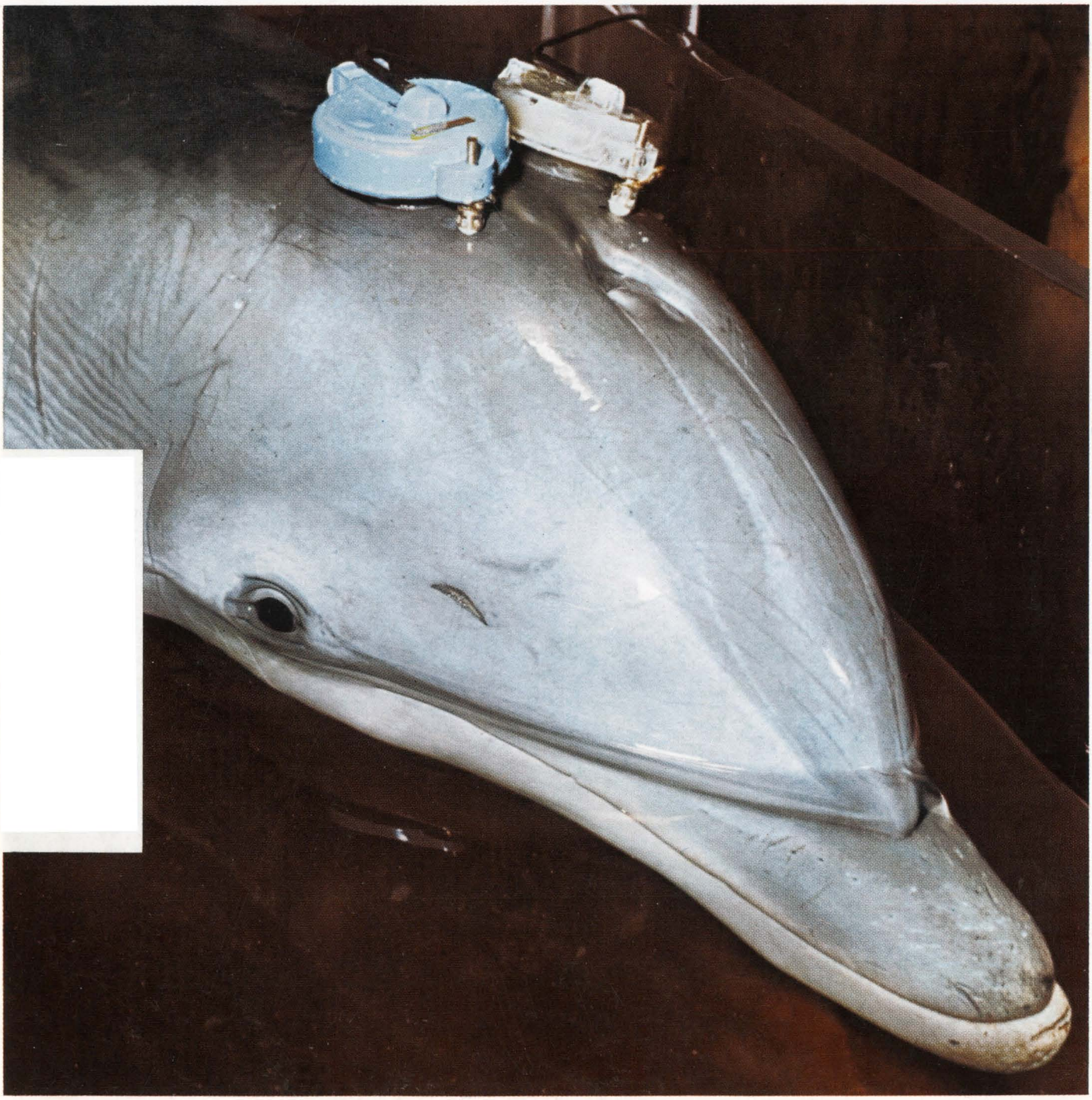
VOL. 15 NO.

Electronic Design 25

FOR ENGINEERS AND ENGINEERING MANAGERS
DEC. 6, 1967

Dolphins challenge the designer. Experiments to unravel nature's mysteries are now revealing how they communicate and sense the environment. Existing electronics doesn't meet the needs, since it wasn't designed for research on animals. Necessary innovations, notably in systems engineering, are outlined starting on page 49.



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MIL-C-19978B/2 hermetically sealed mylar* capacitors are available now from TRW with immediate delivery in production quantities.

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*Du Pont registered trademark

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ON READER-SERVICE CARD CIRCLE 242

VOL. 15 NO.

Electronic Design 25

FOR ENGINEERS AND ENGINEERING MANAGERS

DEC. 6, 1967

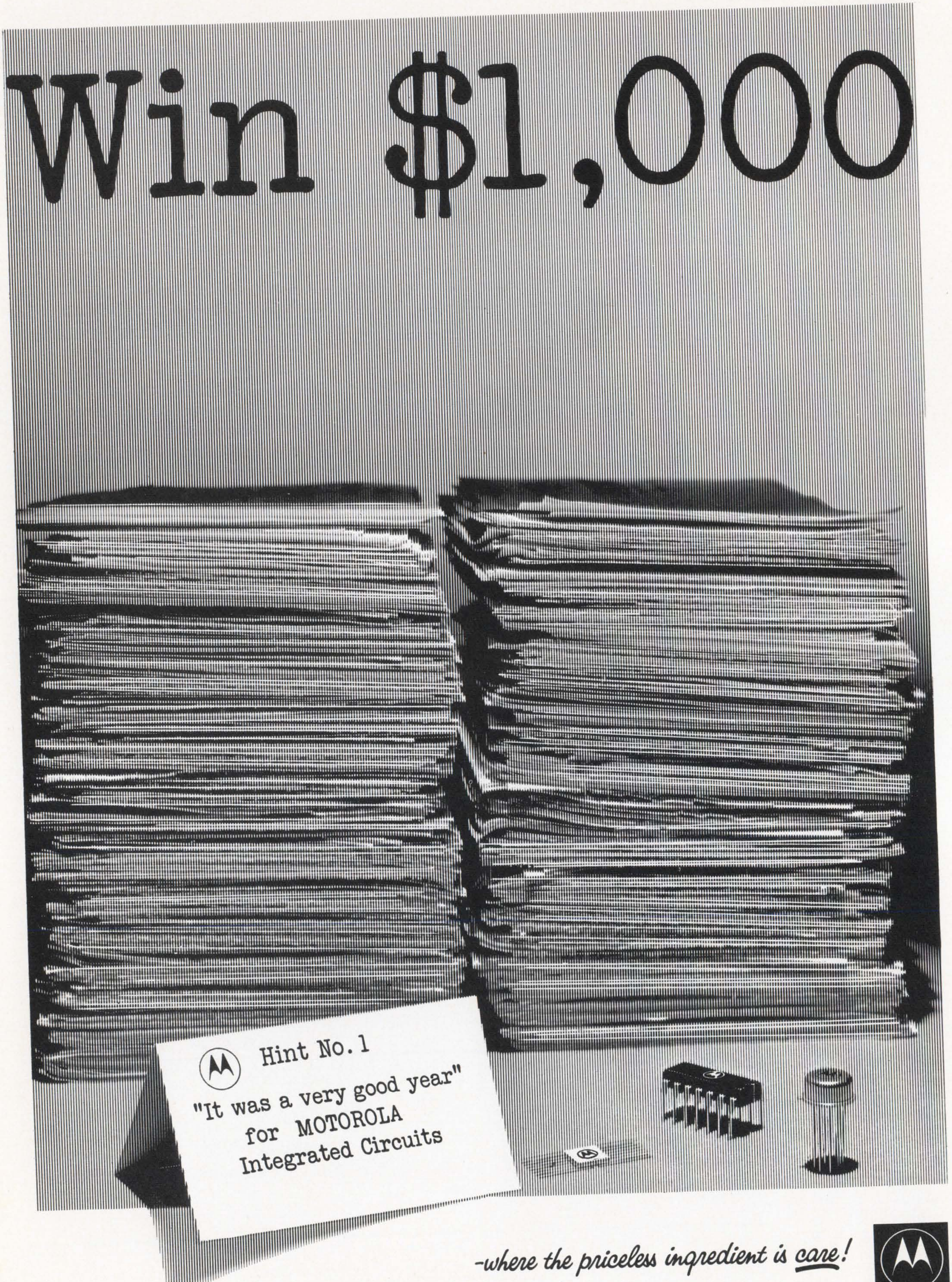
NEWS

TECHNOLOGY

PRODUCTS

Departments

ELECTRONIC DESIGN is published biweekly by Hayden Publishing Company, Inc., 850 Third Avenue, New York, N.Y. 10022. James S. Mulholland, Jr., President. Printed at Brown Printing Co., Inc., Waseca, Minn. Controlled-circulation postage paid at Waseca, Minn., and New York, N.Y. Copyright © 1967, Hayden Publishing Company, Inc. 69,124 copies this issue.


Win $1,000
Hint No. 1
"It was a very good year"
for MOTOROLA
Integrated Circuits
-where the priceless ingredient is care!

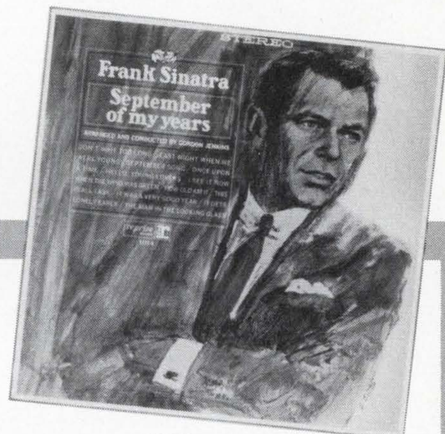
In Motorola's "It was a very good year" Integrated Circuits Contest

Here's your chance to win $1,000 cash. And, it's almost as easy as writing your own name! Simply fill out the coupon below with your best guesses of the number of standard integrated circuits Motorola has formally introduced this year through its franchised distributors, in each linear and logic family.

HERE ARE SOME ADDITIONAL HINTS TO HELP YOU WIN $1,000

- As of October 31, Motorola has introduced 11 new MDTL logic circuits this year. More to come!
- As of November 30, Motorola has introduced 18 MECL integrated logic circuits. Still more on the way!
- Motorola has introduced 15 MTTL integrated logic circuits as of November 15 — and still more coming!

The entry that provides the exact or most nearly exact figures for each circuit category, and the resulting correct grand total, will be declared the winner. In case of ties, the Grand Prize will be divided equally among the winners. (Decision of the Motorola judges will be final, of course.)



I think that Motorola will have introduced the following numbers of new integrated circuits during the past year:

Circuit Family	Number of Circuits:	Circuit Family	Number of Circuits:
MDTL (diode-transistor logic)	______	**MHTL** (high-threshold logic)	______
MRTL (resistor-transistor logic)	______	**I/C Operational Amplifiers**	______
MTTL (transistor-transistor logic)	______	**I/C Diff./Sense Amplifiers**	______
MECL (emitter-coupled logic)	______	**I/C Video, RF & IF Amplifiers**	______

GRAND TOTAL............ [ ]

NAME ______________ TITLE ______________

COMPANY ______________ DIV/DEPT ______________

ADDRESS ______________

CITY ______________ STATE ______________ ZIP CODE ______________

Bonus Prizes

Everyone who guesses the correct grand total (even though the individual circuit categories may be inaccurate) will receive a copy of the Frank Sinatra stereo album, that features "It Was a Very Good Year." So, enter your guesses now (one per entrant, please) . . . just make sure that your entry is postmarked no later than December 23, 1967. Winning totals will be announced after the contest closes.

MOTOROLA Semiconductors

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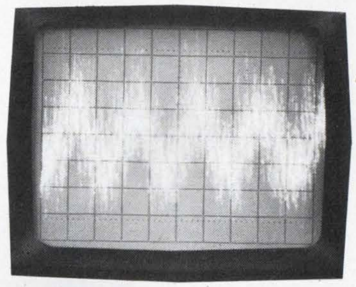
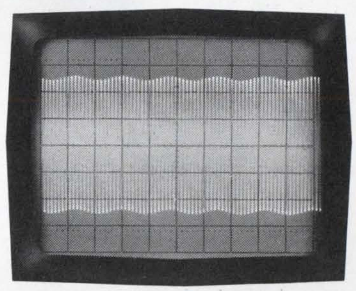
Employees of Motorola Semiconductor Products Inc. and Motorola Inc., Semiconductor Products division, and its distributors are not eligible. Contest is void where prohibited by law or by participant's company policy.

AC MICROVOLTMETER SEES THROUGH NOISE!

