PD050F and PD050L photodiodes have a guaranteed minimum-spectral response of 0.5 A/W, maintained from 0.85 through 0.62 μm wavelengths. These photodiodes have an almost flat response through the visible region that remains high into the blue-violet region. The PD050F is packaged in a flat glass TO-18 windowed case, while the PD050L is in a TO-18 lens windowed case. Chips are also available. The chip size is 0.05 × 0.05 in. with a sensitive area 0.045 × 0.045 in. The units have a response speed of 20 ns typical and a capacitance of less than 3 pF at −20 V bias. Dark current is 20 nA typical at 25 C. NEP is 4 × 10^{-13} W min. measured at a 0.8 μm wavelength.

CIRCLE NO. 377

T-1-3/4 LEDs come in red, yellow or green



National Semiconductors LTD, 331 Cornelia St., Plattsburgh, NY 12901. (518) 561-3160. From $0.36 (1000-up); stock.

The MA 2400 series of GaP LEDs offer red, green and yellow light-emitting chips with a variety of lens styles. All of the MA 2400 series LEDs are provided with panel mounting clips. Typical luminous intensities of 2 mcd at 5 mA are available without compromising viewing angle. The LEDs are available in the popular T-1-3/4 package.

CIRCLE NO. 378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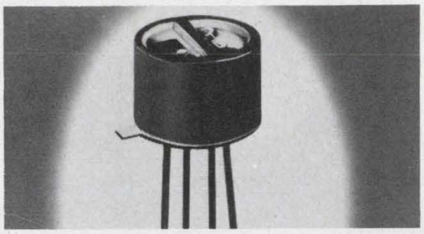
IR reflective sensor housed in four-pin case

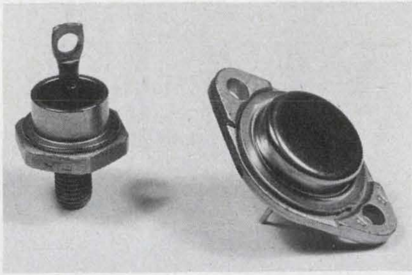


Optron, 1201 Tappan Circle, Carrollton, TX 75006. (214) 242-6571. $3.25 (1000 up); stock.

The OPB 710 reflective object sensor consists of a GaAs infrared LED and a silicon npn phototransistor mounted in a four-lead TO-18 package. A light barrier placed between the emitter and sensor of the OPB 710 allows the phototransistor to respond to emitted radiation only when a reflective surface is placed within in field of view. When located 0.25 in. from a diffused reflective surface, such as white bond paper, a typical output signal of 300 μA is obtained with a 50 mA LED input.

CIRCLE NO. 379

Fast recovery diodes handle currents to 25 A

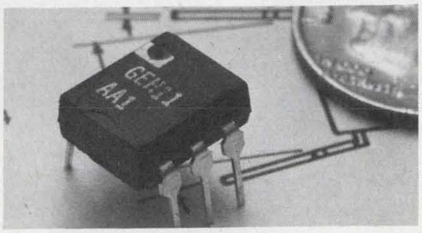


Solitron Devices, 1177 Blue Heron Blvd., Rivieria Beach, FL 33404. (305) 848-4311. $2.40 (100-up); stock.

The SPD 2005-2040 series of fast switching 20 A diodes offers peak reverse voltage ratings up to 400 V. This series utilizes epitaxial planar chip construction with high temperature mounting and aluminum ultrasonic lead attachment. The SPD 2005-2040 series units offer 200 ns typical reverse recovery time. Other features are operating range from −65 to 150 C; typical thermal resistance of 2 C/W (DO-4) and 1.2 C/W (TO-3); and storage temperature of 200 C.

CIRCLE NO. 380

Opto coupler handles bidirectional inputs



General Electric, Bldg. 7, Mail Drop #49, Electronics Park, Syracuse, NY 13201. (315) 456-2021. From $1.50 (OEM qty); stock.

A bidirectional photocoupler uses two LEDs connected anti-parallel and coupled to a phototransistor output. The photocoupler thus is operational on either positive or negative input cycles. The H11AA series features 1500 V isolation, and up to 20% minimum-current transfer ratio. Typical variation in the peak transfer ratio in the two directions is +25% and a 3:1 symmetry is guaranteed. Operation is over a −55 to 100 C temperature range. The unit is available in standard DIP plastic packaging.

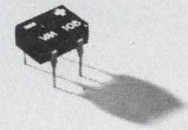
CIRCLE NO. 381

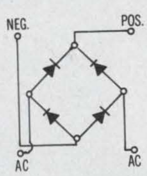
NEW DIB*

DUAL IN-LINE BRIDGE

An integrated bridge rectifier in a dual in-line package

ACTUAL SIZE PACKAGE





Another FIRST from Varo Semiconductor, Inc. An integrated bridge rectifier in a miniature, 4-pin, low-profile DIP.

The DIB, dual in-line bridge, is compatible with automated testing, handling and inserting equipment for production economy, handling ease and greatly reduced assembly errors. They are 100% surge tested at 25 AMPS and meet moisture resistance requirements of MIL-STD 2021, method 106C. Higher component density, reduced labor and materials costs are among other advantages offered by the DIB.

For simplified board layout the four leads are on 0.10" (2,54mm) grid spacing. The bridge can be used with standard DIP sockets.

* TM-Varo Semiconductor, Inc.

Typical applications include electronic calculators, small permanent magnet motors (such as used in shavers and hair dryers), solid state relays and similar applications where full-wave rectification and small size is required.

Two DIB series are available: ½ Amp I_o at 55°C, (T_A) with 25V, 50V, 100V and 200V (V_{RRM}), and a 1 AMP I_o at 40° C , (T_A) with 50V, 100V, 200V, 400V, 600V, 800V and 1000V (V_{RRM}).

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INFORMATION RETRIEVAL NUMBER 151

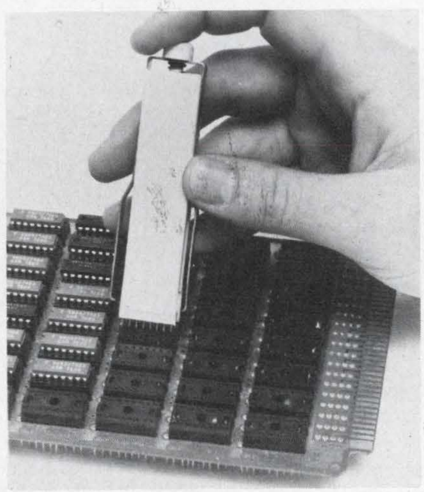
Resistor paste formula features low TCR

Thick Film Systems Inc., 324 Palm Ave., Santa Barbara, Calif. 93101. (805) 963-7007. $45/oz: evaluation packet of five formulas.

Two new low TCR, screen-printable, resistor-paste formulas were added to Thick Film Systems 850 series. The new formulas, with resistivities of 10 and 100 Ω/square, are fired the same as the others in this series—at 850 C for 25 min. The new formulas provide a TCR of 0 to ±100 ppm over the range of −55 to 150 C.

CIRCLE NO. 382

Tools safely insert or extract ICs



Solder Removal Co., 1077 E. Edna Pl., P.O. Box 1678, Covina, Calif. 91724. (213) 966-8321. 870: $2.95; 875: $4.95 (unit qty); stock.

IC insertion and insertion/extraction tools protect leads and provide quick and accurate positioning for IC insertion into sockets. The tools are molded of reinforced nylon. In the 870 Insertic, simply press the IC into the molded tool jaws, line up the lead pins on one side with the circuit-board holes, roll the remaining leads into place and press the ejector button to snap the IC into place. The 875 Pul-N-Sertic operates the same as the 870 except that it also can extract ICs. To use this feature, place the tool over the IC, slide the removal clip over the body of the IC, squeeze the clip and pull the IC free.

CIRCLE NO. 383

Kit contains all needed for making shop signs

W. H. Brady Co., 2223 W. Camden Rd., Box 2131, Milwaukee, Wis. 53201. (414) 332-8100. $99.95 stock.

Do-it-yourself sign-making kit, Sign-Shop-in-a-Box, contains a complete lettering system, sign blanks and OSHA headings. Sign blanks are white and yellow semi-rigid linear polyethylene with brass grommets in each corner for mounting. Also, a supply of double-coated-adhesive foam strips enable quick sign mounting on any clean, dry surface. Self-sticking sign headings that show DANGER, CAUTION, NOTICE and SAFETY FIRST in the size and colors to meet OSHA specifications are provided. A Quick-Align lettering and numbering system provided in the kit contains 560, 2-in. die-cut vinyl, self-sticking letters and numbers assorted according to most common usage. Each character comes on a notched backing card that assures correct alignment and spacing.

CIRCLE NO. 384

Refractory metals available as crystals

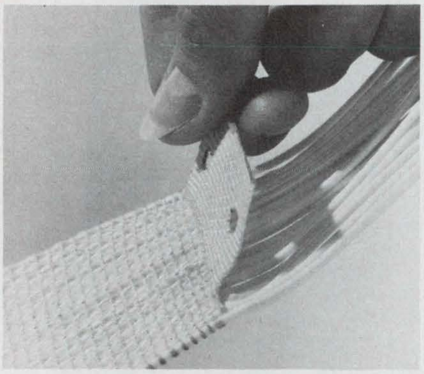
Aremco Products, Inc., P.O. Box 429, Ossining, NY 10562. (914) 762-0685. See text; 3 to 4 wks.

High-purity, single-crystal, refractory metals including niobium, molybdenum, tantalum, vanadium and tungsten with purities in the range of 99.9995% are now available in standard rods of 1/4, 3/8, and 1/2-in. dia and lengths to 8 in. The crystals are grown by use of electron-beam techniques. Though they are normally supplied with random orientation, specific orientations are also available. A typical tungsten single crystal that is 99.9995% pure and 3/8-in. dia is priced at $200 per inch, random oriented.

CIRCLE NO. 385


Electronic Design

Woven cable features strain-relief tabs

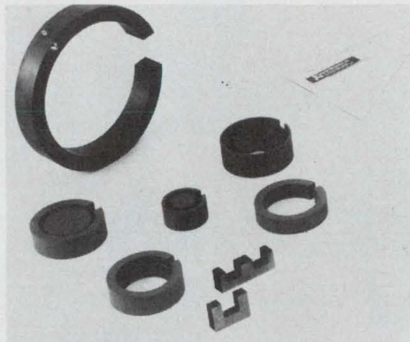


Woven Electronics, P.O. Box 189, Mauldin, SC 29662. (803) 963-5131.

A strain-relief tab can now be included into Woven Electronic's flat woven cables and harnesses at one or both ends of a fixed-length cable. The strain-relief tabs are a woven extension of the binding fibers. Tabs can be secured to the connector, tacked to a panel or otherwise fastened to relieve strain from connector pins.

CIRCLE NO. 386

Ferrite shapes machined from bar stock



Ceramic Magnetics Inc., 87 Fairfield Rd., Fairfield, N.J. 07006. (201) 227-4222.

In contrast to conventional pressed and fired techniques, low-loss ferrite shapes are fully machined from stress-free, homogeneous bar stock. Ceramic Magnetics says that the machining method allows the manufacture of a greater variety of precision shapes than does the conventional approach. The machining method provides reproducibility and traceability of every individual ferrite component.

CIRCLE NO. 387

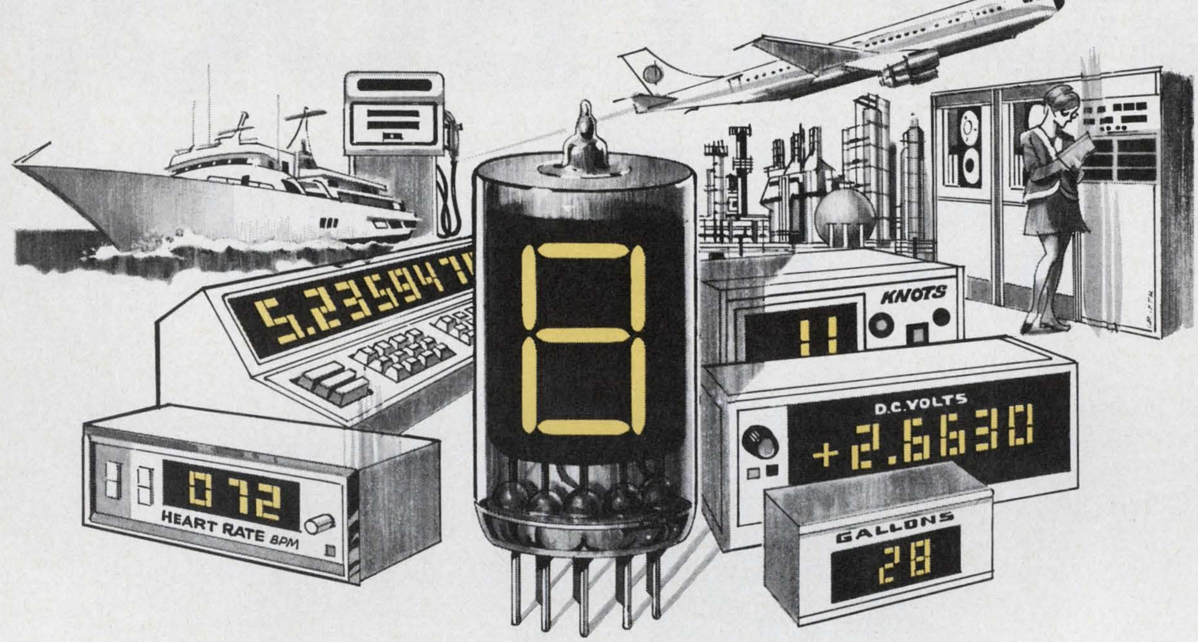
Quick connect terminals in many styles

Zierick Manufacturing Corp., 36 Radio Circle, Mount Kisco, NY 10549. (914) 666-2911.