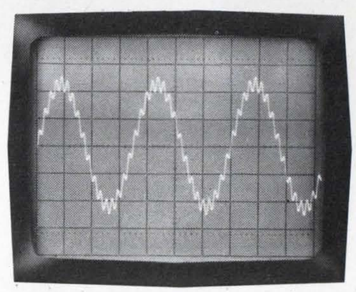
New hp 3410A Measures 300 nanovolts Buried in Noise



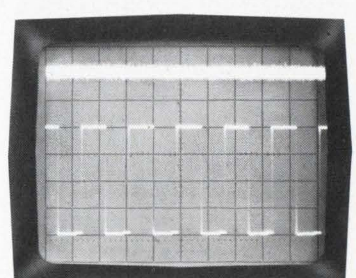
Measure 1 μV, 500 kHz signal out of 40 dB noise.



Measure 10 mV, 5 Hz amplitude modulating 1 V, 400 Hz.



Measure 300 nanovolts, 10 kHz. signal superimposed on 10 μV, 1 kHz



Measure frequency of signal in noise up to 560 kHz by using square wave output, i.e. as a counter preamplifier.

New hp Model 3410A AC Microvoltmeter measures low level repetitive signals obscured by noise—3 μV to 3 V full scale—accuracy ±3%. RMS noise voltages up to 20 dB above full scale *do not affect* readings. Sensitivity, low cost and ease of operation are the 3410A's contribution.

This new microvoltmeter uses an hp designed phase-locked synchronous detector to separate effects of noise from signal. The detector is an electronic gate controlled by an oscillator phase-locked to the input signal. No external reference is required to lock to the input signal. Simply adjust front panel tuning control within 1% of signal frequency and phase-lock circuits *lock-on and track* input signal with ±5% variation in the 5 Hz to 600 kHz frequency range. Phase-lock circuits track 0.5%/sec change in signal frequency without a change in voltmeter accuracy. Input impedance is 10 MΩ shunted by 20 pF.

The new Model 3410A has two outputs on the rear panel. One is a dc recorder output for monitoring long term drifting ac voltage amplitudes. The other is an output for driving an electronic counter to make precise frequency measurements.

For full specifications on the new hp Model 3410A AC Voltmeter, call your hp field engineer. Or, write to Hewlett-Packard, Palo Alto, California 94304. Europe: 54 Route des Acacias, Geneva. Price: hp Model 3410A, $800.00.

097/11

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ON READER-SERVICE CARD CIRCLE 6

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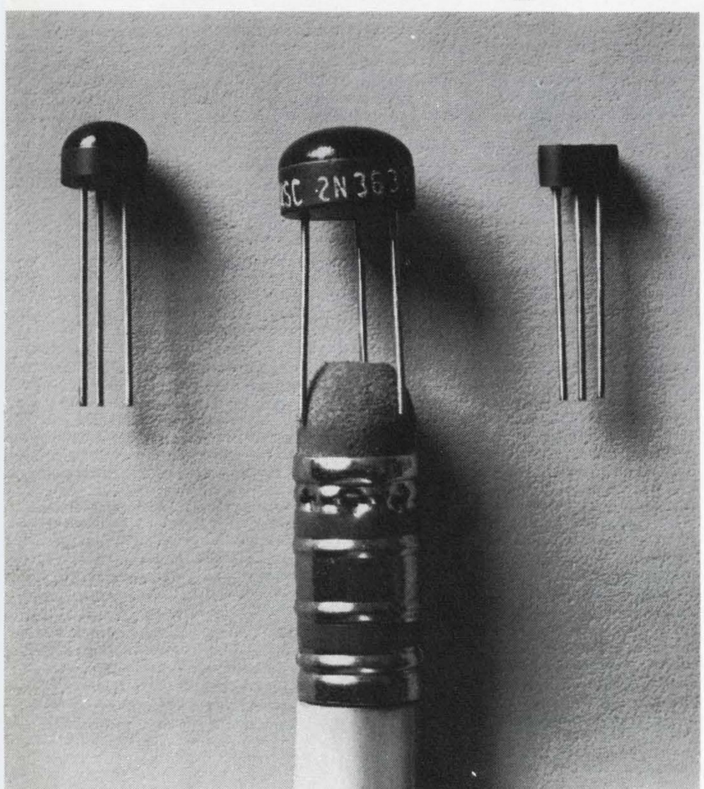

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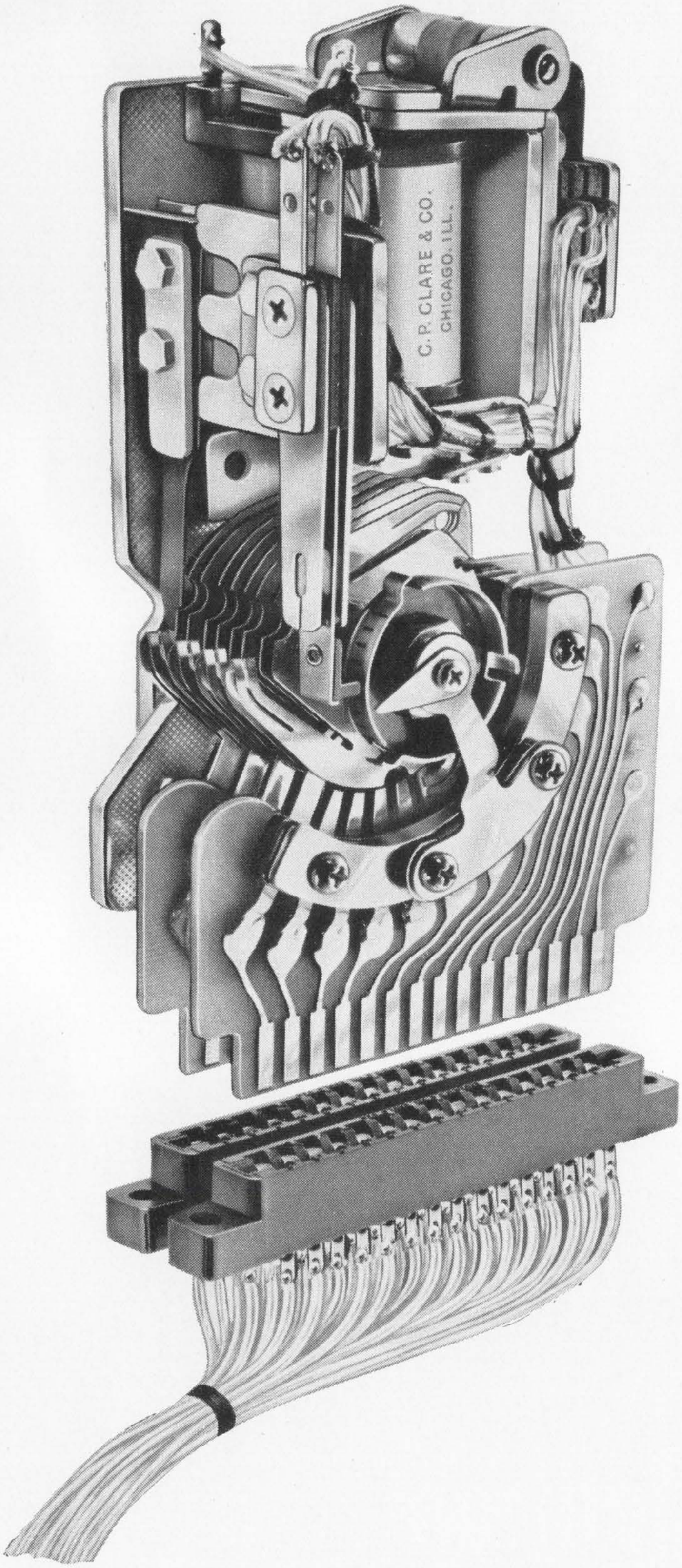
CLARE / Optimity in control



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For complete information, circle reader service number—or ask Clare for Bulletin 651-3... Write Group **12A6**

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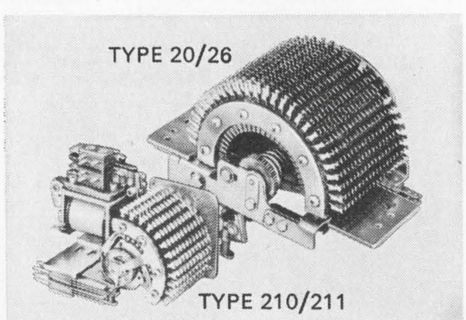

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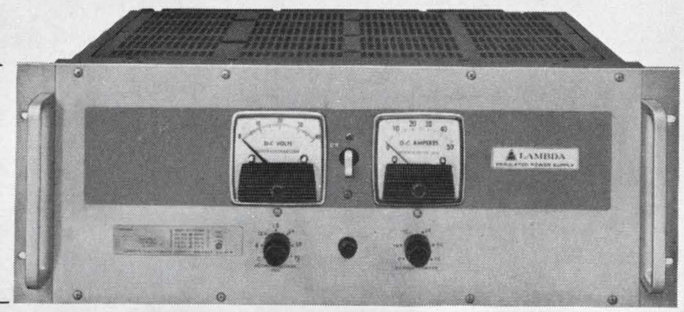
- Ripple—
  LK models—500 µV RMS
  LH models—250 µV RMS, 1 MV P-P
- Meet MIL Environment Specs

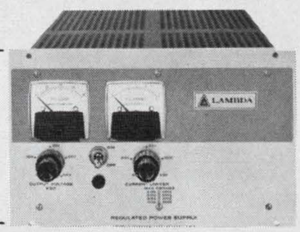
7"



Full Rack 7" LK Series

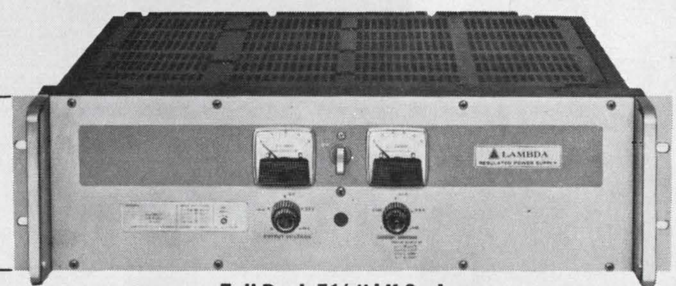
5¼"

¼ Rack LH Series



5¼"

½ Rack LK Series-LH Series



Full Rack 5¼" LK Series

3 Full-rack Models — Size 7" x 19" x 18½"

Model[2]	Voltage Range	CURRENT RANGE AT AMBIENT OF:[1] 40°C	50°C	60°C	71°C	Price[2]
LK 360 FM	0–20VDC	0–66A	0–59A	0–50A	0–40A	$995
LK 361 FM	0–36VDC	0–48A	0–43A	0–36A	0–30A	950
LK 362 FM	0–60VDC	0–25A	0–24A	0–22A	0–19A	995

3 Full-rack Models — Size 5¼" x 19" x 16½"

Model[2]	Voltage Range	CURRENT RANGE AT AMBIENT OF:[1] 40°C	50°C	60°C	71°C	Price[2]
LK 350	0–20VDC	0–35A	0–31A	0–26A	0–20A	$675
LK 351	0–36VDC	0–25A	0–23A	0–20A	0–15A	640
LK 352	0–60VDC	0–15A	0–14A	0–12.5A	0–10A	650

5 Quarter-rack Models — Size 5³⁄₁₆" x 4³⁄₁₆" x 15½"

Model[2]	Voltage Range	CURRENT RANGE AT AMBIENT OF:[1] 30°C	50°C	60°C	71°C	Price[2]
LH 118	0–10VDC	0–4.0A	0–3.5A	0–2.9A	0–2.3A	$175
LH 121	0–20VDC	0–2.4A	0–2.2A	0–1.8A	0–1.5A	159
LH 124	0–40VDC	0–1.3A	0–1.1A	0–0.9A	0–0.7A	154
LH 127	0–60VDC	0–0.9A	0–0.7A	0–0.6A	0–0.5A	184
LH 130	0–120VDC	0–0.50A	0–0.40A	0–0.35A	0–0.25A	225

11 Half-rack Models — Size 5³⁄₁₆"-x 8⅜" x 15⅝"

Model[2]	Voltage Range	CURRENT RANGE AT AMBIENT OF:[1] 40°C	50°C	60°C	71°C	Price[2]
LK 340	0–20VDC	0– 8.0A	0– 7.0A	0– 6.1A	0–4.9A	$330
LK 341	0–20VDC	0–13.5A	0–11.0A	0–10.0A	0–7.7A	385
LK 342	0–36VDC	0– 5.2A	0– 5.0A	0– 4.5A	0–3.7A	335
LK 343	0–36VDC	0– 9.0A	0– 8.5A	0– 7.6A	0–6.1A	395
LK 344	0–60VDC	0– 4.0A	0– 3.5A	0– 3.0A	0–2.5A	340
LK 345	0–60VDC	0– 6.0A	0– 5.2A	0– 4.5A	0–4.0A	395

Model[2]	Voltage Range	CURRENT RANGE AT AMBIENT OF:[1] 30°C	50°C	60°C	71°C	Price[2]
LH 119	0–10VDC	0– 9.0A	0– 8.0A	0– 6.9A	0–5.8A	$289
LH 122	0–20VDC	0– 5.7A	0– 4.7A	0– 4.0A	0–3.3A	260
LH 125	0–40VDC	0– 3.0A	0– 2.7A	0– 2.3A	0–1.9A	269
LH 128	0–60VDC	0– 2.4A	0– 2.1A	0– 1.8A	0–1.5A	315
LH 131	0–120VDC	0– 1.2A	0– 0.9A	0– 0.8A	0–0.6A	320

[1] Current rating applies over entire voltage range.
[2] Prices are for non-metered models (except for models LK360FM thru LK362FM which are not available without meters). For metered models, add suffix (FM) and add $25 to price of LH models; add $30 to price of LK models.
[3] Overvoltage Protection: add suffix (OV) to model number and add $60 to the price of LH models; add $70 to price of half-rack LK models; add $90 to price of 5¼" full-rack LK models; add $120 to price of 7" full-rack LK models.
[4] Chassis Slides for full rack models: Add suffix (CS) to model number and add $60 to the price.