Male and female quick-connect terminals in Zierick Manufacturing's line include binding posts, 45° and 90° lugs and special eyeletting types. New tab sizes are 0.250, 0.205, 0.187 and 0.110 in. Female tab connectors comply with industry standards for insertion and extraction forces. The terminals are available in nickel-plated steel, for high temperature applications, and in brass with cadmium or tin plates. Also, high-conductivity copper, where the current-carrying capacity is critical, is available.

CIRCLE NO. 388

When your design calls for the brightest readout...



consider <u>all</u> the advantages of RCA NUMITRON Display Devices.

In applications where brightness is critical RCA NUMITRON devices meet your most exacting requirements. They don't wash out, even in direct sunlight!

But brightness is just one important feature to think about when selecting display devices. Consider all the features that RCA NUMITRON devices have to offer:

- Unlimited color filter selection because of wide-spectrum light emission.
- Brightness is completely controllable — the device maintains uniform brightness, from segment-to-segment, even when operated at reduced voltages.
- High reliability and rugged construction. Life expectancy is more than 100,000 hours.
- Low-voltage operation (4.5 volts or 2.5 volts nominal).
- Compatible with IC decoder/drivers such as the RCA CD2500E family.
- Freedom from induced or radiated interference.
- Planar construction offers uncluttered, wide-angle viewing.
- Operating temperature range from -50°C to +125°C.

RCA NUMITRON devices are rugged! The DR2200 Series can withstand shock of 200g and vibration of 20g max. over a 60 to 500 Hz frequency range. NUMITRON displays are flexible, too. Solderable base pins permit direct PC board mounting. The DR2000 series of devices fit low-cost 9-contact miniature sockets. DR2100 and DR2200 Series fit TO-5 10-contact sockets.

Bright, sharp, dependable — RCA NUMITRON devices offer many important performance advantages to designers of readout equipment for industrial, commercial, or military applications.

Ask for RCA's NUMITRON Display Devices Designer's brochure (NUM-421A). You'll get the latest application information and data. Contact your RCA representative or RCA NUMITRON Device Distributor, or write, RCA Commercial Engineering, Sec. 57J-25 415 S. 5th St., Harrison, N.J. 07029.

RCA NUMITRON Display Devices

"See RCA's NUMITRON display at the ISA show."

INTERNATIONAL SALES OFFICES: ARGENTINA – Casilla de Correo 4400. Buenos Aires/BRAZIL – Caixa Postal 8460. São Paulo/CANADA – 21001 No. Service Rd. Ste. Anne de Bellevue. 810 Quebec/ENGLAND – Sunbury-on-Thames. Middlesex/HONG KONG – P.O. Box 112/MEXICO – Apartado 17-570. Mexico 17. D.F./SWITZERLAND – 118 rue du Rhone CH1204. Geneva,

INFORMATION RETRIEVAL NUMBER 159

Electronic Design's GOLD BOOK IS READY

VOLUME 1 DIRECTORIES

• PRODUCT DIRECTORY

Want to know who makes a given product? *Electronic Design's* GOLD BOOK is the first place to look. Manufacturers are listed under almost 5,000 product headings or cross references. You'll find everything an electronics manufacturer would require — components, computers, hardware, test equipment, instrumentation, systems and services — they're all there, from "Abrasives" through "Zone Boxes."

Knowing only a name or state isn't much help if you or your secretary want to contact several manufacturers at once for information or a quote. *That's why Electronic Design's GOLD BOOK repeats each manufacturer's full name, street address, city, state, zip and phone number every time the manufacturer is listed.*

• MANUFACTURERS DIRECTORY

You'll find 7,528 manufacturers listed in *Electronic Design's* GOLD BOOK — more than twice the number contained in "the other industry directory." In addition to complete address and phone number, whenever provided by the company you'll also find:

- TWX
- TELEX
- CABLE ADDRESS
- FACSIMILE EQUIPMENT (make and call number)
- 800 (TOLL-FREE) NUMBER
- QPL DESIGNATION
- FEDERAL STOCK CODE NUMBER
- NUMBER OF EMPLOYEES
- NUMBER OF ENGINEERS
- DOLLAR VOLUME
- KEY OFFICIALS
- SALES OFFICES
- FOREIGN OFFICES
- U.S. AND FOREIGN REPS
- U.S. DISTRIBUTORS

• DIRECTORIES OF DISTRIBUTORS

Want to find a distributor near your town? Use the geographic Directory of Distributors. Access is by State, then City. 5,700 distributors are listed. The same distributors are also listed alphabetically for your convenience, often with additional information about their business volume, key personnel, etc.

• TRADE NAME DIRECTORY

If you've heard the trade name, but can't remember who makes it, here's the place to look. Over 4,600 industry trade names are included. Listing includes brief description of item and company name.

TOTAL DISTRIBUTION: 91,000 — 13,200 COPIES OVERSEAS, INCLUDING 11,000 COPIES IN EUROPE

WHEN YOU ARE

VOLUMES 2 & 3 CATALOGS

- 520 CATALOG PAGES ON ICs AND SEMICONDUCTORS
- 300 CATALOG PAGES ON INSTRUMENTS
- 290 CATALOG PAGES ON POWER SUPPLIES
- 210 CATALOG PAGES ON WIRE AND CONNECTOR PRODUCTS
- 150 CATALOG PAGES ON SWITCHES

Volumes 2 and 3 of *Electronic Design's* GOLD BOOK are filled with manufacturers' technical data and product catalogs — a gold mine of information for the engineers, engineering and purchasing managers of this industry. Products are classified by related families and are organized in 52 product categories, over 2,800 catalog pages in all.

Volume 2 contains *Components* and *Materials;* Volume 3 contains *Equipment, Hardware, Panel Components, Power Supplies, Tools* and *Production Equipment, Engineering Aids,* and *"Company Profiles and Capabilities."*

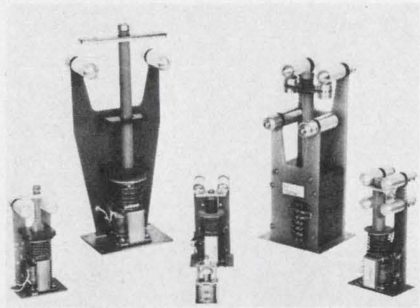
Electronic Design's GOLD BOOK is READY WHEN YOU ARE. Keep it on hand for product search, sourcing, or for instant technical and specifying data. It puts the entire electronics industry at your fingertips.

Electronic Design's GOLD BOOK is the largest, most complete, most comprehensive one-step purchasing and reference tool ever produced in this industry. Its PRODUCT DIRECTORY contains more than twice the number of editorial pages than the other industry directory; almost 50% more pages of TRADE NAMES; half again the number of pages in its MANUFACTURERS DIRECTORY; almost twice the number of pages in its DISTRIBUTORS DIRECTORIES. It's far and away the biggest and best electronics directory in the world.

BETTER BY EVERY MEASURE

	The Other Industry Directory	*Electronic Design's* GOLD BOOK	
Total manufacturers	3,165	7,528	+4,363
Direct product codes	2,250	2,925	+ 675
Cross-reference product codes	985	1,874	+ 889
Total product codes	3,235	4,799	+1,564
Overseas circulation	Nil	13,200	+13,200

High-voltage relays handle to 300 kV



Ross Engineering Corp., 559 Westchester Dr., Campbell, Calif. 95008. (408) 377-4621.

High-voltage relays safely handle 2 to 300 kV for high-voltage transfers, safety grounding and tap or load selection of from 1 to 200 A, or more, or capacitor discharge to 50,000 A. The Ross relays are air insulated. Contacts in most relays can be rotated to renew the contact area and increase service life. Most units are insulated with G-10 epoxy glass laminate. As an option, G-7 silicone-glass-insulated models are available for rf applications. Special modified relays can be immersed in insulating oil, fluid or gas, which doubles the relays' withstand values and enhances their capability. No modification is necessary for operation in an insulating-gas atmosphere.

CIRCLE NO. 389

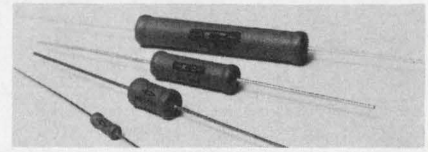
Slide switches feature oversized terminals

Stackpole Components Co., P.O. Box 14466, Raleigh, NC 27610. (919) 828-6201.

A series of slide-switches with special type A terminal configurations can hold a rectifier or power diode. The terminals feature a push-on tab for ease of wiring. The large-sized terminal acts as a heat sink for the diode. Type B terminals have been tooled to receive 0.187-in. connectors and Type C terminals receive a 0.110-in. connector. The switches are available in SPST and SPDT 10-A, 125-V ac ratings.

CIRCLE NO. 390

High-voltage resistors stable to 0.1%

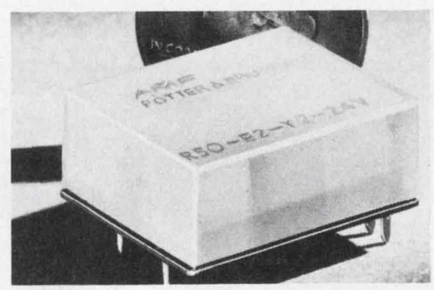


Caddock Electronics, Inc., 3127 Chicago Ave., Riverside, CA 92507.

A new and advanced resistor, Type MG, provides very high resistances (to 2000 MΩ), very high voltage performance (to 30,000 V) and typical long-term stability of 0.1% per 1000 hr at 125 C. It can be operated continuously at overvoltages up to 45,000 V. The Model MG 815, an encapsulated resistor only 6-in. long and 3/8-in. diameter, can dissipate 15 W.

CIRCLE NO. 391

DPDT relay has 0.6 in. PC-board spacing



AMF Potter & Brumfield, 1200 E. Broadway, Princeton, Ind. 47670. (812) 385-5251.

Low-profile DPDT 2-A PC-board relay, the R50-Y2, joins the SPDT R50-Y1 for use in high-density packaging such as 0.6 in. center-to-center spacing of PC boards. Both R50s are available with coil ratings of 5, 6, 12, 24, and 48 V dc and with a contact rating of 2 A at 28 V dc, 1 A at 120 V ac, resistive. A more sensitive R50S series is rated 1 A at 28 V dc, 0.5 A at 120 V ac, resistive. Relay mechanical life is 10 million operations. Contact life expectancy is half a million operations at full rated load. Initial contact resistance is 50 mΩ maximum. Both operate and release times are 6 ms maximum. All R50 models have a cover ultrasonically welded to the base to keep out dust, dirt and cleaning solvents. Gold plated terminals are situated on a 0.1-in. grid spacing. R50-Y2 weighs approximately 0.6 oz., and measures 1.09 × 0.855 × 0.415 in.

CIRCLE NO. 392

Wirewound resistors are absolutely flameproof

Ohmite Mfg. Co., 3601 W. Howard St., Skokie, IL 60076. (312) 675-2600. 4-6 wks.

Where nonflammability is absolutely essential, you can use Series 57 Ceron, flameproof, conformal-ceramic, axial-lead, wirewound resistors. They will not ignite from any overload or exposure to an open flame. The resistors exceed all environmental requirements of MIL-R-26E. Standard resistive tolerance is ±5% and temperature coefficient is ±30 ppm/°C in a wide selection of resistance values and 1, 2, 3, 5, 7, and 10-W sizes. The resistors are of all-welded construction and they can be supplied reel-packaged for machine insertion.

CIRCLE NO. 393

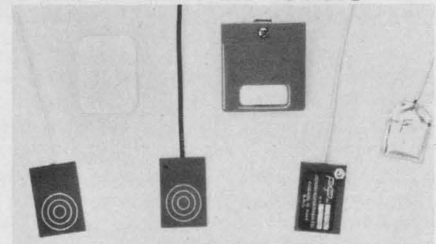
Relays compatible with TTL, DTL ICs

Electrodyne, Inc., 2126 Adams St., Milwaukie, Ore. 97222. (503) 654-0711. Type 21: $5.50.

Both electrical and dimensional compatibility with TTL and DTL ICs is achieved in a family of 4PDT relays. The molded packages are 0.43 H × 0.63 W × 0.95 L in. The packages can be plugged into standard DIP sockets or soldered into 100-mil grid holes of a PC board. The units weigh only 0.2 oz and withstand flow-soldering temperatures and board cleaning materials. Type 21 requires 200 mW of drive power and has a pull-in current rating of 40 mA at 5 V dc, The types 25, magnetic-latch relay, and 28, OR-function relay with two coils, require only 100 mW and have a pull-in current rating of 20 mA at 5 V dc. Dropout voltages are 1 to 3 V dc and contacts are rated from dry-circuit to 1 A. Maximum contact resistance is 0.05 Ω. Excluding bounce time, the maximum operating and release times are 3 ms and 1 ms at nominal coil voltages. Maximum bounce time is 2 ms. Capacitance between normally open and normally closed contacts is 0.3 pF and minimum insulation resistance is 10,000 MΩ at 25 C and 500 V dc.

CIRCLE NO. 394

Transducer detects hard-radiation levels



Photon Transducers, Inc., 2900 Glascock St., Oakland, Calif. 94601. (415) 261-0551. $85 to $92 (unit qty); stock.

RT-1 X-ray and gamma-ray transducers provide a real-time, millivolt-level electrical signal proportional to the radiation dose rates. The transducer responds to both isotope and machine radiation sources. Its response frequency range is from dc to 300 Hz, and it acts as a dosimeter that is proportional to total dose for the typical short-pulse-flash X-ray and Linac sources. The unit is packaged in an unfilled epoxy structure 1.5 × 1.0 × 0.21 in. and it is smaller than the usual film-badge dosimeter. The total-dose lifetime of the transducer is typical of most silicon devices. Thus the RT-1 is a very attractive alternative to G-M detectors for industrial gaging and monitoring applications.

CIRCLE NO. 395

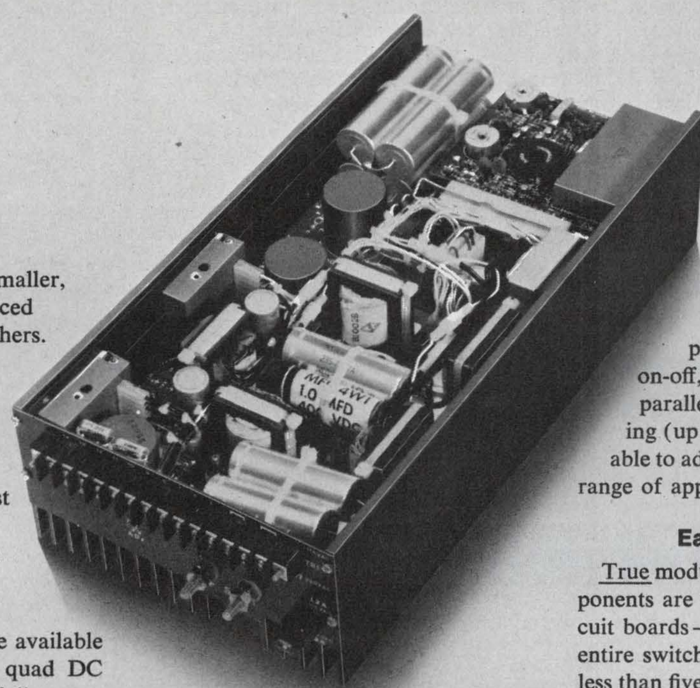
Solid-state counter replaces mechanical unit

Automatic Timing & Controls Co., King of Prussia, Pa. 19406. (215) 265-0200. $110 (unit qty).

The Series 346 general-purpose, automatic-reset count controller is a plug-in, solid-state, digital replacement unit for all ranges and models of the knob-set Series 310 ON-delay electromechanical counter. One model retrofits the 310B and 310C. The other retrofits the 310D. Each model can be easily converted to the other by the movement of a single wire from one push-on terminal to another on its PC board. The new counters have bounce-immunity circuitry to maintain accuracy at high speeds and they count at least four times faster—to 2300/min.—than the electromechanical counters they replace. Life is at least 10 times longer.

CIRCLE NO. 396

New! A 600-watt, 5V, 100 amps switching regulated power supply that has four outputs, measures just 3.9" x 7.5" x 16.12", weighs only 14 lbs., is 75% efficient and costs only $493.*



And LH has 84 other equally exciting models to choose from — all of them smaller, lighter, more efficient and priced lower than competitive switchers.

250 to 1500 watts

LH offers 7 standard wattage ratings — 250, 300, 500, 600, 1000, 1200 and 1500** watts. This is the most comprehensive line of high-efficiency switchers available anywhere.

4 outputs

Standard LH switchers are available with single, dual, triple or quad DC outputs. Primary output is fully regulated. 2nd, 3rd and 4th outputs are semi-regulated, but may be fully regulated for $30 per output.

Low DC voltage, high power outputs

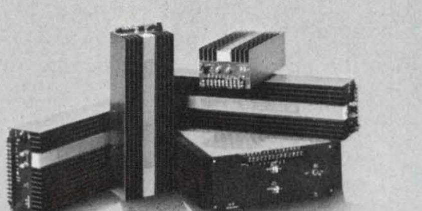
Primary voltages are at 5 VDC; 50, 100, 200 and 300** amps. 2nd and 3rd voltages are standard ±12, ±15 and ±18V at 8 amps each; 4th voltage is 24V at 2 amps. Other voltages available.

Input voltages externally selectable

110/220 VAC, 47 to 440 Hz, can be selected by simply changing a jumper on the front terminal strip. DC input, 24 to 300 VDC, also available.

6 case configurations

All LH switchers use one basic *proven* design and package it in six different case shapes — wide and short or narrow and long — for customer convenience. With a nominal power density of 1.37 watt/cu. in., LH switchers pack more power into a smaller package than any other switchers you can buy.



80% efficient

On single output models, over 80% of the primary input power is delivered to the output terminal. On models with dual, triple and quad outputs, efficiency averages 75%.

Lighter weights

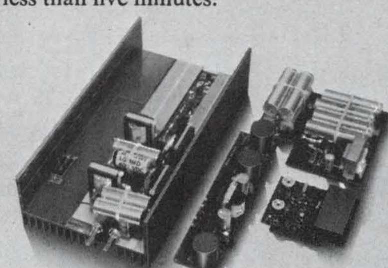
For example, LH's 250-watt single output model weighs only 7 lbs.; the 1200-watt, quad output unit, just 30 lbs.

A number of options

Over-voltage protection, power fail detection, remote on-off, thermal cutoff, DC input, paralleling, master-slave paralleling (up to 10 units) — all are available to adapt LH switchers to a wide range of applications.

Easy maintenance

True modular construction — all components are mounted on just three circuit boards — make servicing easy. The entire switcher can be disassembled in less than five minutes.



Priced as low as 63¢/watt

Watt-for-watt, LH units are the lowest priced switching regulated power supplies you can buy. In 1 to 24 quantity, a 250-watt single output model sells for $360; a 1200-watt quad goes for $1245.

Ask for full-line folder

The LH rep in your area has a new six-page folder that fully describes the 85 standard LH switchers, and discusses possible options and modifications to meet specific requirements.

Ask him for a copy today.

LH RESEARCH

*1000 pc. qty.
**Available Sept. '74

LH RESEARCH, INC., 2052 South Grand Avenue, Santa Ana, CA 92705 • (714) 546-5279

INFORMATION RETRIEVAL NUMBER 161

application notes

Choosing a calculator

Called the "Executive's No-Nonsense Guide to Computing Calculators," a 16-page booklet gives the reader the computing alternatives offered by calculators that fall between the electronic adding machine and a large computer. Hewlett-Packard, Palo Alto, Calif.

CIRCLE NO. 397

Photographic measurements

How to use the J16 digital photometer/radiometer for photographic exposure measurements is described in an application note. Graphs are included for converting scene luminance readings to shutter times and f numbers for various ASA film speeds. The note describes averaging readings for a wide angle camera lens and estimation of exposure settings using reflectance from a scene. Tektronix, Beaverton, Ore.

CIRCLE NO. 398

RENEW your ELECTRONIC DESIGN subscription today! (See inside front cover)

Pulse transformers

An eight-page pulse transformer bulletin covers simplified equivalent circuits, parameters, methods for measuring turns ratio, ac measurements, pulse measurements and common-mode rejection. DIL packaging is discussed, and commonly used conversion factors and fractions with metric equivalents are listed. Technitrol, Philadelphia, PA

CIRCLE NO. 399

Forced air cooling

How forced air cooling substantially improves system survival is the subject of a four-page article. Included are graphs and illustrations showing how forced air cooling increases the life expectancy of a high-density electronic system, and why heat sinks cannot dissipate excessive heat in a system when the air around them does not move rapidly. Rotron, Woodstock, NY

CIRCLE NO. 400

design aids

Humidity conversion chart

A relative humidity conversion slide chart is made of sturdy bristol board, measuring 8-1/2 × 3-1/8 in. It has Fahrenheit-Centigrade conversion indices from −320 to +500 on the reverse side. The chart costs $1. Tenney Engineering, P.O. Box 434, Springfield, NJ 07081

INQUIRE DIRECT

Linear IC wall chart

A quick-reference wall chart features capsule data and functional diagrams on op amps, arrays, differential amplifiers, broadband amplifiers, and power control circuits. RCA.

CIRCLE NO. 490

Thermocouple tables

A reprint of the latest National Bureau of Standards temperature-calibration tables for thermocouples, tabulated in one-degree increments in both °C and °F, are given in a 36-page booklet. Many useful graphs and charts are supplied. Omega Engineering.

CIRCLE NO. 491

Circular connectors

Quick reference charts designed to make the selection of general-purpose circular connectors for specific applications easier are featured in an eight-page publication. The charts provide information on the choice of receptacles, plugs, insert configurations, available finishes, contact sizes, mounting dimensions and accessories. Amphenol Connector Div.

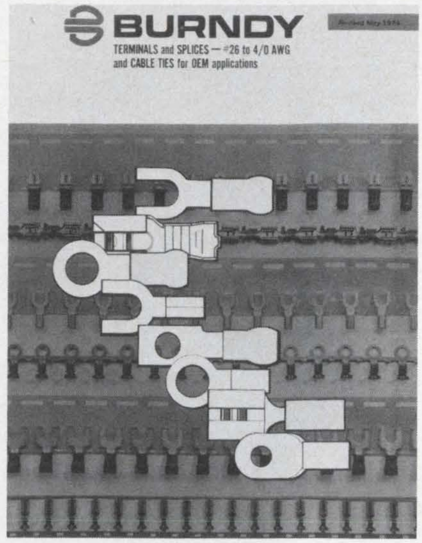
CIRCLE NO. 492

Metric/inch slide chart

The easy way to get the "jump" on metrics and metric conversion is to use this handy pocket-sized, plastic-coated calculator, which helps anyone convert lengths, weights, areas and volume. List price is $2.50 each or $10 for quantities of 5. Jaydee Specialties, P.O. Box 536, Wilmette, Ill. 60091.

INQUIRE DIRECT

new literature



Terminals and splices

Insulated terminals and splices for copper wire (sizes 26 to 4/0 AWG), cable ties for OEM applications and installation tooling from hand tools to automatic machines are described in a 34-page catalog. Performance requirement tables and Burndy equivalent tables for MIL specs are included. Burndy, Norwalk, CT

CIRCLE NO. 493

Metal-film resistors

Metal-film resistors are featured in a four page, two-color brochure. Wagner Electric/Vamistor Div., Livingston, N.J.

CIRCLE NO. 494

Temperature controllers

The West 600 line of digital set point temperature controllers is detailed in a four-page catalog. Outline drawings, mounting dimensions, scale ranges and specifications are provided. Gulton Industrics, Measurement & Control Systems Div., East Greenwich, R.I.

CIRCLE NO. 495

Time synchronizer

The theory of operation and application of the Model SP-465 WWVB time synchronizer are covered in a handbook. Datametrics, Wilmington, Mass.