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circuit problems?

Signalite Glow Lamps have solved problems in these areas:

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• Memory • Switching • Digital Readouts

Signalite glow lamps combine long life, close tolerance and economy, and are manufactured with a broad range of characteristics to meet individual application requirements. For a creative approach to your design problem . . . contact Signalite's Application Engineering Department.

PHOTO-CELL APPLICATIONS The A074 and A083 have been designed for use with Cadmium Sulfide or Cadmium Selenide photocells. Applications include photo choppers, modulators, demodulators, low noise switching devices, isolated overload protector circuits, etc. Speed of operation is limited only by the photo-cells.

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VOLTAGE REGULATORS BETTER THAN 1% ACCURACY These subminiature voltage regulators are used in regulated power supplies, as reference sources, photomultiplier regulators, oscilloscope calibrators, etc. They are available in voltages from 82 to 143 V. They are used in multiples as regulators in KV ranges.

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ON READER-SERVICE CARD CIRCLE 248

NEON TIMERS The bi-stable characteristics and high leakage resistance of Signalite's special glow lamps make them ideal as a component for timing circuits. The basic circuit resembles a relaxation oscillator network.

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MEMORY SWITCHES Neon lamps have proven to be an excellent memory switch since they store information and provide visual indication. The properties of neon lamps provide a large differential between breakdown and maintaining voltages, stable electrical characteristics and high "off" resistance (20,000 meg ohms). Other applications include switching, information storage, timing circuitry, etc.

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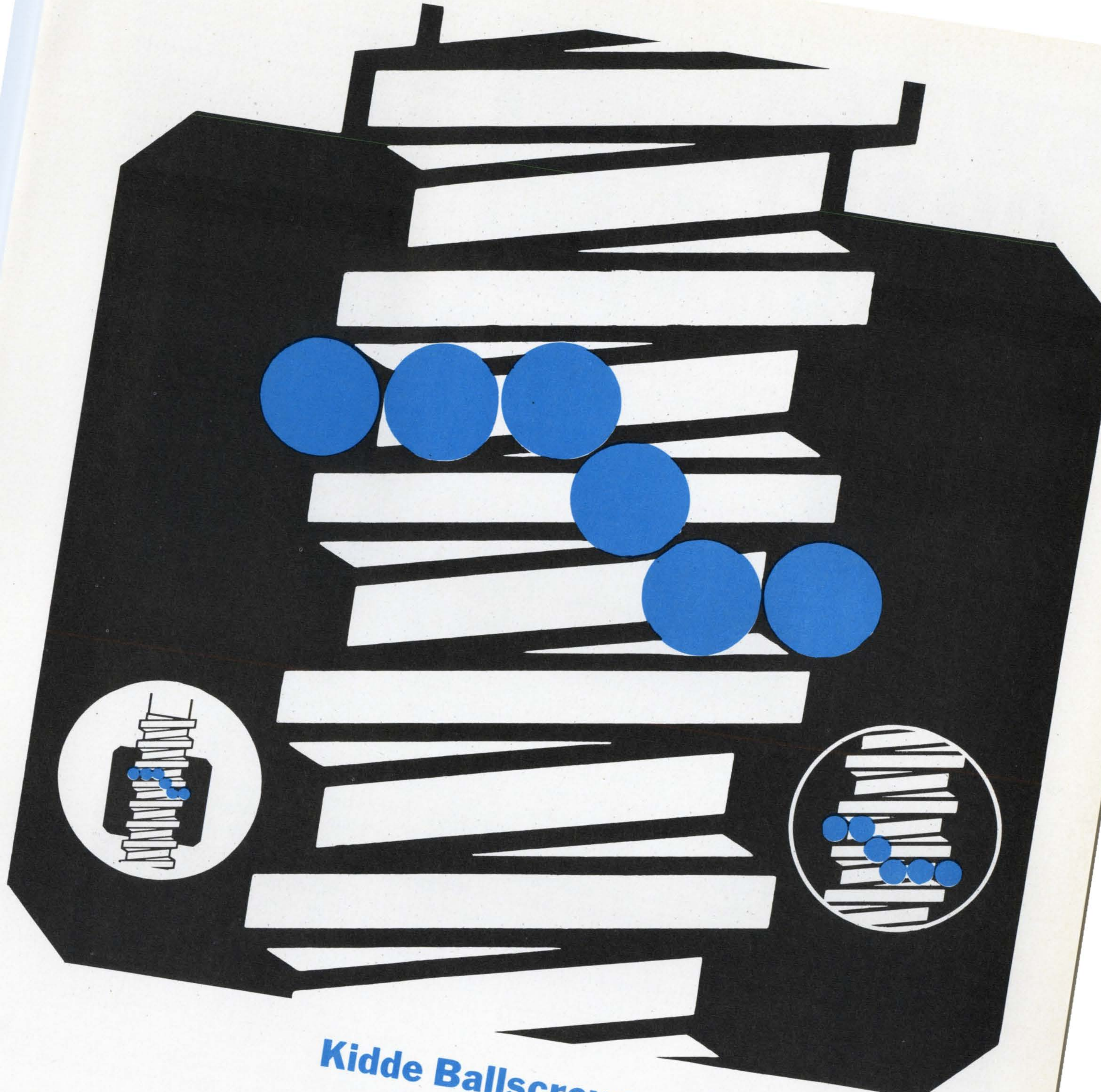
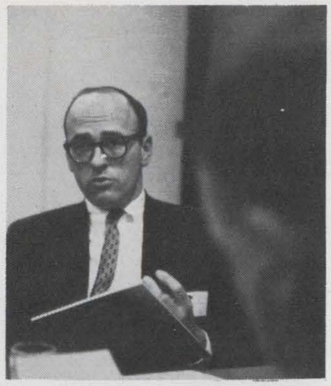


SWITCH CRAFT FORUM



Look, a lever switch is a lever switch is a lever switch. As far as I know, there hasn't been anything new or different in lever switch design since the old telephone type that was introduced over seventy years ago.

How about a totally new telephone type lever switch? Switchcraft recently intro. . . . . .

Sorry to interrupt, but when I say "new", I don't mean just changes in the properties of materials or construction changes brought on by the value analysis people. Unless your lever switch is compatible with modern circuit procedures, then in my book it isn't "new".

Fair enough. Let's just look at one of the compatability problems regarding lever switches and solid state switching devices.

Manual switching devices often introduce transients into the controlled circuit because of contact bounce, etc. Semi-conductor circuits are highly susceptible to these transients and false triggering can easily result.

The new Switchcraft Series 41000 "LT" Switch (Fig. 1) is a new telephone type lever switch that has a specially designed damping block to reduce contact bounce and a rugged "U" shaped frame for increased spring stack stability under conditions of vibration. Another feature is a unique "Can't Cheat" detent guide that prevents accidental actuator by-pass of a switching position. This protects your equipment from damage and guards against programming failures, too. Besides, this new switch extends only 2⅛" behind the panel, providing the smallest telephone-quality lever switch on the market.

FIG. 1

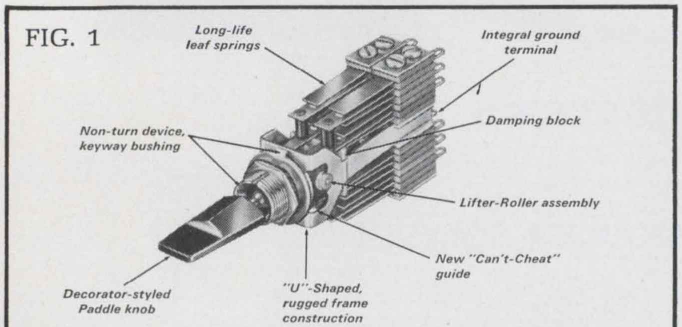
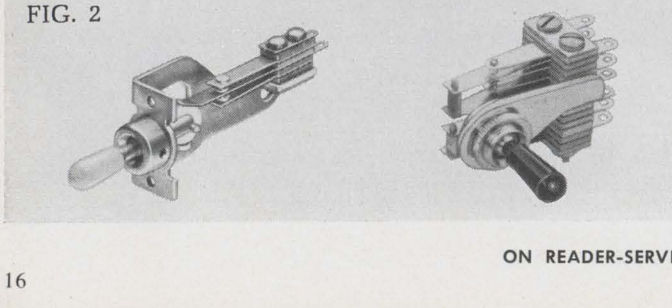


FIG. 2



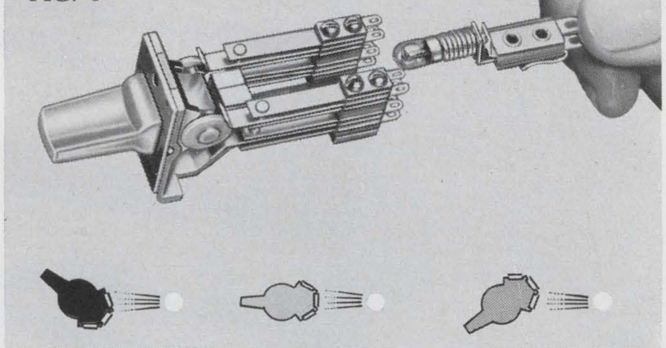
O.K., I'm convinced you've got something new. But, what if I need a miniature size lever switch, or special lighting? Would these have to be engineered from scratch?

Actually, Switchcraft makes a greater variety of lever switches than anybody else. (Just circle the reader service number for proof). Let's look at your requirements and see if we can match your specs from our regular line of switches.

Miniaturization poses no problems. Our miniature "Feather Lever" switch (Fig. 2. left) uses only 7/16" front panel mounting space. It's only 1¾" deep, and that's a lot less than the conventional type. When your behind-the-panel space really gets critical, just shift to our Series 12000 type (Fig. 2 right) that has the springs mounted parallel to the mounting surface. Behind-the-panel depth is only ⅞".

When you need lighted switches, take a close look at Switchcraft's "Lever-Lite" Series. They let one lamp do

FIG. 3



the work of three by a unique system of color filters. You can have a complete color change for each position, and need provision for only one light circuit. Fig. 3 shows how it works and, incidentally, the lamp assembly snaps out for quick replacement and has a spring loaded socket just to keep the lamp from jarring loose.

If you really want flexibility, then check the Switchcraft Series 16000 "Telever" switches. You can convert it from locking to non-locking right in the field, in just a matter of minutes. It requires only one mounting hole, too, and that's being pretty versatile for a standard telephone type switch. What more can we say?

Just make sure my staff gets all the back-up information on your lever switch line. They'll want complete technical details.

All we need is their request on your company letterhead for our "FORUM FACTS on Lever Switches" handbook. We'll also add their name to our TECH-TOPICS mailing list. This engineering-application magazine is received by over 10,000 design engineers every other month and features informative, technically oriented application stories on switches and related products.

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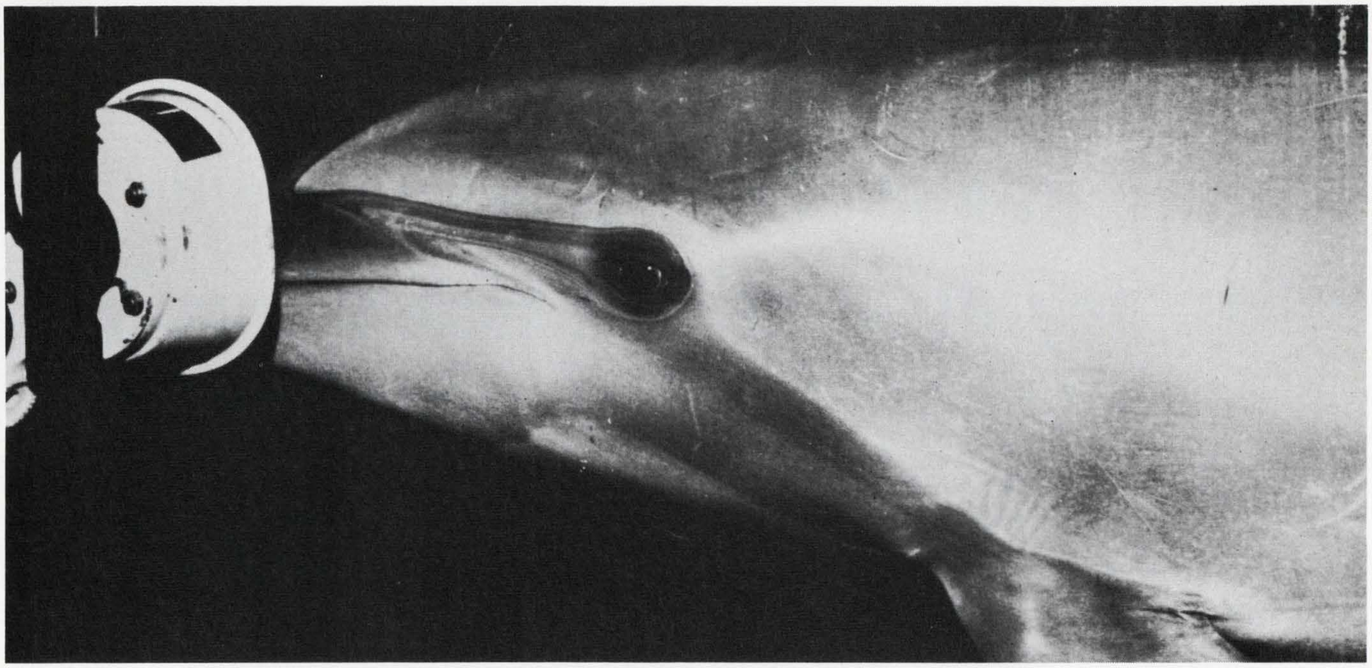
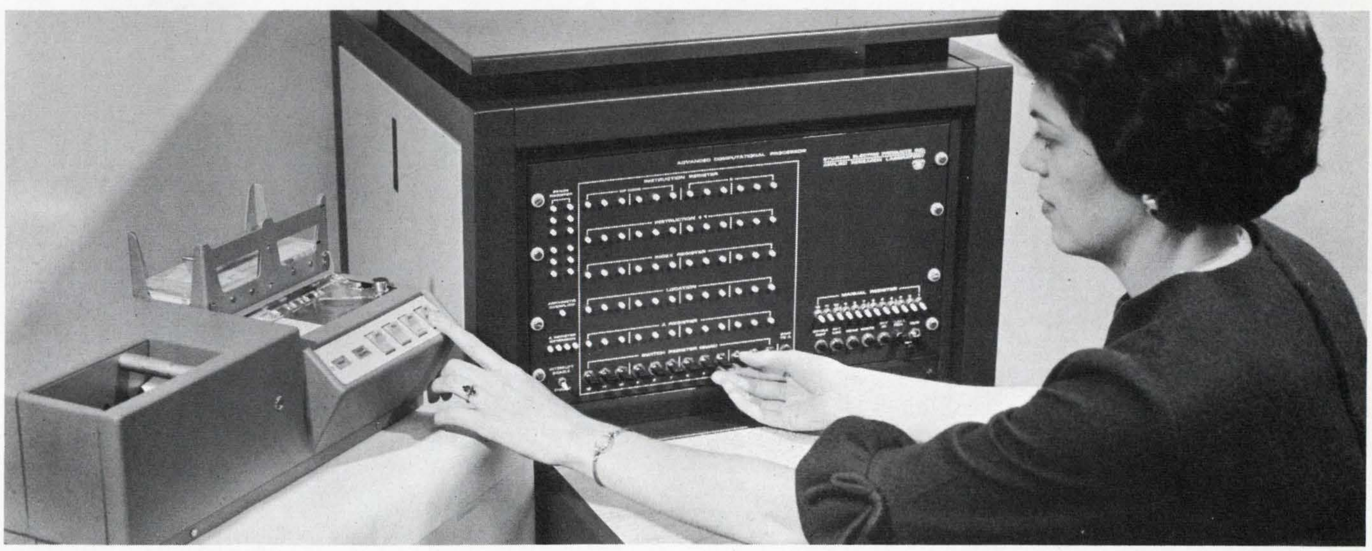
ON READER-SERVICE CARD CIRCLE 14

ON READER-SERVICE CARD CIRCLE 15

News



Dolphins push the state of the art in sound detection and projection devices for use under water. A feature traces research into their communication and navigation. Page 49



Signal processing is being revolutionized from audio frequencies to microwaves by fast Fourier transforms—mathematical tricks that permit real-time computation. Page 25

Also in this section:

LSI and the computer: New designs predicted

What will large-scale integrated circuits (LSI) do for computers? Speakers at the Fall Joint Computer Conference in Anaheim, Calif., agreed that two trends are in view: the design of computers will change radically, with better performance as a result, but there will be no significant reduction in system costs.

Speaking in a session on advances in computer circuits, Martin G. Smith, a researcher of International Business Machines, Yorktown Heights, N.Y., asserted that even with an order-of-magnitude reduction in logic-circuit costs, the eventual saving to a computer user would be only 7 per cent or less. Supporting this forecast was Rex Rice of Fairchild Semiconductor, Palo Alto, Calif., who was chairman of a later panel discussion on the impact of LSI. Rice argued that LSI hardware would most likely account for less than 6 per cent of the over-all user cost and that even order-of-magnitude reductions in logic costs would result in only a few percent reductions in total system costs.

These reductions, Smith pointed out, would allow the addition of significantly more circuitry at no increase in cost. "More functions per dollar, may be expected with LSI," Smith said. He contended that about three times as much logic and twice as much special memory could be expected for the same price as older IC hardware.

On the new computer architecture that will emerge, Henry S. Miiller of RCA Laboratories, Princeton, N.J., noted that LSI would be available in very regular arrays of gates. However, only about 40 per cent of the computer associated with the data path requires regular-array logic circuits. The control logic is often very irregular. Miiller suggested making the control logic regular by partitioning the central processor control into simplified units. Scientists at RCA Laboratories have already succeeded in reducing the control logic of a computer to less than 30 per cent, Miiller reported.

Another supporter of the new computer architecture, Prof. David Evans, head of the Department of Computer Science at the University of Utah, suggested that LSI might lead to an associative computer in which the processor and memory characteristics would be defined by the program at the time the program was run. Thus the programmer would be in control of the machine oganization and could adapt it to suit his needs.

Sounding a warning among the LSI enthusiasts was Robert Creech of the Burroughs Corp., Pasadena, Calif., who feared there was too much "idol worship" of LSI. "We mustn't merely find a use for LSI. Find the best machine organizations first, and then see if LSI can be used to implement them." Computer designs are difficult and expensive to modify and should be hardened before manufacturing starts.

Copies of the Proceedings of the 1967 Fall Joint Computer Conference may be obtained from the Thompson Book Co., National Press Building, 14th and F Streets N.W., Washington, D.C. 20005. The price is $20.70 with a 50 per cent discount to members of affiliates of the American Federation of Information Processing Societies.

Semiconductor makers see strong 1968 sales

More than 400 electronic buyers and engineers assembled in the warehouse of Schweber Electronics, Westbury, N.Y., to get the word from the top on the outlook for the semiconductor market. Four speakers poured it out with unhesitating optimism: integrated circuits, large-scale integration and plastics—all add up to a bright market in 1968.

On the podium in the makeshift auditorium last month were Keith Sueker, marketing manager of the Westinghouse Semiconductor Div., Youngwood, Pa.; Thomas Connors, vice president of Motorola Semiconductors, Phoenix, Ariz.; George Farnsworth, general manager of the General Electric Semiconductor Div., Syracuse, N.Y., and Jerry Sanders, director of marketing of Fairchild Semiconductor, Mountain View, Calif.

The gathering was billed by Schweber, an electronic parts distributor, as a private "summit meeting," called to unravel "the inside story on semiconductors and integrated circuits."

Connors predicted: "Discrete semiconductors will gain 10 per cent and ICs will gain 50 per cent in 1968. This compares with a 10 per cent drop in sales for the discretes and a 50 per cent rise in ICs in 1967."

Sanders looked for sales of 130 million ICs in the United States next year. He indicated that large-scale integration devices would move closer to off-the-shelf status. "At Fairchild we have 90 professional people working in LSI," he reported.

From Sueker, whose company specializes in high-power semiconductors: "More accurate and efficient control, simply not possible several years ago in process industries, transportation, steel mills, electroplating and others, is a reality today. The future will see development of high-frequency, high-power transistors, faster-recovery [100-ns] thyristors and more and more plastic units. By 1969 we expect all devices under 50 amperes to be in plastic."

The rapid gains being made by plastic types were futher emphasized by Farnsworth. "It is reasonable to expect that 70 per cent of all discrete small signal transistors in 1968 will be in plastic," he said. "Due to significant improvements in plastics, these devices will be sold not only to the consumer markets, but also to industrial and

News Scope CONTINUED

military users. Even today 50 per cent of industrial silicon sockets are filled by plastic devices."

What of formal acceptance of plastic devices by the military? Connors observed: "It seems that the biggest stumbling block here is generating a specification." "It'll take at least another year," Farnsworth said.

As in the past, semiconductor prices will continue to fluctuate, the speakers agreed. Connors put it: "How can you stabilize prices if the industry is surrounded by new and growing markets? Automobiles, appliances, home entertainment—we have barely scratched the surface. We expect a 50 per cent growth by 1971."

U.S. Army favors TWTs for Nike X-Arrays

The U.S. Army is expected to decide this month on the transmitter power sources to be used on the Nike X (Sentinel) perimeter array radar (PAR). (See "Nike-X: A merger of radars and computers," ED 22, Oct. 25, 1967 pp. 17-24). It is believed to prefer new high-power traveling-wave tubes to solid-state devices or gridded triodes.

Sources close to the program believe that the Army prefers uhf traveling-wave tubes because of their past record of reliability and efficiency. They say the chances are about three to one that the Army will opt for traveling-wave tubes.

The General Electric Co.'s Heavy Military Equipment Div., Syracuse, N.Y., the contractor for PAR, will need scores of the selected power sources to feed the elements of the PAR's transmitting aperture. New, longer tubes will have to be developed for traveling-wave tubes are not normally used at the PAR transmitters' low frequencies.

The length of traveling-wave tube oscillators and amplifiers is related to frequency. The delay-line element, usually a tungsten helix, may be 2 to 3 feet long for low microwave frequencies.

Varian Associates of Palo Alto, Calif., known to be a participant in the Sentinel program, recently consolidated its TWT production and development facilities, and is believed to be a strong contender for TWT production contracts. Another company capable of fulfilling the Army's requirements is Raytheon Co. of Waltham, Mass.

Advocates of high-power transistors, such as Texas Instruments, Dallas, will try again to sell the Army on the merit of all-solid-state transmitters in advanced over-the-horizon radar programs, if their proposals for the PAR transmitters are unsuccessful.

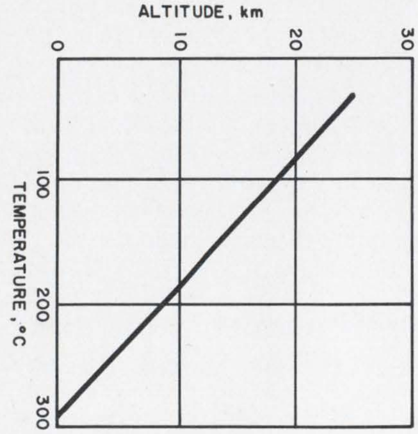
The Air Force's FPS-85 phased-array radar at Elgin AFB, Fla., for tracking and cataloguing spacecraft uses gridded triodes in its transmit array.

More details on Venus 4 revealed in Soviet press

An article in *Pravda* has shed further light on technical aspects of last month's Soviet Venus 4 spacecraft, which landed a capsule on the Venusian surface.

The article disclosed that the instrument package entered the planet's atmosphere at a velocity of 6.9 miles per second. It had then to decelerate at rates up to 300 g and withstand temperatures approaching 11,000°C. In spite of these extremes, all electronics worked without the use of a redundant system, the article stated.

Another interesting aspect of the flight was that trajectory correction was carried out when the spacecraft was some 12 million kilometers from Earth. Only one correction was made, though there was enough liquid fuel for two.



Linear temperature gradient was revealed by Venus 4 during its descent through the Venusian atmosphere.

The internal temperature of the craft was maintained by forced circulation of a cooling gas around hot components and through an external heat exchanger. The craft also carried an atmospheric-entry thermal shield made of insulating material, optical coatings and "other substances."

During the flight to Venus, the instrument-package battery was charged by the solar cells of the mother craft. During descent through the Venusian atmosphere power was supplied by the battery.

Pravda also reported the apparent linear relationship of temperature vs altitude measured by the descending package. The linear temperature gradient was measured at 10°C/km, reaching about 280°C on the planet's surface.