CIRCLE NO. 496

Back panels

A 72-page, four-color brochure provides data needed to design a custom back panel by selecting from standard connectors and accessories. Specifications, including dimensional drawings and application data, are included. Winchester Electronics, Oakville, Conn.

CIRCLE NO. 497

Pressure transducers

"The Pressure Transducer Handbook," a 142-page reference, covers the uses and types of pressure measurement. Topics included are factors in transducer selection, pressure sensor technology, selecting a transducer, calibration and signal conditioning. The book contains 65 illustrations, photographs and schematic drawings, along with 35 conversion tables and charts. The price of the book is $3. Bell & Howell, Electronics & Instruments Group, 360 Sierra Madre Villa Ave., Pasadena, Calif.

INQUIRE DIRECT

Wire insulation tester

A technical bulletin features a magnet wire insulation tester that provides automatic, continuous monitoring of enamel wire during manufacture. Operating procedures and application notes are detailed, along with an application illustration. Hipotronics, Brewster, N.Y.

CIRCLE NO. 498

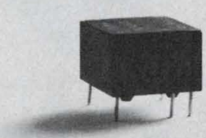
TECHNITROL Takes The Tough PT'S.

When it comes to pulse transformers (PT'S), Technitrol's experience leads the field. Technitrol was first with DIP transformer packaging and the H case. But, Technitrol is first where it really counts: getting the job—no matter how tough—done right. Here are two examples:

1/Tough Performance

Check these specs for a high-inductance transformer:

CMRR: 30 db @ 10 MH_Z
Bandwidth: 5KC to 3 MH_Z
Inductance: 20 mh min.

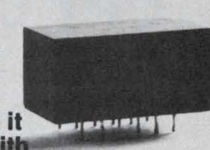


Here's Technitrol's answer!

2/Tough Packaging

Here's what one customer wanted in a DIL-type case:

4 pulse transformers
8 diodes
8 resistors



Technitrol put it all together with discrete, reliable components.

Tough Competitor

That's Technitrol—whether your spec pushes the state-of-the-art or not. Next job, call Bill Chamberlin at (215) 426-9105. Or write for information.

T-1

Technitrol, Inc.

TECHNITROL, INC. 1952 E. Allegheny Avenue / Philadelphia, Pa. 19134.

Specialists in pulse transformers and completely transfer molded, welded DIP delay lines, under 3/16" high—to 250 ns.

INFORMATION RETRIEVAL NUMBER 182

Electronic components

A compilation of current technical publications covers fixed and variable resistors and resistor networks. Illustrations, tables and charts supplement the text in detailing the components' performance features, characteristics, dimensions and applications. Allen-Bradley, Milwaukee, Wis.

CIRCLE NO. 499

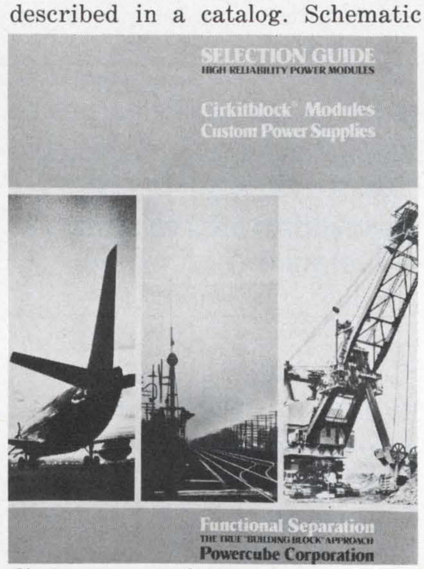
Ion pumps

Two eight-page data sheets describe ion pumps and control units. Both publications explain and diagram ion pump operation and the difference between the company's D-I ion pumps and conventional ion pumps. Perkin-Elmer Ultek, Palo Alto, Calif.

CIRCLE NO. 500

Power modules

Industrial power modules are described in a catalog. Schematic



diagrams, performance data and outline drawings are shown. Powercube Corp., Waltham, MA

CIRCLE NO. 501

Digital logic analyzer

An eight-page brochure describes the company's MD-107 memory/digital logic analyzer. Complete with photographs and block diagrams, the brochure includes a discussion of memory and random logic board testing plus specifications. Macrodata, Woodland Hills, Calif.

CIRCLE NO. 502

Peripheral input device

A 46-page "Computer Eye Handbook," is an introduction to image digitization. Concepts of image digitization, optics, photography and electro-optics are covered. Spatial Data Systems, Goleta, Calif.

CIRCLE NO. 503

Pulse transformer

Standard and special pulse transformers are featured in a 12-page catalog. Sampling plans, test groups and dual-inline packaging specifications are given. Technitrol, Philadelphia, Pa.

CIRCLE NO. 504

Selector switches

Data covering the company's standard switch series are contained in a 16-page catalog. CTS of Elkhart Div., Elkhart, Ind.

CIRCLE NO. 505

Cabinets and consoles

Steel and aluminum pre-engineered cabinets, consoles and accessories are covered in a 28-page catalog. Data cover miiltary specifications, RFI attenuation, EMI shielding, hardware and accessories. Zero Manufacturing, Burbank, Calif.

CIRCLE NO. 506

Welding products

Resistance welding products are described and illustrated in a 48-page catalog. Several hundred dimensional drawings are shown along with tips for the use of these products. Mallory Metallurgical, Indianapolis, Ind.

CIRCLE NO. 507

Microwave products

Photographs and typical specifications for solid-state microwave diodes, oscillators, transmitters, receivers and systems are given in an eight-page catalog. Cayuga Associates, Plainview, N.Y.

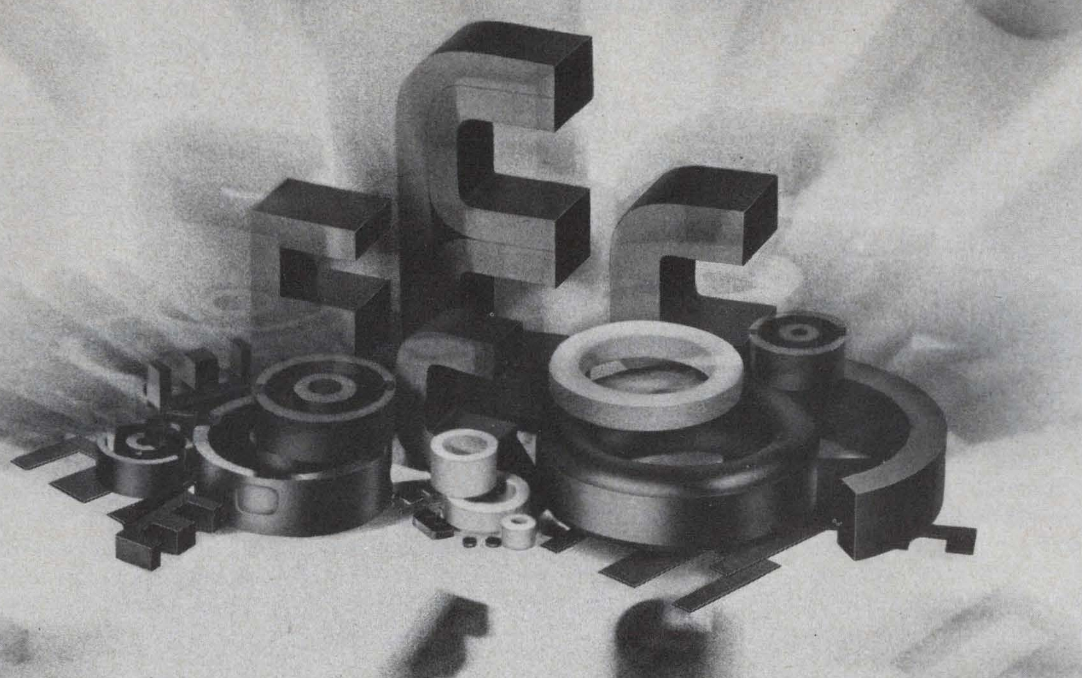
CIRCLE NO. 508

Ferrites

A 24-page reference source describes ferrite components and materials. Indiana General, Keasbey, N.J.

CIRCLE NO. 509

When Viking talks to us from Mars it'll use cores by Magnetics.



Best reason on earth to rely on us for your own communications components.

Magnetics' miniature tape cores were used in the computers that sent our astronauts to the moon and back. And now we're exclusive supplier of tape cores, powder cores, nickel-iron C cores and bobbin cores for the Viking Mars Lander.

In addition to reliability, we offer you a choice when it comes to your magnetic components—whether they're off-the-shelf or something specially developed for your needs.

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MAGNETICS

A DIVISION OF SPANG INDUSTRIES INC.

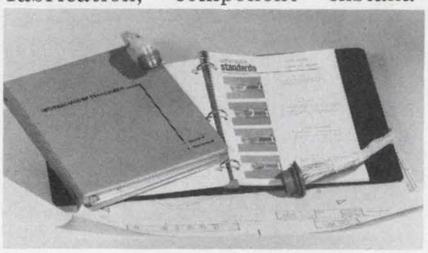
Butler PA 16001.

INFORMATION RETRIEVAL NUMBER 184

IT TAKES MONTHS to get back on ELECTRONIC DESIGN's qualified subscription list. Keep your copies coming. RENEW NOW (see inside front cover).

Standards

A workmanship standards manual portrays 139 electrical and mechanical standards, including soldering of all types, PC-board fabrication, component installa-



tion, conformal coating, wire wrap, bonding and welding. Full-color photographs illustrate preferred, acceptable, minimal acceptable and rejected workmanship. Martin Marietta Aerospace, Orlando, FL

CIRCLE NO. 510

Transducers

Precision transducers and instrumentation for sensing, measuring and analyzing all aspects of sound and vibration are covered in a 44-page catalog. B&K Instruments, Cleveland, Ohio.

CIRCLE NO. 511

Disc drives

The Series 9000 cartridge disc drives are described in a six-page bulletin. Illustrations and information covering reliability, structural integrity, packaging, safety and specifications are given. Microdata, Irvine, Calif.

CIRCLE NO. 512

Interface products

A 400-page interface integrated-circuit catalog contains information on all types of interface products, whether they be linear, digital or MOS. The catalog includes product selection guides, a cross-reference guide and an applications section. National Semiconductor, 2900 Semiconductor Dr., Santa Clara, Calif. 95051.

INQUIRE DIRECT

Flat woven cable

"Everything You Always Wanted to Know About Flat Woven Cable" describes design and performance advantages provided by programmed weaving of cables and harnesses. Woven Electronics, Mauldin, S.C.

CIRCLE NO. 513

Instrumentation

A 48-page electronic instrumentation catalog covers digital multimeters, frequency counters, spectrum analyzers, pulse generators and voltage/current standards. T.R.I., Sunnyvale, Calif.

CIRCLE NO. 514

Custom power supplies

Design data on custom power supplies such as switching preregulators, high-frequency generators, transformer isolated output modules, EMI terminal modules and Block-Pac kits are included in a brochure. Wiring diagrams and outline drawings are shown. Powercube, Waltham, Mass.

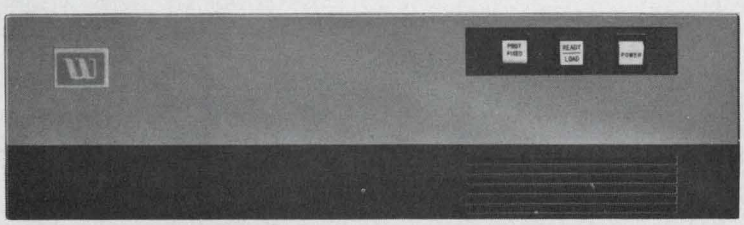
CIRCLE NO. 515

WANGCO's low cost Series-N ...the non-floppy disc!

The Series-N, with flying head and hard-disc reliability, gives you 25, 50 or 100 megabit capacity, in a single, compact package . . . at *one-sixth the cost-per-bit* of floppy discs.

The Series-N, with one or two fixed discs, and with 100 or 200 tracks-per-inch capability, lets you fit its capacity to *your* system requirements, without compromise. For main memory extension, point-of-sales systems, software storage, process control programming . . . any application calling for small size, fast access and low cost, there is a Series-N model to fit *your* system.

In your system, the reliable Series-N costs little more than a floppy disc, because controller costs for the two are equal. But the far greater reliability of non-contact rigid disc technology will pay its way many times over. And in addition, you get far greater capacity in only 6 inches of a standard 19-inch rack.



Model	Capacity (Megabits)	Transfer Rate (KB/Sec.)	Recording Density (Bits/Inch)	Track Density (TPI)	Rotation Speed (RPM)
N-1211	25	1562	2200	100	1500
N-1212	25	2500	2200	100	2400
N-1221	50	1562	2200	100	1500
N-1222	50	2500	2200	100	2400
N-2211	50	1562	2200	200	1500
N-2212	50	2500	2200	200	2400
N-2221	100	1562	2200	200	1500
N-2222	100	2500	2200	200	2400

For more information call the WANGCO office nearest you, or write to WANGCO Incorporated, 5404 Jandy Place, Los Angeles, Calif. 90066. (213) 390-8081. TWX 910/343-6246.