Radiation may announce new one-chip 709 unit

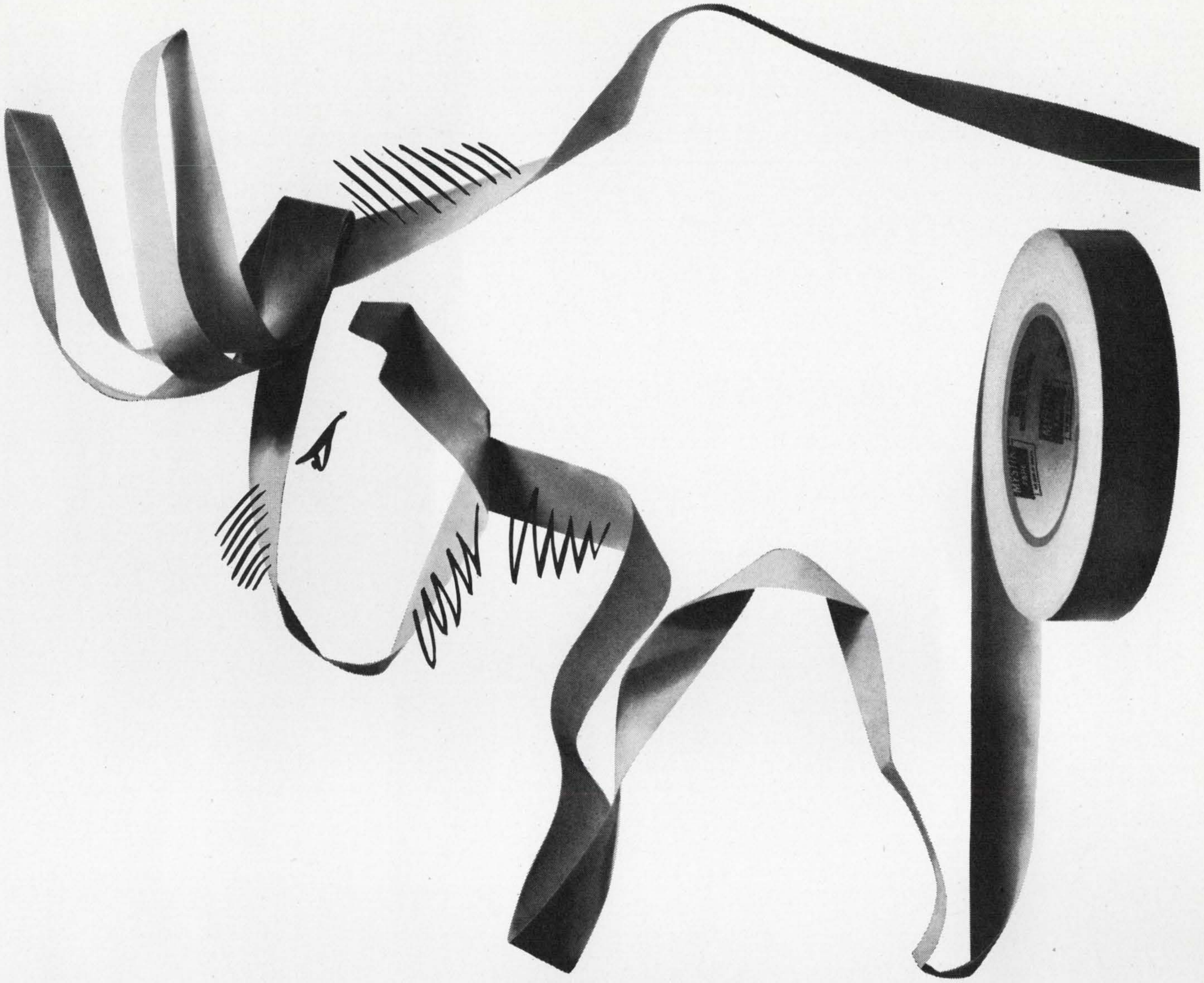
A new 709 dielectrically isolated IC operational amplifier may shortly be put on the market by Radiation, Inc., of Melbourne, Fla.

Believed to be a one-chip unit, it comes after the company's development earlier this year of a dielectrically isolated two-chip amplifier. The one-chip unit was to have been displayed at Wescon but production problems prevented this.

Isolation in the new 709 is said to allow a reduction in the number of stages from three to two, improving the circuit's phase stability and simplifying its compensation network at closed loopgains near unity. The isolation is also reported to improve slew rate by about one-third and frequency response by nearly 20 per cent. Thin-film feedback resistors are believed to be included on the same chip.

Though the circuit is expected to cost more than the current 709, which is priced at about $15 for the military version, the improvements are expected to be worth the price to many customers.

The circuit, however, will have to compete in the market with Union Carbide's dielectrically isolated monolithic operational amplifier (UC4000) and National Semiconductor's two-stage operational amplifier (LM 101).



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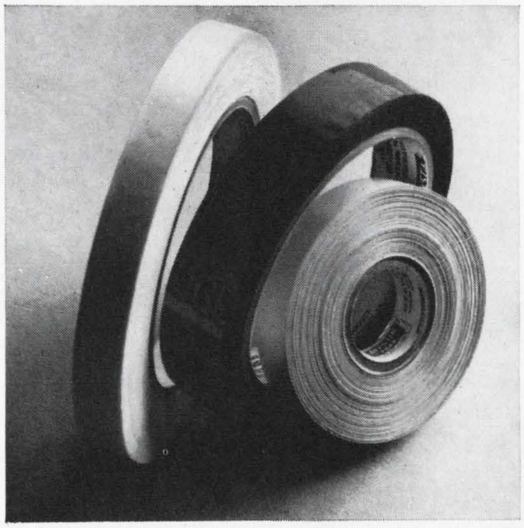

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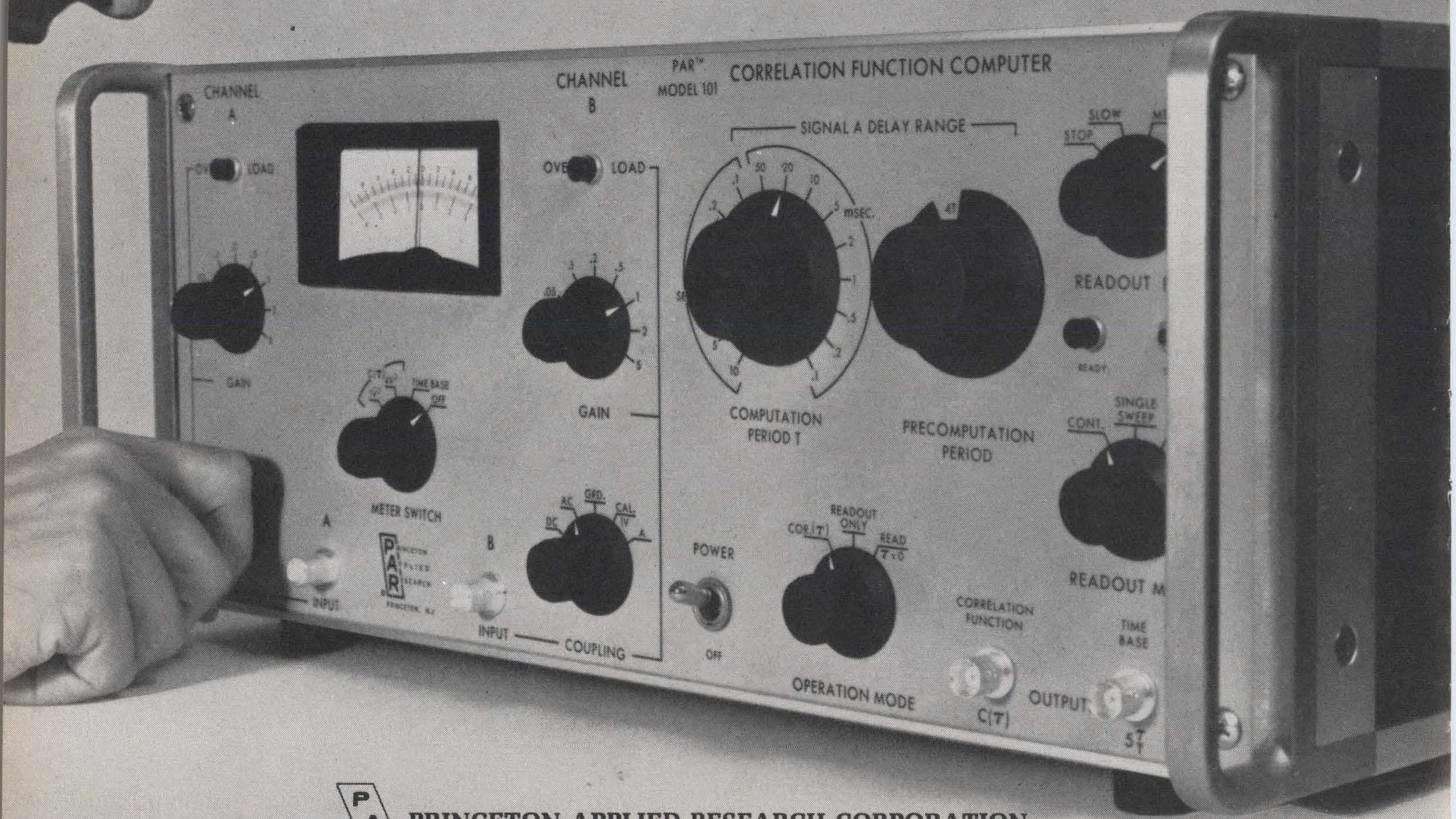


PRINCETON APPLIED RESEARCH CORPORATION

The FFT computer: Designer's 'missing link'

Fast-Fourier-transform black boxes capable of real-time results, are altering signal processing

Robert Haavind
Managing Editor

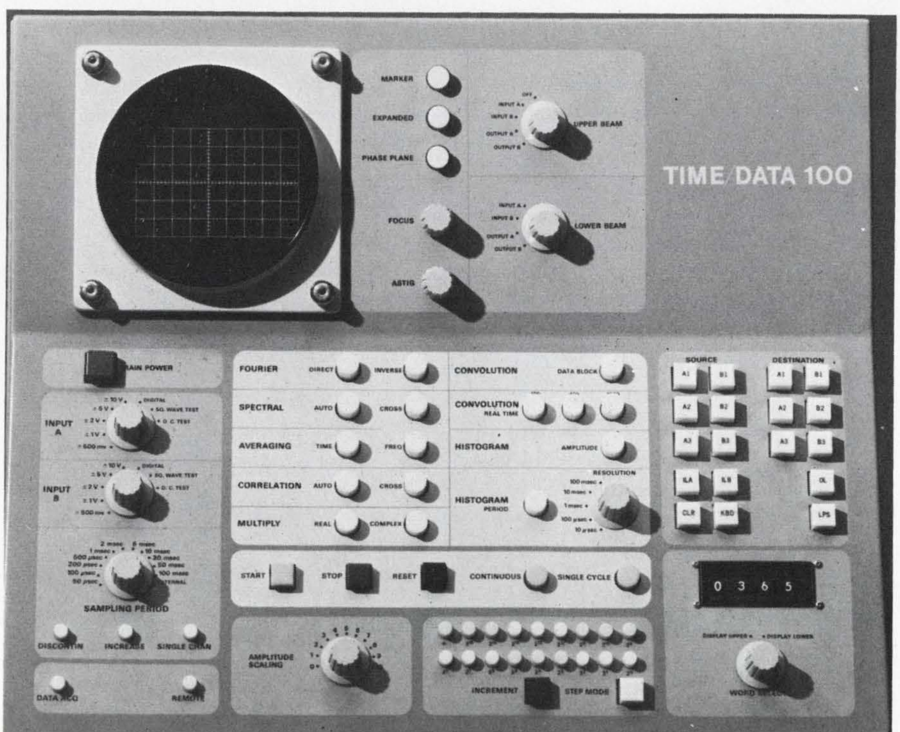
Some mathematical sleight of hand, called fast Fourier transforms (FFT), is revolutionizing the field of signal processing—from the audio range to microwaves. The underlying theory for many types of signal-processing systems is being reworked.

One small special-purpose digital computer designed to do real-time Fourier transforms is on the market and several more are on the way. The next round of military systems will make use of FFT black boxes for several purposes. Antisubmarine warfare, a field where the signals are audio and can be processed easily even by fairly slow processors, will be the first big user. The Sperry Gyroscope Co., of Great Neck, N.Y., for example, will include an FFT processor in its proposal for a new Navy antisubmarine aircraft, the VSX, when requests for bid are issued around the first of the year. IBM's Federal Systems Div., on another contract, has proposed an FFT processor capable of handling up to 90,000 thirteen-bit samples with 1024-point resolution.

But microwave applications may not be far behind. The Sylvania Electronic Systems Div. of Waltham, Mass., has built an FFT processor that will generate real-time transforms for signals ranging to 1 MHz. There is no inherent reason, except for cost at this point, why future designs could not push up the frequency limitation.