WANGCO

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INFORMATION RETRIEVAL NUMBER 187

Modular power supplies

Encapsulated modular dc power supplies are described in a 10-page catalog. The catalog lists specifications, mounting configurations and prices. Computer Products, Fort Lauderdale, Fla.

CIRCLE NO. 516

SOS wafers

"SOS—Silicon-on-sapphire Wafer Guide" describes the properties and advantages of SOS wafers and films. Topics covered in the eight-page book include processing, thermal characteristics and quality control. The booklet contains supportive graphs and illustrations. Inselek, Princeton, N.J.

CIRCLE NO. 517

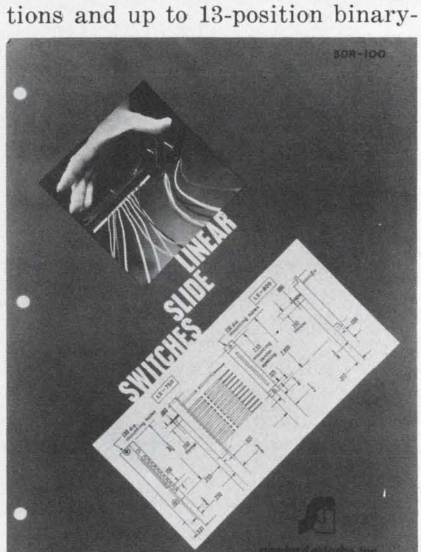
Laminated plastics

"Laminated Plastics Designer's Guide," a 12-page brochure, reviews the specifications, properties and performance data needed to select technical plastics for nearly any thermal, mechanical, chemical or electrical applications. Synthane-Taylor, Valley Forge, Pa.

CIRCLE NO. 518

Linear slide switches

LS Series linear slide switches are covered in a four-page catalog. Engineering drawings, mechanical and electrical specifications and up to 13-position binary-

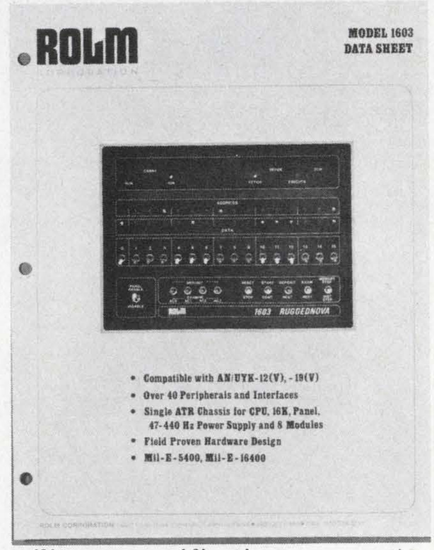


coded output circuits are described. Standard-Grigsby, Aurora, IL

CIRCLE NO. 519

Minicomputer

A six-page data sheet covers a rugged minicomputer, including



military specifications, computer power, software, reliability, interfacing, instruction set, instruction execution times, documentation, training and service. Rolm Corp., Cupertino, CA

CIRCLE NO. 520

Image intensifiers

A four-page, two-color brochure describes 18-mm microchannel wafers for image pickup applications under low light or infrared ambient light conditions. Principles of operation, applications and specifications are listed. Tube types, options, specifications, figures and mechanical configurations are included. ITT Electro-Optical Products, Roanoke, Va.

CIRCLE NO. 521

Potentiometers

An eight-page short-form catalog contains information on precision and trimming potentiometers, concentric and digital turns-counting-dials, miniature switches and special designs. The catalog includes scaled photos of the products, specifications and performance and application data. Spectrol Electronics, City of Industry, Calif.

CIRCLE NO. 522

A/d and d/a converters

Data sheets describe the Models 815 a/d and 817 d/a converters. The data sheets give specifications on these units, including scope pictures and some typical applications. Biomation, Cupertino, Calif.

CIRCLE NO. 523

Microdata thinks that when a package is unbundled, it shouldn't be full of cobwebs and old components that never sold anyway.

Microdata unwraps its fresh new OEM Peripherals Group.

Microdata's surprising new peripherals package is based on a thorough examination of your total requirements. Today, our OEM Peripherals Group offers you the best products in the business - proven peripherals with many important and exclusive advantages.

These include our advanced 5440 disc drives, the first built for 200 tpi operation from the very beginning. Magnetic tape transports with such a simple, inherently reliable design you'll wonder why nobody ever thought of it before. Tape data formatters that mount right in the transport and include functions you'd normally have to build into your controller.

With Microdata peripherals, you don't have to trade off price to get performance. We give you the best of both. Plus straight answers to your questions, not twelve pages of puffery to color our story.

Contact our OEM Peripherals Group for all the engineering, production, marketing and service support you need.

Microdata

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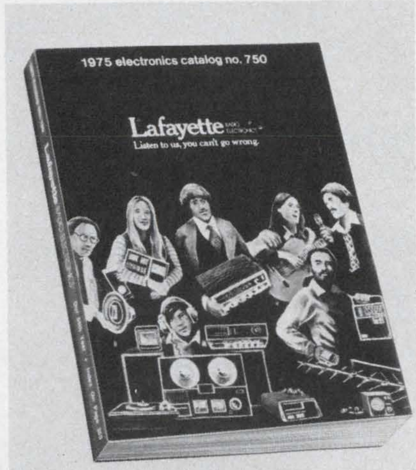
INFORMATION RETRIEVAL NUMBER 189

NEW LITERATURE



Lafayette catalog

Over 18,000 individual items ranging from stereo and four-channel components and music systems for the home, business and automobile to complete offerings of CB, ham and PA gear; test equipment, antennas and security devices; calculators and all parts, tubes, hardware, batteries and miscellaneous products are described in a catalog. Lafayette Radio Electronics, Syosset, NY

CIRCLE NO. 524

Power supplies

Open-frame, enclosed and custom power supplies are featured in a 20-page catalog. Photos, diagrams and specifications are shown. Elexon Power Systems, Santa Ana, Calif.

CIRCLE NO. 525

Connectors

How metal, heat-shrinkable connectors facilitate such operations as interconnecting guidance computer modules and cables, making bus connections between circuit boards, connecting battery cells and terminating stranded wire are included in a six-page bulletin. Raychem, Devices Div., Menlo Park, Calif.

CIRCLE NO. 526

Power relays

A 20-page power relay catalog includes specifications, photos, dimensional line drawings and accessories. Magnecraft Electric, Chicago, Ill.

CIRCLE NO. 527

Amplifier survey

The results of a survey that establishes the future performance requirements for high-accuracy instrumentation amplifiers are detailed in a four-page booklet. Preston Scientific, Anaheim, Calif.

CIRCLE NO. 528

Fasteners

Bolts, screws, nuts and other fastener devices in popular types, styles and sizes are detailed in an eight-page illustrated catalog. Shigoto Industries, New York, N.Y.

CIRCLE NO. 529

Stepping motors, controls

A six-page synchronous/stepping motors and motor controls catalog contains ratings, specifications, technical data, terminology, application and selection information for these control components. The Superior Electric Co., Bristol, Conn.

CIRCLE NO. 530

VOMs

General multipurpose VOMs from laboratory and special features testers to general-purpose portables, temperature testers and accessories are covered in a 16-page catalog. Triplett, Bluffton, Ohio.

CIRCLE NO. 531

Control devices

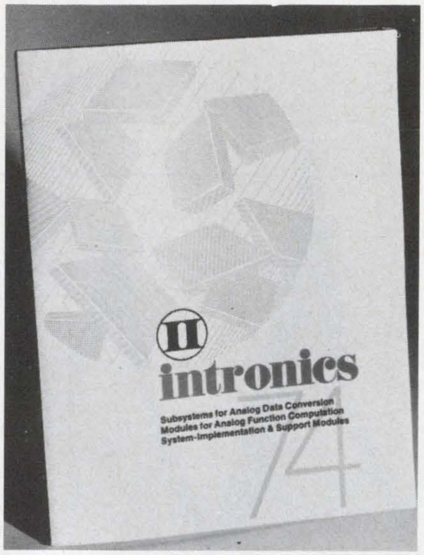
A 120-page catalog characterizes over 970 microwave solid-state control devices. The products include diode switches (spst, spdt, spmt), diode limiters (high-power and low-loss) and diode attenuators (analog and programmable). Alpha Industries, Woburn, Mass.

CIRCLE NO. 532

Ceramic capacitors

Rectangular ceramic plate capacitors for general-purpose and temperature-compensating applications are covered in a four-page catalog. Included are specifications, temperature curves, dimensional drawings and electrical and temperature characteristics. Murata, Rockmart, Ga.

CIRCLE NO. 533



Analog function modules

Data on analog function modules including rms/dc converters, op amps, analog multiplier/dividers, multiplying d/a converters, modular power supplies and dc-to-dc power converters are given in a 48-page catalog. Intronics, Newton, MA

CIRCLE NO. 534

Software programs

More than 25 software programs for use with the company's interactive graphic systems are detailed in a six-page brochure. Vector General, Woodland Hills, Calif.

CIRCLE NO. 535

Digital instrumentation

A 22-page catalog highlights digital instrumentation. Takeda Riken Industry, Tokyo, Japan.

CIRCLE NO. 536

Test instruments

Eighty pages cover precision measurement instruments in voltage, resistance and capacitance. Also included are digital and linear testers, generators-detectors, standards, decades, dividers and high-precision resistors. Production laser systems for resistor trimming and substrate scribing are covered briefly. Electro Scientific Industries, Portland, Ore.

CIRCLE NO. 537

Custom ICs

This issue of a 12-page quarterly publication contains an article on op-amp design, describing both practical circuit and compensation methods. The booklet illustrates three new product examples with custom ICs and the company's Monochip. Interdesign, Sunnyvale, Calif.

CIRCLE NO. 538

Minicomputers

A 76-page brochure describes the first minicomputers to use a 4-k RAM semiconductor memory. The brochure contains illustrations, tables and detailed text on the HP-21MX family of minicomputers. Hewlett-Packard, Palo Alto, Calif.

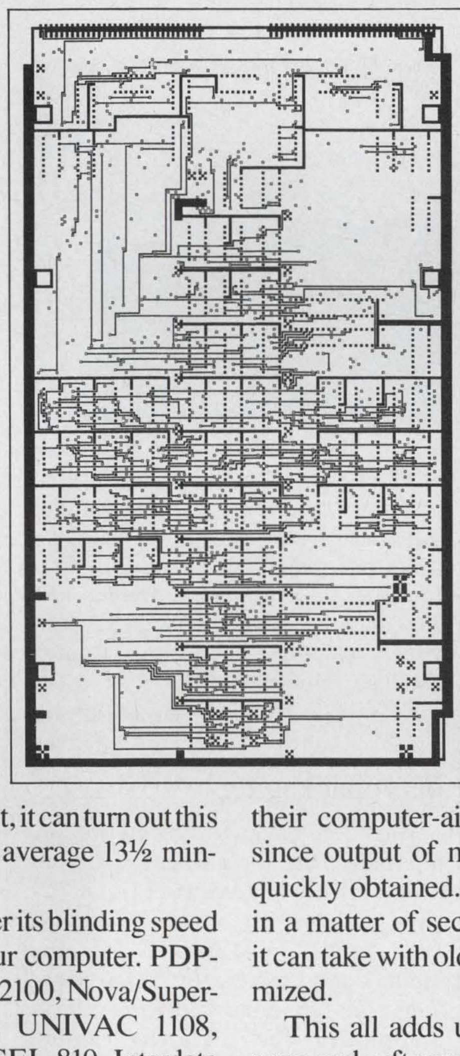
CIRCLE NO. 539

Power film resistors

A test report graphically illustrates the long-term stability of power film resistors. Caddock Electronics, Riverside, Calif.

CIRCLE NO. 540

By the time your drum plotter turns this out, a Gould printer/plotter can turn it out 400 times.



If what you're looking for is higher plotting speed and lower plotting cost, we've got something that can give you both. And something else besides.

A Gould electrostatic printer/plotter. The one that makes your old drum plotter remarkably underproductive. The one that gives you a useful printing capability in the bargain. A Gould plotter is so fast, it can turn out this plot in only 2 seconds – versus an average 13½ minutes for your old drum plotter.

And what gives that Gould plotter its blinding speed is its direct on-line operation to your computer. PDP-8/E, PDP-9, PDP-11, PDP-15, HP2100, Nova/Supernova, H316/516, Raytheon 704, UNIVAC 1108, IBM 360/370, CDC 3000/6000, SEL 810, Interdata 70 and more.

In addition to output speeds up to 400 times faster, a Gould printer/plotter gives you a lower unit cost, as well as lower paper cost. Better-looking output, since there's no ink to smudge, clog or run out of. Few moving parts for quiet operation, high reliability. Software that's upward compatible with the leading drum plotter. Without any sacrifice in mainframe CPU time.

And, in addition to everything else, it gives you an alphanumeric printing capability that also lets you compile management reports at speeds up to 3000 lines per minute.

Users will tell you that a Gould electrostatic printer/plotter makes their computer-aided design system truly interactive since output of modified data for verification can be quickly obtained. And by producing hardcopy output in a matter of seconds – instead of the many minutes it can take with older methods – time savings are maximized.

This all adds up to the best printing/plotting hardware and software available anywhere. And it's backed by Gould's own factory-trained service technicians.

To learn more about Gould electrostatic printer/plotters – get in touch with Gould Inc., Instrument Systems Division, 20 Ossipee Road, Newton, Mass. 02164 U.S.A., or Kouterveldstraat 13, B 1920, Diegem, Belgium.

GOULD

INFORMATION RETRIEVAL NUMBER 194

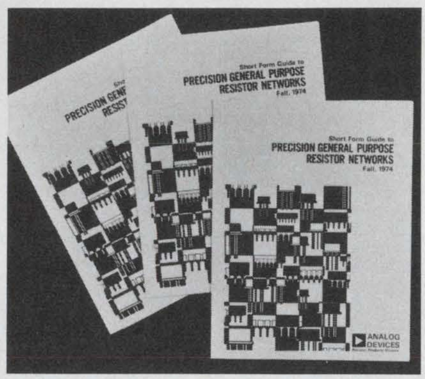
Modular connectors

A 16-page catalog describes modular connectors from simple single hermaphroditic modules to complex 200 pin rack and panel connectors with jack screws. Hypertronics, Stow, Mass.

CIRCLE NO. 541

Resistor networks

A six-page guide to precision resistor networks describes the



latest generation of thin-film products. Specifications including pricing, guaranteed performance, schematics and package configurations are provided, describing four families of attenuator/divider and four series of circuit element thin-film resistor networks. Analog Devices, Norwood, MA

CIRCLE NO. 542

Micropackaging

Hermetic-package assemblies for microcircuits, including covers and preforms, are featured in a 52-page catalog. It covers standard flat packs, dual-inline and the Modu-Pack series of micropackages—all on color-coded pages to distinguish the different catalog sections. The Bendix Corp., Sidney, N.Y.

CIRCLE NO. 543

Buyers' guide

The "EDRI Buyers' Guide for Electronics" lists over 100 manufacturers' product lines covering items used in the manufacture, maintenance, repair and service of industrial equipment. EDRI Buyers' Guide, Fort Lauderdale, Fla.

CIRCLE NO. 544

Thermistors

An eight-page bulletin details sizes, types and resistances of thermistors, plus a series of thermistor probes. Five thermistor applications, including detailed circuits, are shown involving liquid-level detection, surge protection, automatic power level control, time switching and low-cost temperature control. Thermistor Div., Keystone Carbon, St. Marys, Pa.

CIRCLE NO. 545

Plastic and metal closures

A 56-page catalog/price list provides information on plastic and metal closures for the protection of tubing, threaded fittings, electrical connectors and machined parts. Caplugs Div., Buffalo, N.Y.

CIRCLE NO. 546

IT TAKES MONTHS to get back on ELECTRONIC DESIGN's qualified subscription list. Keep your copies coming. RENEW NOW (see inside front cover).

Capacitors

Radial and axial lead capacitors are described in a 24-page catalog. Specifications, configurations, lead spacing dimensions, values and maximum dimensions and performance characteristics are included. Paktron, Vienna, Va.

CIRCLE NO. 547

Computer system

An eight-page brochure describes the company's dual NOVA, a dual-processor, shared-disc computer system that uses standard hardware and software. Data General, Southboro, Mass.

CIRCLE NO. 548

CMOS 4000 series

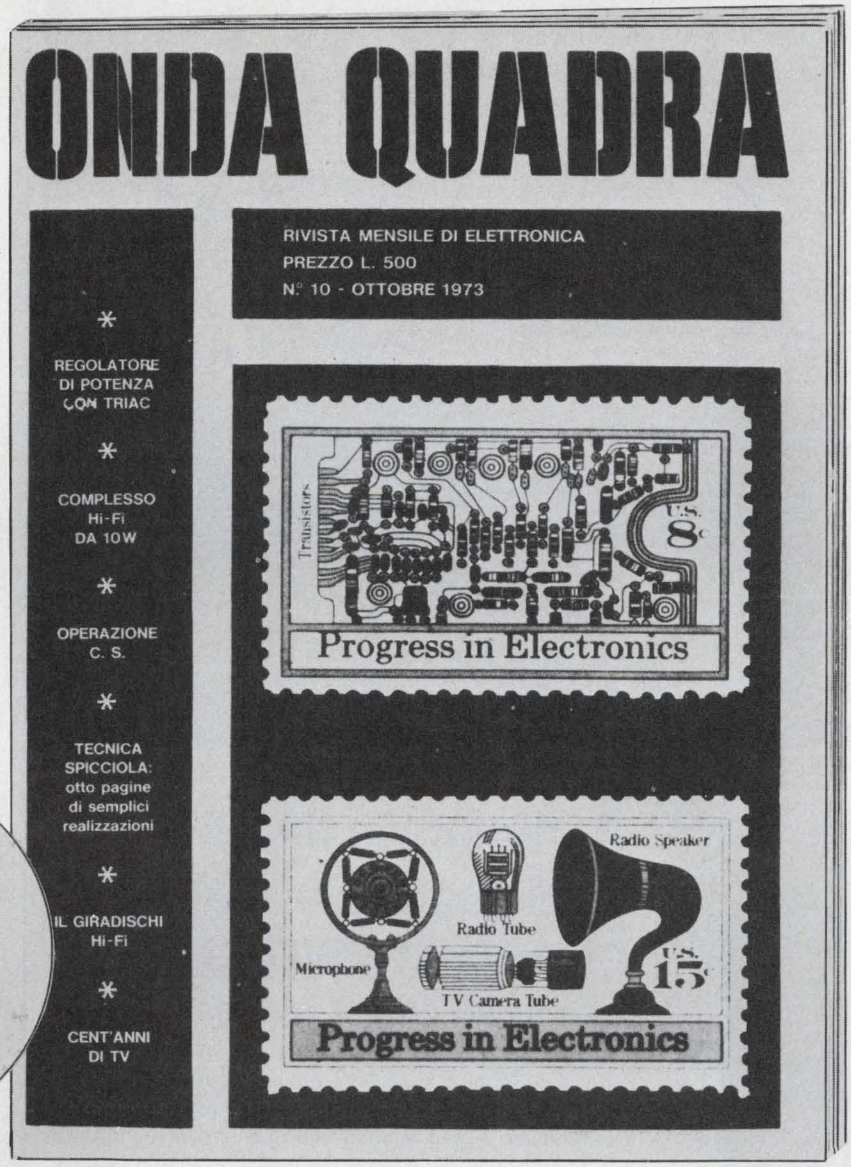
CMOS 4000 series digital integrated circuits are described in a six-page brochure. The brochure lists applications, features, maximum ratings and provides schematic logic diagrams. It also provides a typical characteristics table and package dimensions. Stewart-Warner Microcircuits, Sunnyvale, Calif.

CIRCLE NO. 549

IF YOU WANT TO KNOW WHAT'S HAPPENING IN

ELECTRONICS IN EUROPE...

READ:



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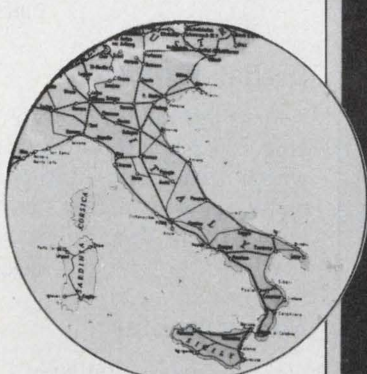

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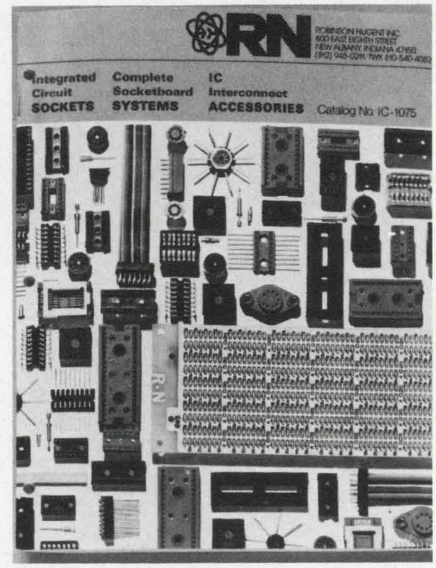
INFORMATION RETRIEVAL NUMBER 197

INFORMATION RETRIEVAL NUMBER 198

INFORMATION RETRIEVAL NUMBER 199

IC interconnects

A 68-page catalog features test data on IC sockets, complete socketboard systems and IC inter-



connect accessories. It is illustrated with photographs, line drawings and specifications. Robinson-Nugent, New Albany, Ind.

CIRCLE NO. 550

Digital displays

Highlighted in a four-page catalog are neon tube digital displays which are cold cathode, single plane, high-contrast readout devices. IEE, Van Nuys, Calif.

CIRCLE NO. 551

Minicomputer

A 12-page bulletin describes the high-speed, 16-bit Model 85 minicomputer. The bulletin lists features, specifications and the instruction repertoire of the minicomputer. Interdata, Oceanport, N.J.

CIRCLE NO. 552

Alarm equipment

A 96-page catalog describes over 450 intrusion and fire alarm products. The alarm equipment shown ranges from relatively simple kits with instructions to the latest ultrasonic, radar and infrared intrusion detectors. The catalog includes eight pages of application notes. Mountain West Alarm Supply, Phoenix, Ariz.

CIRCLE NO. 553

FUJI MEMORIES

WANTED

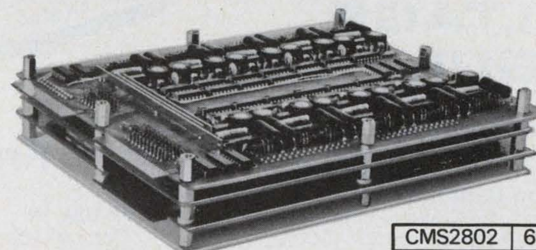
partners to manufacture ADD-ON memories and OEM systems with us.

OEM System

This self-supporting memory system is centered around memory cards and incorporates a power supply, self checking device, interface and other similar circuits and can be used for memory expansion use and OEM control computer use memory. We can also design the arithmetic unit and interface.

MB2000	65KB max.

RAM CARD 8K×18



CMS2802	650ns
CMS2803	850ns

CMS2802 and CMS2803 have been specifically developed as the core memory of electronic computers and designed to feature compact size, high performance and low price. Moreover, since a byte control function is incorporated as standard, they can also be used as 9 bits wordlength as well as 18 bits.

FUJI ELECTROCHEMICAL CO.

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INFORMATION RETRIEVAL NUMBER 201

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If you have solved a design problem, developed a new circuit, gained experience in depth in a specific technical area, why not share your knowledge with *Electronic Design's* 232,000 readers. Do your professional image a favor and earn some extra money at the same time. Send for our 12 page AUTHOR'S GUIDE. It covers criteria for acceptability, form, length, writing tips, illustrations, and payment for articles published.

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Editor-in-Chief

Electronic Design

50 Essex Street, Rochelle Park, New Jersey 07662

The Digisec® Encoder keeps little bits from becoming big mistakes.

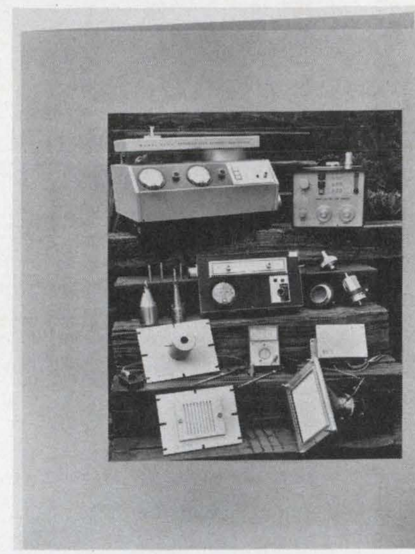
As some people have found out the hard way, all bits are not of equal length. And what may appear to be just a small error—say a fraction of an arc-second, can lead to a large accumulated error.