Why all this activity? The answer is that a machine that performs Fourier transforms in real time is a "missing link" for many types of systems engineers and for researchers in a broad variety of disciplines. Up to 1965, it took long, expensive, time-consuming runs on big digital computers to generate Fourier transforms for even a small time-slice of waveform. Because the transforms were so impractical to produce, the mathematical concepts of signal processing were based on power spectra. Workers in signal processing simply assumed that Fourier transforms were not feasible in systems applications.

Then, in 1965, J. W. Cooley of IBM Research Laboratories, and J. W. Tukey of Bell Telephone Laboratories and Princeton University, reported a programing technique that greatly reduced the computing time for Fourier transforms.[1] The old method required computer time proportional to N^2, where N samples of the waveform are to be converted into N spectral components. The Cooley-Tukey algorithm required computing time proportional to $N \log_2 N$. For $N = 1024$, this represents a computation that is over 100 times faster. As N gets even bigger, the savings get much greater. Furthermore the old method loses accuracy as N increased. The Cooley-Tukey algorithm retains its accuracy.



First commercial Fourier transform computer can generate a spectrum of 1000 complex values from 1000 samples in 1 second. The Time/Data 100 uses a variation of the FFT, called the Rapid Fourier Transform (RFT). The machine sells for $63,425.

A radical time-saver

It soon became apparent that Cooley-Tukey was far more than a programing aid. It suddenly made real-time Fourier transforms feasible. And the algorithm showed how a designer might design a set of microcircuit chips to do the necessary calculations.

A Bell Laboratories' experimental FFT processing system is the one that has been most completely described.[2]

The system includes a special-purpose FFT processor, an IBM 1800 process-control computer, and a graphic display system. The 1800 was chosen because of its ability to input, process and output data concurrently, and because of its programing flexibility and its multi-

(continued on p. 26)

What is the fast Fourier transform?

There are actually a number of mathematical tricks that are variations on the basic theme of the fast Fourier transform. Although the current wave of activity is based on the Cooley-Tukey algorithm,[1] it is agreed that some of the basic notions were worked out previously.[3, 4]

The continuous Fourier integral transform, familiar to all electronic engineers, is compared below with the discrete Fourier transform:

Continuous

$$F(\omega) = \int_{-\infty}^{+\infty} f(t) \exp(-2\pi i \omega t) dt.$$

Discrete

$$A_r = \sum_{k=0}^{N-1} X_k \exp(2\pi irk/N)$$

$$= \sum_{k=0}^{N-1} X_k W^{rk}$$

where: $i = \sqrt{-1}$

$W = \exp(2\pi i/N)$

N = number of samples

r = harmonic number = $0, 1, \ldots, N\text{-}1$

k = time-sample number = $0, 1, \ldots, N\text{-}1$

Thus, A_r is the r^{th} coefficient of the Fourier transform. X_k is the k^{th} sample of the time series.

This discrete transform involves a couple of assumptions. Equal spaced time samples are assumed. Also the sampling rate must be above the Nyquist rate, that is, at twice the frequency of the highest frequency in the waveform being sampled. When these criteria are met, the discrete Fourier transform has parallel properties to the continuous transform. The original waveform can be completely recreated from the samples. Transformations between the time and frequency domains are performed by using the discrete transform and its inverse.

The samples, X_k, may be complex, and the coefficients, A_r, are almost always complex.

Working through an example in which $N = 8$ will illustrate some of the calculation short cuts.*

In this case: $j = 0, 1, \ldots, 7$

$k = 0, 1, \ldots, 7$

To put these into binary form:

$$j = j_2 (2^2) + j_1 (2^1) + j_0$$

$$k = k_2 (2^2) + k_1 (2^1) + k_0$$

where: $j_0, j_1, j_2, k_0, k_1, k_2 = 0, 1$

Thus:

$$A(j_2, j_1, j_0) = \sum_{k_0=0}^{1} \sum_{k_1=0}^{1} \sum_{k_2=0}^{1} X(k_2, k_1, k_0)$$

$$[(k_2, k_1, k_0)\ W^{(j_2 4 + j_1 2 + j_0)(k_2 4 + k_1 2 + k_0)}]$$

Now the W can be broken down further:

$$W^{(j_2 4 + j_1 2 + j_0) k_2 4} = [W^{8 (j_2 2 + j_1) k_2}]\ W^{j_0 k_2 4}$$

$$W^{(j_2 4 + j_1 2 + j_0) k_1 2} = [W^{8 j_2 k_1}]\ W^{(j_1 2 + j_0) k_1 2}$$

$$W^{(j_2 4 + j_1 2 + j_0) k_0} = W^{(j_2 4 + j_1 2 + j_0) k_0}$$

Since $W^8 = [\exp(2\pi i/8)]^8 = \exp(2\pi i) = 1$, the bracketed terms equal one, and can be dropped from the computation. (Note that $[\exp(2\pi i)]^2 = 1^2 = 1$.) This saves many calculations.

This leaves the expression at the bottom of the page. Note that as each summation proceeds, one of the k terms becomes a dummy variable.

Then $A(j_2, j_1, j_0)$ can be obtained by sequentially calculating the Xs as follows:

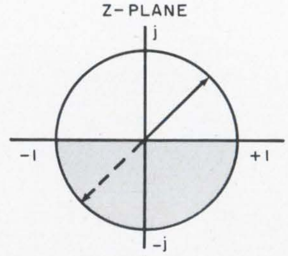
$$X_1 (j_0, k_1, k_0) = \sum_{k_2=0}^{1} X(k_2, k_1, k_0) W^{j_0 k_2 4}$$

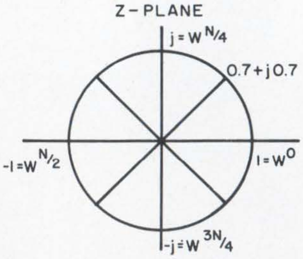
$$X_2 (j_0, j_1, k_0) = \sum_{k_1=0}^{1} X_1 (j_0, k_1, k_0)\ W^{(j_1 2 + j_0) k_1 2}$$

$$X_0 (j_0, j_1, j_2) = \sum_{k_0=0}^{1} = X_2 (j_0, j_1, k_0) W^{(j_2 4 + j_1 2 + j_0) k_0}$$

$$A(j_2, j_1, j_0) = X_3 (j_0, j_1, j_2)$$

Once these computation savings were found, even more savings were spotted. For example, the W or weighing values, have an equal but negative value. This means that the lower half, or shaded portion of the circle (below), can be eliminated from the computation, since those values produce the same complex values differing only in sign.





Other symmetries also exist. The major axis values are exploited by using a base-4 rather than a base-2 radix. The symmetries in the 45-degree axes can also be used, (circle at the right.)

$$A(j_2, j_1, j_0) = \sum_{k_0=0}^{1} \sum_{k_1=0}^{1} \underbrace{\sum_{k_2=0}^{1} X(k_2, k_1, k_0) W^{j_0 k_2 4}}_{X_1 (j_0, k_1, k_0)} W^{(j_1 2 + j_0) k_1 2}\ W^{(j_2 4 + j_1 2 + j_0) k_0}$$

$$\underbrace{\qquad\qquad}_{X_2 (j_0, j_1, k_0)}$$

$$\underbrace{\qquad\qquad}_{X_3 (j_0, j_1, j_2)}$$

*Derivation based on private communication from G. D. Bergland of Bell Laboratories.

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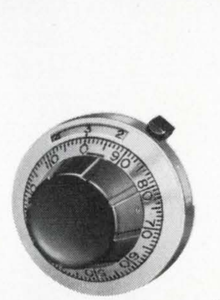

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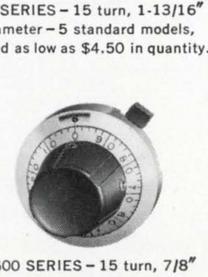

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NEWS

(**FFT computers,** *continued*)

plexing of analog inputs. The 1800 has nine data channels with independent address registers that operate concurrently, only stealing memory cycles. The core memory stores 32,000 sixteen-bit words.

The FFT processor itself has two memories. A table memory stores weights, or sine and cosine values, and a record memory stores inputs, intermediate values and final results.

The system is capable of operating on several independent audio-frequency signals simultaneously. The sine-cosine weighting values required in the FFT processor are pre-computed to increase accuracy and to save time. The data or record memory, a 1-microsecond-cycle-time store for 8192 words, holds intermediate values generated as the computation proceeds.

Although the Bell Laboratories processor is essentially a fixed-point machine, researchers there refer to it as a "poor man's floating-point" computer. This is because it checks the immediate values before a set of multiplications takes place. If it finds that any single multiplication will result in an overflow, it divides the entire array by two and maintains a record of this to derive a common scale factor for the results.

The first commercial machine is the Time/Data 100, which uses a modified approach to computation called the rapid Fourier transform (RFT).

The RFT is actually designed by use of a modified version of a method for computing Fourier transforms. The method, which preceded the Cooley-Tukey approach, was developed for hand calculation of Fourier coefficients for X-ray diffraction studies of liquids. It was published by G. C. Danielson and C. Lanczos in 1942.[3] Details of the modified procedure are not available, because the Time/Data Corp., Palo Alto, Calif., has applied for patents on its approach.

There was a good reason for using this approach rather than the Cooley-Tukey algorithm, according to Edwin Sloane, vice president of Time/Data Corp. and conceptual designer of the machine. "Our approach," he says, "does not suffer from the cumulative error inherent in the nested multiplication used in the Cooley-Tukey approach."

A small, fast general-purpose computer just introduced by Sylvania Electronic Systems of Waltham, Mass., has been used to do Fast Fourier Transforms. This Advanced Computational Processor has a 0.125-μs, nondestructive-read-out, integrated-circuit memory. It can do a Fourier transform on 246 samples in 8 to 8.5 ms, according to Dr. Edmund Cohler, manager of Sylvania's Computer Research Dept.

A much faster machine, capable of handling signals up to 1 MHz, has been built in prototype under the supervision of Joseph Fisher, manager of the Digital Signal Processing Dept. of Sylvania's Eastern Div.

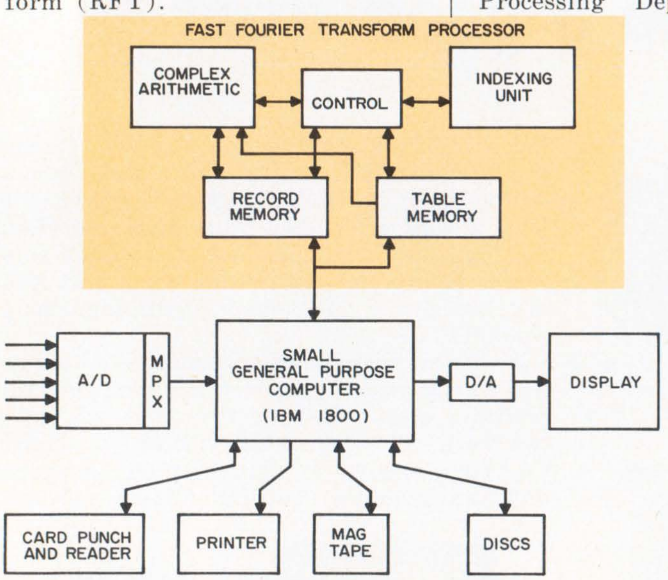
The key to the high speed, Fisher says, is that a mechanization of the Cooley-Tukey algorithm has been accomplished with a single memory.

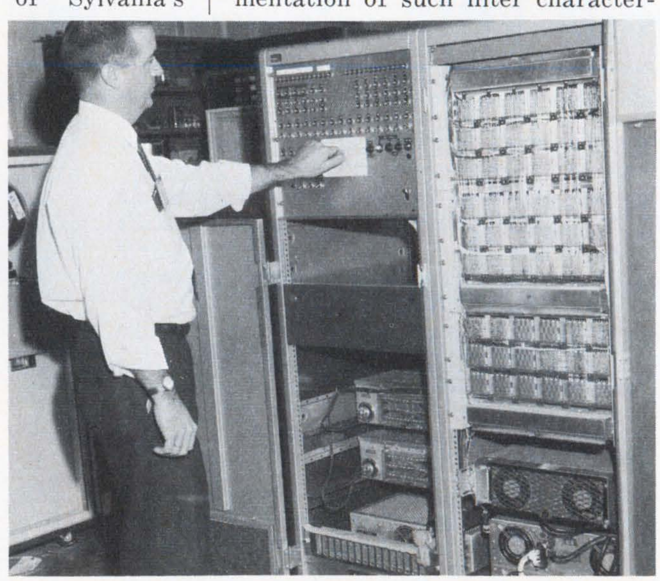
Fisher predicts that Sylvania and other manufacturers will go much higher in speed with future FFT computers. Two radar applications that he cited are pulse-compression and side-looking radar.

In pulse compression a fairly long radar pulse—coded in some manner, such as by frequency sweeping or by digital coding—is transmitted. Then any return pulse is fed into a matched filter, which performs a cross-correlation between the return pulse and the transmitted pulse. When there is a perfect "match" between the two, an output pulse is generated; otherwise the filter output is near zero. This greatly increases the radar resolution, since two objects close together in range would generate separate pulses.