As the long recognized leader in encoders, Itek realizes the importance of maintaining accuracy commensurate with resolution. And Digisec Encoders have resolutions and accuracy up to 22 bits/revolution. But that's just part of the story.

Write for our free catalog. Read all about Digisec Encoders. They're more than a bit ahead of their time.

Itek Measurement Systems
A Division of Itek Corporation
27 Christina Street, Newton, Mass. 02161

INFORMATION RETRIEVAL NUMBER 200



Instruments

An illustrated brochure gives information on environmental and control instrumentation. Sierra Instruments, St. Paul, Minn.

CIRCLE NO. 554

Wire and cable

A 90-page brochure contains listings of spark plug cable sets and battery cables as well as data on high-tension wire, starter cable, primary wire, trailer lead cord, terminals, boots and accessories. Prestolite Electrical Div. of Eltra, Toledo, Ohio.

CIRCLE NO. 555

Waterproof connectors

A six-page, three-color brochure describes waterproof connectors for heavy duty and rough field service. The brochure includes data on materials, environmental characteristics, mechanical and electrical features plus contact arrangements and shell sizes in both inches and millimeters. ITT Cannon Electric, Whitby, Ontario, Canada.

CIRCLE NO. 556

Elapsed time indicators

Data designed to simplify the specifying of elapsed time indicators are contained in a 16-page booklet. The guide is tabbed for easy reference and includes photographs, specifications and dimensional drawings. Conrac Corp., Cramer Div., Old Saybrook, Conn.

CIRCLE NO. 557

Printing calculator

Information on the operation and design features of the 9212 electronic printing calculator is provided in a four-page brochure. Facit Addo, Secaucus, N.J.

CIRCLE NO. 558

Silicon-iron alloys

Test data on two major types and seven thin gauges of silicon-iron electrical steels are given in a 28-page catalog. Magnetics Specialty Metals Div., Butler, Pa.

CIRCLE NO. 559

Silicon photodetectors

Solid-state silicon p-i-n photodiodes, avalanche photodiodes, photovoltaic diodes and hybrid photodetector-preamplifier modules are described in a six-page brochure. RCA Commercial Engineering, Harrison, N.J.

CIRCLE NO. 560

Electrical insulation

Basic descriptions and characteristics of the company's electrical insulating and mechanical products are given in a 22-page catalog. Spaulding Fibre, Tonawanda, N.Y.

CIRCLE NO. 561

Elastic stop nuts

"When Reliability and Safety Hang by a Thread," an eight-page brochure, illustrates critical applications of various types of elastic stop nuts on a variety of heavy industrial and transportation equipment as well as military aircraft and jet engines. Esna Div., Amerace Corp., Union, N.J.

CIRCLE NO. 562

Thermocouple tables

Condensed temperature-EMF tables for common thermocouple calibration types J, K, T, E, R, S, B, tungsten-rhenium combinations and Platinel II have been updated based on the latest International Practical Temperature Scale (IPTS 1968). Tables include temperature in degrees fahrenheit and celcius and are carried out to three decimal places. Barber-Colman, Rockford, Ill.

CIRCLE NO. 563

INFORMATION RETRIEVAL NUMBER 210

INFORMATION RETRIEVAL NUMBER 211

bulletin board

Du Pont's Film Dept. has increased the price of most **types and gauges of Kapton polyimide and Mylar polyester films.** Price increases for Mylar film will be 10 to 20%. Price increases for Kapton will be 2 to 9%.

CIRCLE NO. 564

Two new videotape instructional courses on digital and MOS ICs are being presented across the nation by **Texas Instruments.** Classroom presentation will continue through April 17, 1975, with sessions in 20 major locations.

CIRCLE NO. 565

A low-cost, real-time, multiprogramming software system designed to operate on the full range of PDP-11 computers has been introduced by **Digital Equipment Corp.** Designated RSX-11M, the disc-based software system can be used for on-line program development and concurrent execution of real-time tasks.

CIRCLE NO. 566

Mohawk Data Sciences has introduced a **software package** designed to allow the user to create Form Description Programs (FDPs) for his MDS 2300 document processing system. The programs are compiled on a MDS System 2400 which relieves the mainframe computer from the task.

CIRCLE NO. 567

Johanson Monolithic Dielectrics has added a **chip capacitor** 0.04 × 0.03 × 0.015 in. thick with a 3900-pF capacitance value at 6 WV dc to its TR series.

CIRCLE NO. 568

Silicon General has introduced the **SG556/SG556C,** the equivalent of two industry-standard **555-type timers** in one 14-pin dual-in-line package.

CIRCLE NO. 569

Beckman Instruments, Helipot Div., has raised prices an average of 10% on most of its **electronic component products.**

CIRCLE NO. 570

Periphonics has added another **terminal support module** to its front-end software library. The device handler is designed to permit T-COMM 7 front-end users to add Hazeltine Models 1000 and 2000 display terminals to their data communications systems.

CIRCLE NO. 571

Hamamatsu has announced a 10% price increase on all **photosensitive devices and lamps.**

CIRCLE NO. 572

RCA Mobile Communications Systems has announced price increases averaging 7% on its **two-way radio communications equipment.**

CIRCLE NO. 573

Corning has added **two new precision components to its metal-film resistor line.** Designated NE55 and NC55, the resistors offer tempcos of ±25 ppm and ±50 ppm, respectively, over the range of −55 to +175 C. The parts have been qualified to MIL-R-10509, RN 55 characteristics C and E, and are rated at 1/8 W at 70 C and 1/10 W at 125 C.

CIRCLE NO. 574

Precision Methods offers computer users a **total low-cost service including inspection and preventive maintenance on any make or model disc pack or cartridge.**

CIRCLE NO. 575

Two **software packages** for engineering computation and process-control applications within the electrical utility field are now available for use with **General Automation's** SPC-16 family of minicomputers. The two are called PTAC-16 and PSS/2-16. Each can be used as a free-standing processor under GA's disc based operating system (DBOS-II) or as a background function under the real-time operating system (RTOS-II).

CIRCLE NO. 576

RCA Broadcast Systems has announced price increases averaging 9% on all of its **radio and TV broadcast equipment.**

CIRCLE NO. 577

Tri-Data has expanded its PDP-11 **software package** to include linkage editor, PAL-11s assembler and PDP-8 PAL-III/PDP-11 cross-assembler programs. The company's P103 program package is designed to provide software support for PDP-11 computers when used with its CartriFile 10, 20 and 40 cartridge tape memory systems.

CIRCLE NO. 578

Microcomputer Technique is conducting a series of **seminars** across the country ranging from introduction to software for engineers and hardware for programmers to evaluation and selection of microcomputers and microprocessors and system design using specific brands of microprocessors equipment.

CIRCLE NO. 579

Price reductions

GHZ Devices has announced price reductions ranging up to 50% on the company's **microwave diodes.**

CIRCLE NO. 580

Power Hybrids has announced 25 to 60% price decreases for all its **microwave power transistor standard products.**

CIRCLE NO. 581

Texas Instruments has lowered prices on four **hand-held electronic calculators.** The price changes bring the TI-1500 down to $59.95 from $69.95; the TI-2550 down to $69.95 from $79.95; the SR-10 down to $69.95 from $74.95 and the SR-11 down to $79.95 from $89.95

CIRCLE NO. 582

DON'T MISS AN ISSUE. FILL IN AND RETURN YOUR RENEWAL FORM TODAY. (See inside front cover.)

vendors report

Annual and interim reports can provide much more than financial-position information. They often include the first public disclosure of new products, new techniques and new directions of our vendors and customers. Further, they often contain superb analyses of segments of industry that a company serves.

Selected companies with recent reports are listed here with their main electronic products or services. For a copy, circle the indicated number.

Lloyd's Electronics. Home stereo systems, radios, calculators and tape recorder/players.

CIRCLE NO. 583

Solid State Scientific. CMOS ICs and rf discrete transistors.

CIRCLE NO. 584

Viking Industries. Connectors, connecting systems and related products.

CIRCLE NO. 585

Dataproducts. Line printers, core memories, data cards and telecommunications.

CIRCLE NO. 586

Air Transport. Scheduled airline industry.

CIRCLE NO. 587

Sola Basic. Power and communication systems, electrical equipment, electrical components, heat processing and microelectronic assembly equipment.

CIRCLE NO. 588

Unitrode. Diodes, thyristors, transistors and SCRs.

CIRCLE NO. 589

L M Ericsson. Public telephone exchange, telephones and subscriber equipment, transmission equipment, cable and wire, packaging equipment, data communications, intercoms, defense electronics, railway and street signaling equipment, radio communications, components, power supplies, measuring instruments and cryptography equipment.

CIRCLE NO. 590

Electronic Arrays. Calculator circuits, read/write RAMs, ROMs and shift-register (serial memory) circuits.

CIRCLE NO. 591

Ampex. TV, radio, CCTV and CATV equipment; memory, data products and peripherals and prerecorded and blank tapes.

CIRCLE NO. 592

Porta Systems. Telephone line fault detection systems.

CIRCLE NO. 593

Park Electrochemical. Electronic materials, epoxy reinforced copper-clad laminates, multilayer products, adhesive tapes and flexible circuits.

CIRCLE NO. 594

Optel. Liquid-crystal displays, liquid-crystal watches and electronic timepieces.

CIRCLE NO. 595

Englehard. Minerals, metals and ores.

CIRCLE NO. 596

Computer Machinery. KeyProcessing systems, magnetic tape drives and communication systems.

IRCLE NO. 597

Hipotronics. Ac dielectric test systems, integrated fault locating systems, dc power supplies and test equipment, megohmmeters, kilovoltmeters, hipot testers, power packs, wire and cable, transformers and capacitors.

CIRCLE NO. 598

Modular Computer Systems. Computers and data-communications products.

CIRCLE NO. 599

Phone-Mate. Automatic answering systems.

CIRCLE NO. 600

Belden. Electrical wire, cable and cord products.

CIRCLE NO. 619

Scan-Data. Data-entry systems, key-to-disc systems, key-entry systems and mixed-media data-entry systems.

CIRCLE NO. 620

Interdata. Minicomputers, software and peripherals.

CIRCLE NO. 621

Dynascan. Remote-control radio systems, CB radios and test equipment.

CIRCLE NO. 622

Comten. Data-communications system, hardware and software, front-end processors and proprietary software.

CIRCLE NO. 623

Sealed Air. Cushioning products.

CIRCLE NO. 624

ARINC Research. Design and analysis.

CIRCLE NO. 625

Aeronautical Radio. Air-ground-air communications systems, electronic switching systems, intercity communications and data processing.

CIRCLE NO. 626

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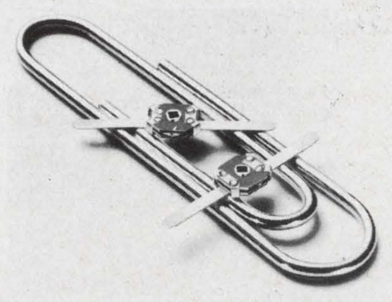
INFORMATION RETRIEVAL NUMBER 217 ▶

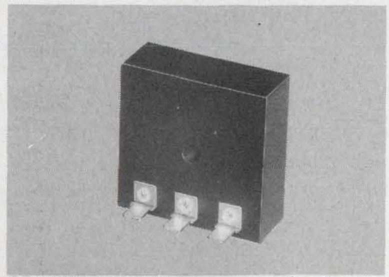
quick ads

New and current products for the electronic designer presented by their manufacturers.



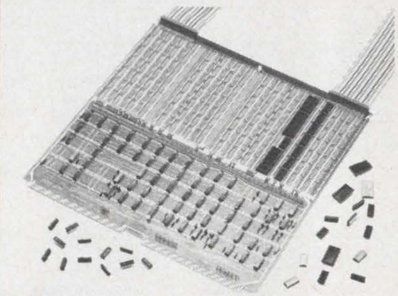
Thin-Trim variable capacitors provide a reliable means of adjusting capacitance without abrasive trimming or interchange of fixed capacitors. Series 9401 has high Q's and a range of capacitance values from 0.2-0.6 pf to 3.0-12.0 pf and 250 WVDC working voltage. Johanson Manufacturing Corporation, Boonton, New Jersey (201) 334-2676.