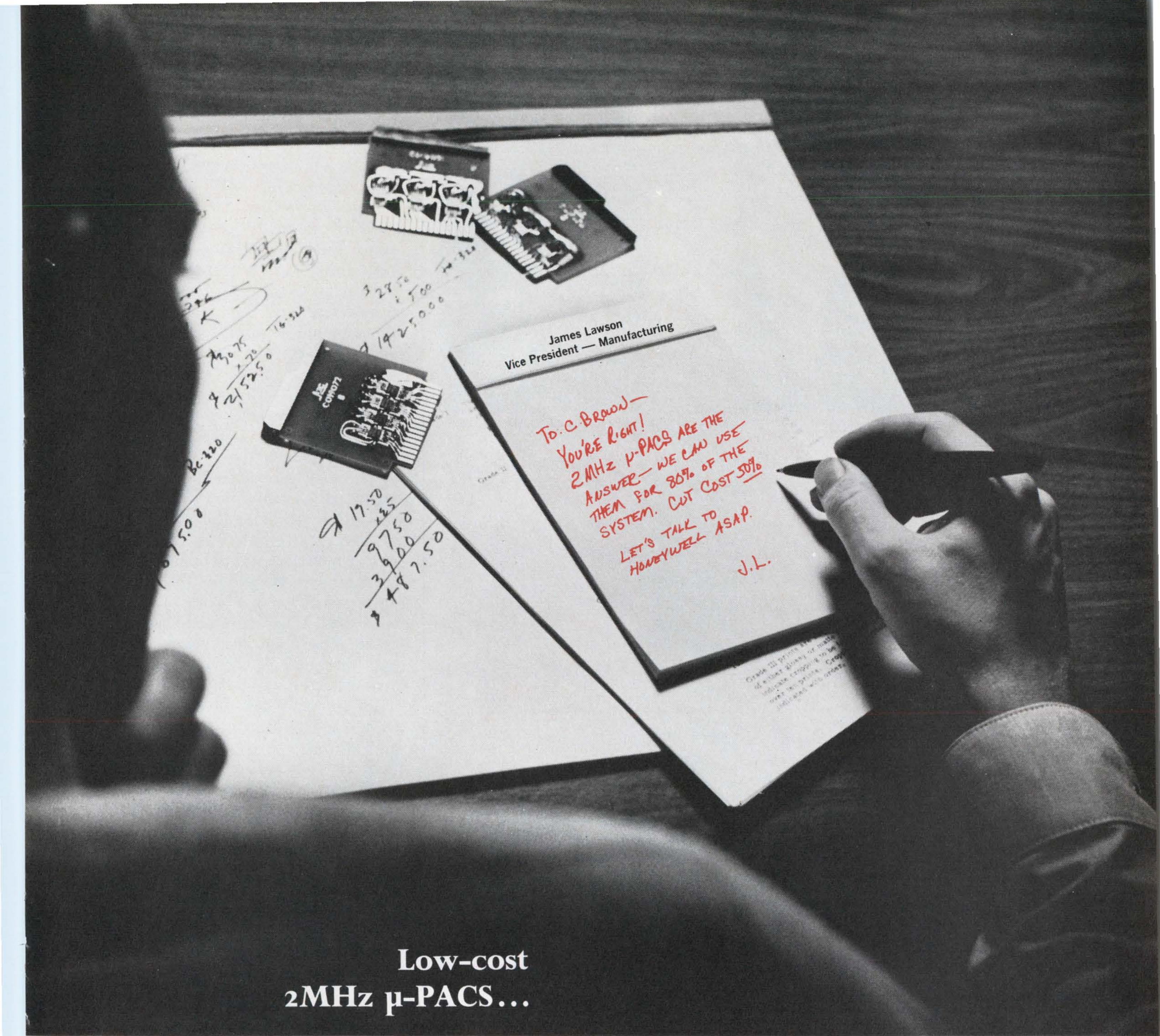
This matched filter characteristic can be implemented digitally within a fast Fourier transform computer. It is the Fourier transform of the impulse response of the matched filter. When this transform is multiplied by the Fourier transform of the return pulse, the cross correlation is performed.

Analog filters suffer from drift. Also they are tricky to design, and once designed, they have fixed characteristics. The digital implementation of such filter character-





Bell Laboratories' experimental FFT processing system includes an IBM 1800 process control computer. It can calculate the Fourier transform of 1024-samples in 30 milliseconds. FFT processor is at right.



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(**FFT computers,** *continued*)

istics by a FFT computer allows any desired variation, and there is no drift problem.

In side-looking radar systems, an FFT computer could do in real time the computation task now performed by a combination of an optical and film system and by computers on the ground. The same techniques might be used in side-looking sonar to produce real-time displays of bottom terrain.

FFT processors could be used in several ways in antisubmarine systems. In passive sonar the sounds of quiet submarines could be detected and recorded. The sampled signal thus obtained might be treated by taking the logarithms of all vaues. This serves to emphasize fundamental frequencies and to diminish the values of higher harmonics. Then a Fourier transform of this new log-series is taken. The result is known in signal processing circles as "cepstrum" made up of "quefrencies."

Then a matched filter characteristic could be digitally synthesized and stored.

In active sonar, a system designer might take Fourier transforms of natural ocean sounds, such as those of whales and dolphins, and from these synthesize sonar emissions that could not be detected, as the normal "ping" would be, by an approaching submarine.

Frequency sweeping of the type required in electronic countermeasures equipment can be implemented with FFT computers. Digital vocoders can be built in which pitch extraction, a vital step in good reproduction of a voice, is achieved by use of an FFT computer. ■■

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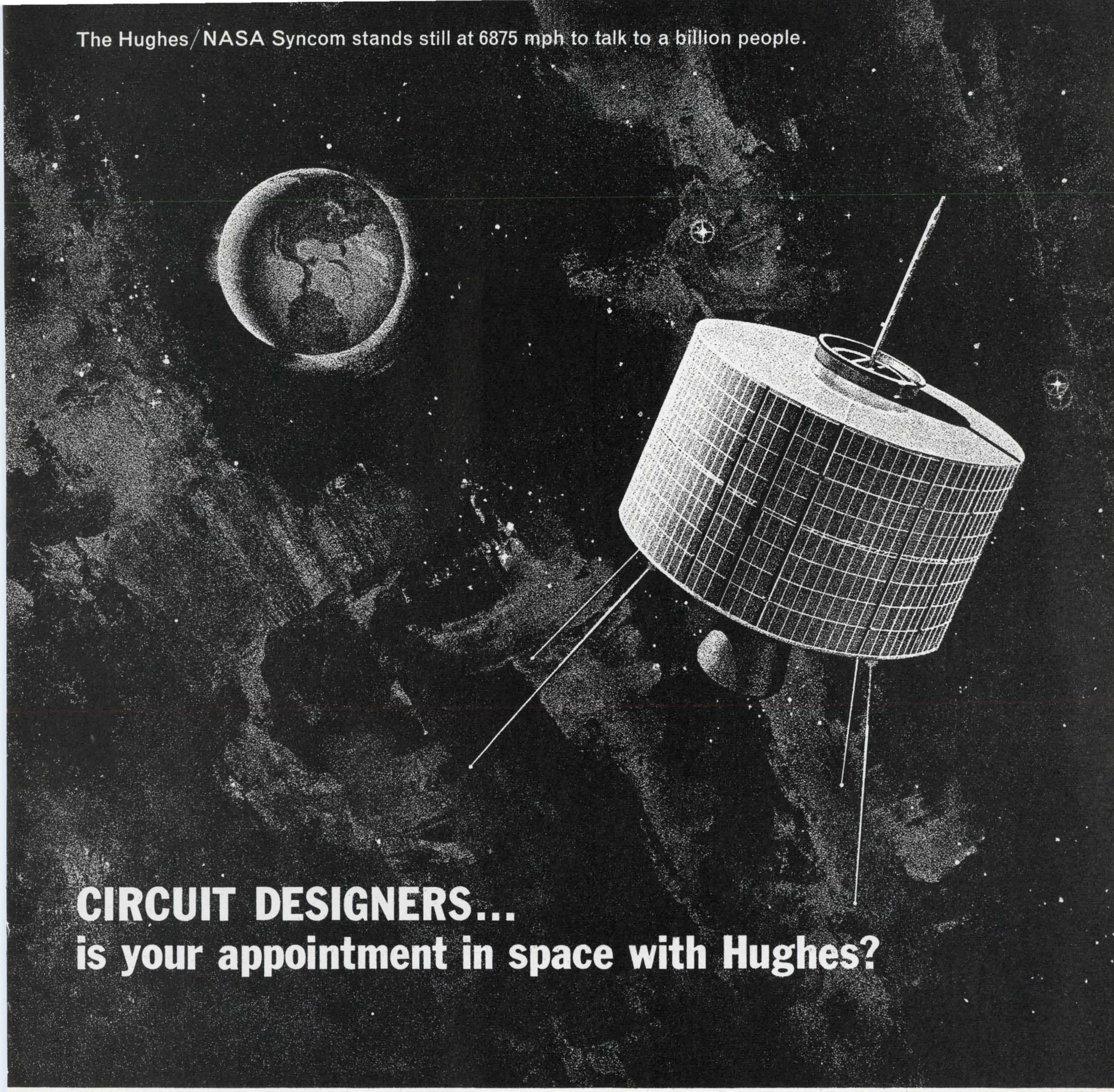
4. I. J. Good, "The interaction algorithm and practical Fourier analysis," *J. Roy. Statist. Soc.*, Ser. B, XX, 1958, 361-372; Addendum, XXII, 372-375.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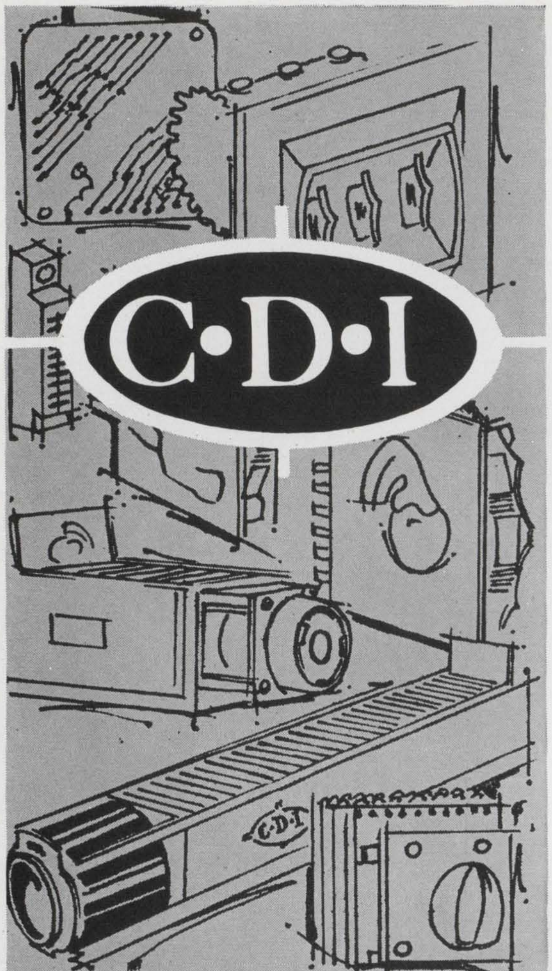
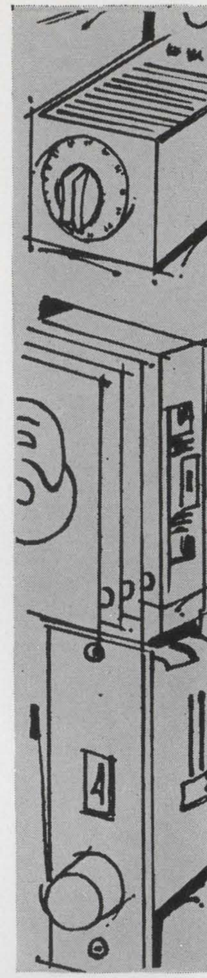


PRECISION SWITCHES



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Digital & Binary. Meet MIL-S-22710.

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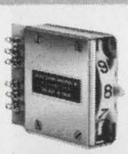

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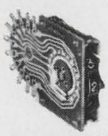

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CDI patented switches with dust covers are available in sizes 2" x 2", 3" x 3", and 4" x 4" with lengths to accommodate up to 36 wafers. Switches can be customized to your specifications.

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ON READER-SERVICE CARD CIRCLE 24

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ON READER-SERVICE CARD CIRCLE 25

Civilian markets beckon microwave ICs

But military research still dominates as designers seek the best approaches to economical devices

Neil Sclater
East Coast Editor

Several years from now, underdeveloped countries unable to afford telephones may find a convenient substitute: small, light microwave terminals for voice communications. Cheap enough to be mass-produced, they could be set up easily and carried by one man.