INFORMATION RETRIEVAL NUMBER 601



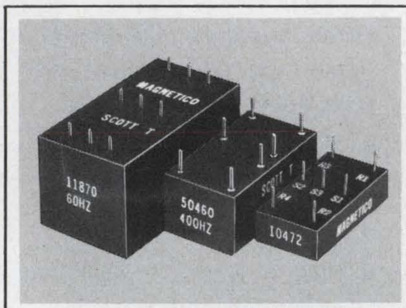
Solid-State full wave ac flasher—Type FS154 handles 12 amp resistive, incandescent, inductive loads at 120 VAC. High current. Zero voltage switching for minimum RFI. Circuitry totally encapsulated. Phenolic housing with single mounting hole. Ask about our complete line of solid state flashers and signal controls. SSAC Precision Products, Inc. P.O. Box 395, Liverpool, N.Y. 13088. (315) 457-9610.

INFORMATION RETRIEVAL NUMBER 604



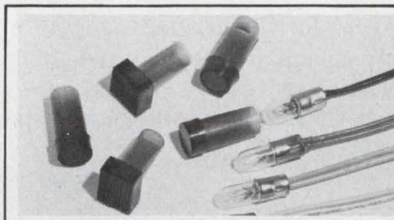
NOVA/DCC-116 general purpose interface board provides: multiple device selection, 4 I/O registers, DMA zero word count detect, 105 socket positions for 14, 16, 24 & 40 PIN IC's. Basic board (all features of data general 4040 plus multiple device select) $350. MDB Systems, Inc., 981 N. Main St., Orange, CA. (714) 639-7238.

INFORMATION RETRIEVAL NUMBER 607



Scott T Transformer. 11870: 60HZ, 90v, L-L in. 1.1x2.1x1.1. 50460: 400HZ, 90v, L-L in. 7/8x1-5/8 x11/16. 50642: 400HZ, 11.8v, L-L in. 7/8x1-5/8-11/16. 10472: 400-HZ, 11.8v, L-L in. 3/4x1-1/2x3/8. All with 6v RMS sine & cosine output. MAGNETICO, INC., 182 Morris Ave, Holtsville, N.Y. 11742 516-654-1166.

INFORMATION RETRIEVAL NUMBER 602



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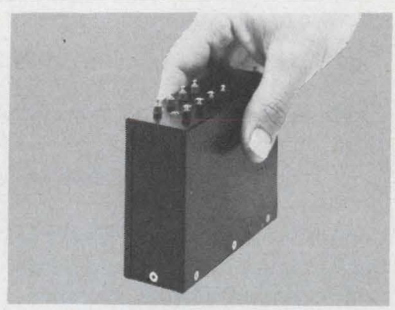

Big power supply for little spaces. 115 VAC, 50-500 Hz input. 1 to 6 isolated & regulated DC outputs. 120 W per output. 3.9 W delivered per cu. in. Modular construction lets you "Design-As-You-Order". Over 1200 configurations using off-the-shelf modules. Immediate deliveries! Arnold Magnetics Corp., Culver City, Ca. (213) 870-7014.

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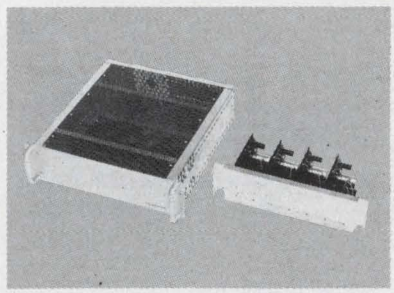
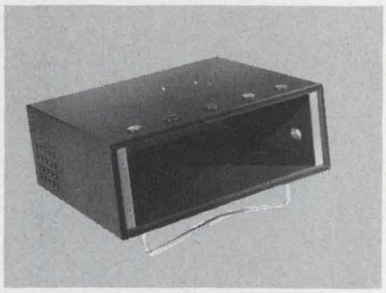


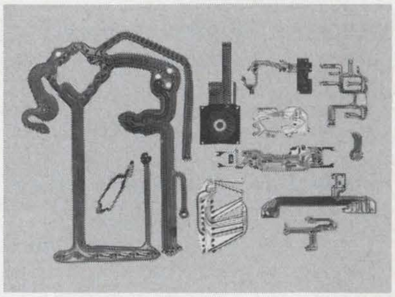
VERSATILE RACK ADAPTER for OEM DC power supplies. Interpanel design accepts almost any combination of Powertec single and multiple OEM Series. All-steel frame, brushed aluminum front panels and handles. Standard 5¼" x 19" rack compatible—depths of 14", 17.5", and 21". From $60.00. Powertec, Inc. Chatsworth, CA. 213 882-0004.

INFORMATION RETRIEVAL NUMBER 603



HANDSOME, RUGGED ENCLOSURES Custom-crafted laminated Formica-wood-Formica construction, internally reinforced corners, rich wood grain or solid color exteriors. Superb workmanship, competitive prices, any quantity. W. A. Miller Co., Inc., 307 Mingo Loop, Oquossoc, Maine 04964. Phone: 207/864-3344

INFORMATION RETRIEVAL NUMBER 606

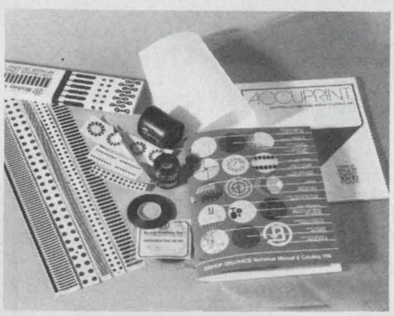


Low-Cost Flexible Printed Circuits NOW from Spectra-Strip! Specify from 1 to 1,000,000 pieces! Quick action on your orders. Now, one stop for your Flexible Printed Circuits as well as widest variety of Ribbon Cable and Connectors! Spectra-Strip Corp., 7100 Lampson Ave., Garden Grove, CA 92642. (714) 892-3361.

INFORMATION RETRIEVAL NUMBER 609

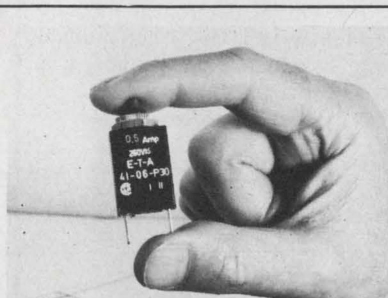
Free catalog of 34,500 power supplies from the worlds largest manufacturer of quality Power Supplies. New '74 catalog covers over 34,500 D.C. Power Supplies for every application. All units are UL approved, and meet most military and commercial specs for industrial and computer uses. Power Mate Corp. (201) 343-6294.

INFORMATION RETRIEVAL NUMBER 610



Free 84-page Printed Circuit Drafting Aids Technical Manual & Catalog contains hundreds of time & money-saving tips, plus details on over 15,000 component symbols & tapes, film, vellum, grids. Bishop Graphics, Inc., 20450 Plummer St., Chatsworth, California, 91311, (213) 993-1000.

INFORMATION RETRIEVAL NUMBER 611



Overcurrent Protector, manual reset eliminates fuse replacement. Convenient panel mounting. 15 fractional ratings from 0.1 to 3 amp. Other models up to 400 amp. Trip-free and fool-proof, UL and CSA approved. High quality, low cost $1.20 ea. in 1000 lots. E-T-A Products Co. of America, 7400 N. Croname Rd., Chicago, Ill. 60648. Tel: (312) 647-8303. Telex: 253780.

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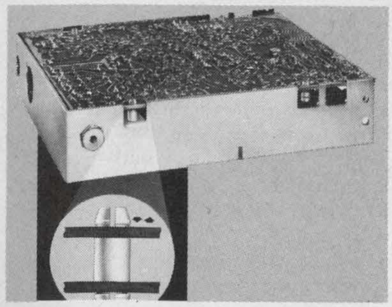

New combination spacer/bushing. Cut assembly time and costs substantially with these new, low Polyamide Spacer/Bushings from Johnson. Allows quick mount of PC boards to chassis. "Mechanically secure, yet P.C. boards easily removed." Made of non-conductive polyamide in various sizes. E. F. Johnson, Waseca, MN. 56093 (507) 835-2050.

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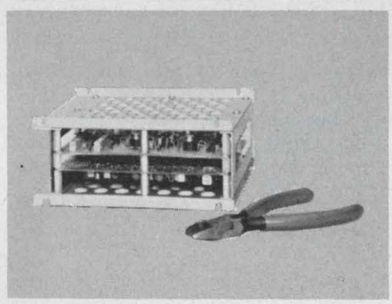

Model MOD-815 A/D Converter. Digital data with 8-bit resolution at any random or periodic word rate from DC through 15 MHz. Only 100 cu. in. Power dissipation approx. 20 watts. Computer Labs, 1109 S. Chapman St., Greensboro, N.C. 27403.

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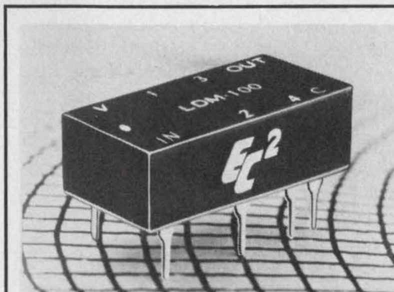


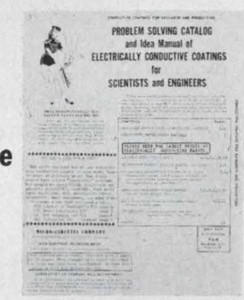
EC²'s new T²L Compatible Logic Delay Module features; 14-pin DIP package (.250 high); precise delays from 25nf to 250nf; with 10 T²L input and outputs; tops at 20% increments, each isolated and with 10 T²L fan-out capability. Engineered Components Company, 3580 Sacramento Drive, San Luis Obispo, CA 93401 (805) 544-3800.

INFORMATION RETRIEVAL NUMBER 615

Contact United States Crystal Corporation for our new quartz crystal catalogue. It gives you the most up to date specifications on military CR numbers and information for designing and specifying crystals. Free engineering assistance on your crystal requirements. 3605 McCart St., Fort Worth, Texas 76110. (817) 921-3014.

INFORMATION RETRIEVAL NUMBER 616

FREE
10 Ways To Use Conductive Paints



Our electrically conductive paints are solving "impossible" lab problems and reducing unit production costs. One customer saves a fortune each year PAINTING on four MILLION pin head 1000 meg resistors. Add that up. Why not request "Ten Ways To Use Conductive Paints"? Micro Circuits Co., New Buffalo, Mich. 49117. (616) 469-2727.

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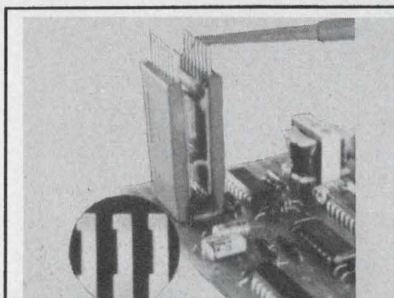

New PROTO-CLIP® for power-on, hands-off signal tracing. Eliminates shorting leads. Plastic construction eliminates springs and pivots. Scope probes & test leads lock onto Dynagrip inset. 14-pin: $4.50 each. 16-pin: $4.75 each. From distributors or Continental Specialties Corp., Box 1942, New Haven, CT 06509.

INFORMATION RETRIEVAL NUMBER 618

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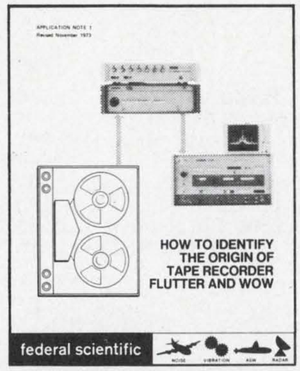
HOW REAL-TIME SPECTRUM ANALYSIS PINPOINTS THE CAUSES OF FLUTTER & WOW IN TAPE RECORDERS.



Even the finest magnetic tape recorders/reproducers exhibit some unwanted tape-speed fluctuations due to flutter, wow, stiction, & imperfections in tape itself. 4-page technical paper presents actual data which illustrates the diagnostic value of on-line high-resolution spectrum analysis in the maintenance & evaluation of tape transports. A fine-resolution (500-line) spectrum analyzer easily resolves otherwise-missed flutter & wow contributions due to unbalance in reels, capstans, idlers, etc. In contrast, measurements taken with commercial flutter & wow meters lump together the effects of these disturbances, thereby greatly diminishing the diagnostic value of these measurements. Also shows how to convert flutter data, obtained with a high-resolution spectrum analyzer, to percentage peak-to-peak flutter, & how to make an on-line measurement set-up.

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Immediate, circle No. 170
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CIRCLE NO. 172

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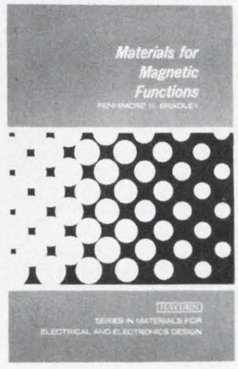
MATERIALS FOR MAGNETIC FUNCTIONS



by Fennimore N. Bradley

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