Factories everywhere may get new low-cost supervision and control aids for their machine operations: microwave measurement systems that could determine motion to an accuracy of 0.0002 inch.

These applications and more are envisioned by microwave integrated-circuit manufacturers as they press their present development programs for the military. Microwave technology is being revolutionized by the introduction of integrated circuitry. But because of special problems, miniaturization at microwave frequencies has, for some time, trailed the advances being made at lower frequencies. This gap is being closed rapidly, however.

Recent gains were noted at this fall's International Electron Devices Meeting in Washington. In describing the optimism with which manufacturers view the future, Tom C. Hyltin, manager of the microwave products branch at Texas Instruments, Dallas, said the microwave "telephone" for underdeveloped countries could be set up this way:

"Two stations, each containing about a dozen low-frequency and microwave integrated circuits, can establish a two-way voice-channel communication link over several miles. With these few circuits, the cost will be less than that for building an open telephone line across the same distance. The time-to-failure of the microwave link will be longer than the time-to-failure of the open telephone line.

"A slightly more complex version of these stations could provide 10 or 15 channels over 10 or so miles. Powered by solar cells and storage batteries, these stations could provide emerging nations with economical and reliable communications in powerless areas."

Automatic measuring envisioned

As for the microwave measurement system of the future, Hyltin said:

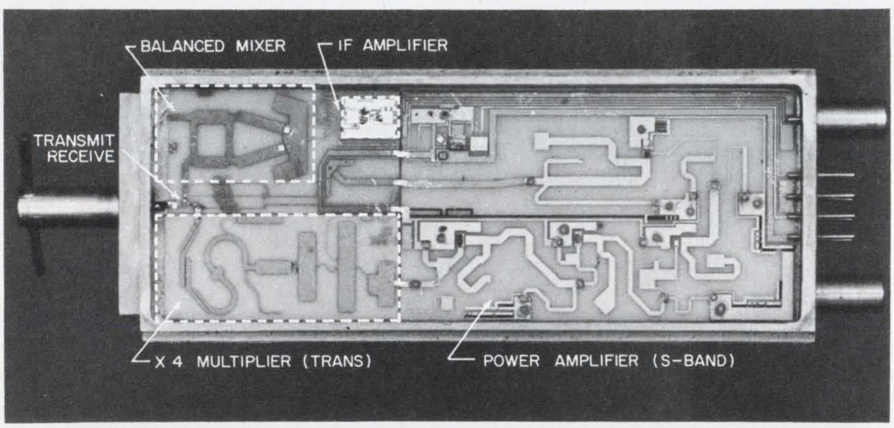
"Using a 94-GHz interferometer, the position of a tape-controlled milling machine table could be determined automatically, without backlash, to an accuracy of 0.0002 inch through several feet of travel."

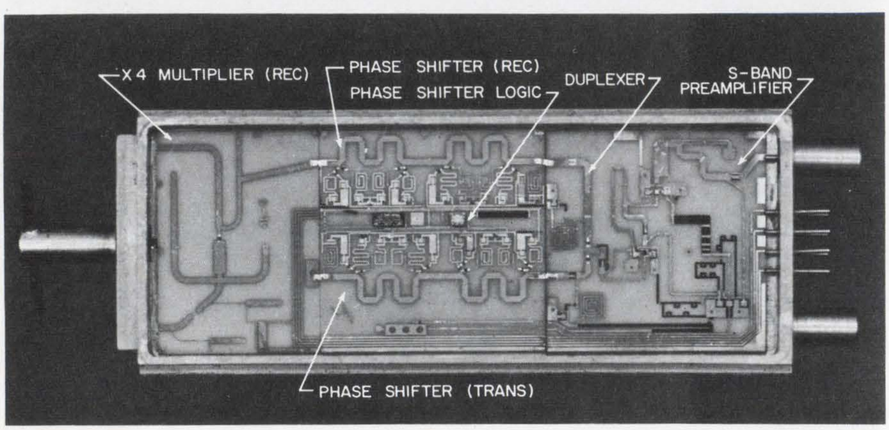
Up to now, the barriers to fuller miniaturization at microwave frequencies have included:

- Incomplete knowledge of the transmission-line characteristics suitable for integrated circuits.
- Lack of satisfactory solid-state active components.
- Difficulties in controlling and using the distributed inductive and capacitive effects that turn up in circuitry whose dimensions are close to those of the wavelengths propagated.

Hyltin says these problems have been largely solved; other industry sources tend to be more cautious. But the trend is forward.

Present work to push up the upper frequency limits of integrated circuitry has been largely devoted to miniaturizing radars. In addition to a major program to create small reliable modules for an all-





A wide range of microwave integrated circuits is shown on both sides of this phased-array module built by Texas Instruments (output side top, input side below). Many of these circuits could be adapted for commercial microwave applications. Individual circuit substrates are mounted back-to-back on the approximately 2-1/2-by-1-inch mounting plate. Most are thin-film hybrids.

solid-state airborne phased-array radar, other efforts aim to furnish miniature component replacements for existing radars. These programs will furnish circuitry that will be useful for all microwave applications. They will lead to the solution of many materials and design problems.

"Microwaves have been limited in the past to select applications where their high cost could be justified," Hyltin says. Equipment to generate and detect at microwave frequencies has cost up to 10 times more than the cost of performing similar functions at audio, ultrasonic, infrared and lower radio frequencies.

Microstrip key to design

Microwave integrated-circuit devices have been built that operate successfully at frequencies up to 94 GHz. The designs are based on microstrip transmission lines that are formed by metal film printing, deposition and plating techniques on dielectric substrates. The designer has computer-aided design programs to help remove the trial and error. He has the option of forming active and passive devices as part of a complete fabrication process, or of attaching the devices after the microstrip is formed. His choice depends on the complexity of the circuitry desired, the economics of development and production, and, to some extent, the operating frequencies.

Fabrication techniques for microwave microcircuits now are much the same as those for lower-frequency integrated circuits: thick-film hybrid, thin-film hybrid and monolithic.

Hybrid techniques used

The thick-film hybrid circuits use thick conductive coatings bonded to insulating substrates, and they are comparable to conventional printed circuits. The microstrip transmission lines are usually silk screen printed on a porous ceramic substrate and fired so that the metal film becomes part of the substrate.

Passive and active devices are bonded, or "outboarded," to the substrate. Films range from tenths of a mil to several mils in thickness. This category also includes metallic films on a wide variety of other insulating materials, including Teflon and epoxy board. Most microwave-circuitry today is made by this technique.

Thin-film hybrid circuits generally use depositions of several layers of metallic and dielectric films on dielectric substrate to form all the passive circuitry. Other deposition techniques permit more precise formation of microstrip transmission lines, components, capacitors and resistors. Capacitors are typically in the range of 0.5 to 1.0 pF/mil,[2] and resistors, 10 to 100 Ω square.

Masking during deposition, or selective etching after deposition, is used to achieve the desired network topology. The substrates used in this technique are nonporous — glass, glazed ceramic, quartz or silicon, for example. Active devices, however, are bonded to the circuit in chip form, as in thick-film hybrids.

The monolithic approach makes use of masking, deposition and diffusion, etching and growth techniques. Both active and passive devices are formed as part of the complete process.

Application dictates technique

Probably the most ambitious microwave microcircuitry is intended for use in phased-array radars. One program is developing integrated circuits for an airborne terrain-avoidance radar. The circuits are assembled in miniature modules that are effectively miniature radars. Each consists of power and i-f amplifiers, frequency multipliers, a TR switch, balanced mixer, modulator, phase shifters and phase-shift logic.

For proper formation of a radar

Microstrip: The basis for microcircuitry

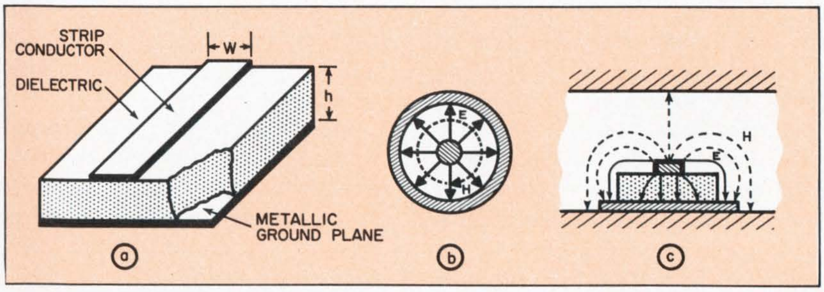
A form of transmission line known as microstrip (a) is used in most microwave integrated circuits because it can be easily formed by printing and deposition methods. It is a flat center conductor, separated from a ground plane by a dielectric material. It has impedance transfer properties that permit the designer to form many waveguide and coaxial cable components in microcircuitry, such as filters, transformers, couplers and cavities.

To take advantage of the properties of microstrip, the designer must know three parameters: characteristic impedance, wavelength on the transmission line, and the attenuation.

Propagation along microstrip, however, is not in a mode as pure as that found in either coaxial cable or waveguide, thus complicating the designer's problem. It is similar to the transverse electric magnetic mode (TEM) found in coaxial cables (b). A popular microstrip configuration (c) shows that there is an appreciable amount of fringe capacitance that propagates microwave energy. Also, the boundary between the high dielectric substrate and the surrounding material is indefinite.

Useful formulas have been derived to relate microstrip's characteristic impedance and wavelength to the ratio of conductor width (W) to dielectric height (h).

In the case where the dielectrict constant (ε_r) of the substrate equals 10 and both the width of the conductor and thickness of the substrate are 20 mils (thus making $W/h = 1$), the wavelength in microstrip is reduced by a factor of 2.46. This is slightly longer than the wave length for a pure TEM mode with the same dielectric.



(**Microwave ICs,** *continued*)

beam, the amplitude and phase transfer characteristics of all modules must be identical. This requirement for uniformity, along with consideration for the thousands of modules that must be produced, has encouraged serious consideration of automated production methods.

Texas Instruments, as part of its MERA (Molecular Electronics for Radar Applications) program for the Air Force, has developed these complex modules for evaluation. Economic and technical difficulties have ruled out the monolithic approach, so that the modules in their present form are thin-film hybrids, with both monolithic and discrete circuit devices bonded to glazed alumina ceramic substrates. Texas Instruments assembles the various circuit substrates back-to-back in a module frame, complete with connectors and adaptors.

The MERA program, is being supported by the Avionics Laboratory at Wright-Patterson Air Force Base, Ohio.

Integrated-circuit phase shifters and phase-shift logic have been developed by a number of organizations, including Bell Telephone Laboratories of Murray Hill, N.J., and Microwave Associates of Burlington, Mass., for possible use in large-scale, ground-based phased arrays.

Another representative application for microwave microcircuitry is a front end for an airborne X-band weather radar. The Army's Electronics Command at Fort Monmouth, N.J., wants it to replace a heavy, bulky waveguide-and-vacuum-tube assembly, so it can fit a standard weather radar on light reconnaissance aircraft.

Less ambitious than a MERA module, this design provides only preamplification, mixing and local oscillator functions. However, the Army will make practical use of this development in the very near future. The developer, Microwave Associates, has built workable models despite initial difficulties.

Vladimir Gelnovatch, who designs ICs and supervises microwave IC development contracts for the Army Electronics Command, recently reviewed some of the current design problems.

He said that the designer, in choosing the method for making the microcircuit, considers the numbers and types of active and passive components that he wants on the substrate, the function of the circuit and, to some extent, the operating frequency.

Breadboards point way

Preliminary designs are frequently built with a variety of techniques as thick-film breadboards, the Army engineering supervisor said. Most designers, he added, use computers to assist in the design. The computer offers optimum solutions for active and passive circuit elements and microstrip.

Many manufacturers, he said, have programs that will permit their designers to feed in noise figure, gain, and bandwidth and have the computer search for the microstrip network that will yield the desired characteristics.

Some circuits, particularly at uhf and L band, may remain thick-film hybrids, Gelnovatch said, because it is more economical to "outboard" both active and passive devices. In addition there is the possibility of higher yields than with other methods. On the other hand, he said, where the quantity of circuits is great enough to justify it, the breadboard designs may be advanced to thin-film hybrids. In these cases it usually is desirable to include the fabrication of passive elements, particularly resistors and capacitors, in successive deposition operations.

Active elements bonded

Provision is made in the circuit design for the bonding of such active elements as diodes and transistors and for complete monolithic chips for i-f amplification and phase shifting.

The more complex passive elements, such as circulators and inductors, may also be outboarded or built up by various deposition techniques.

Most engineering work in microwave ICs is directed toward including as many active and passive devices as are economical and practical in the manufacturing process, Gelnovatch said.

"All waveguide and coaxial components have now been synthesized in microstrip with electrical performance more or less equal to the original components," he noted. These include matched loads, filters, hybrid rings, couplers and transformer sections.

The decision to use the monolithic approach is based on two engineering considerations, Gelnovatch said.

The first takes into account materials that can be used. To minimize electrical losses and to eliminate processing problems, the substrate and the active device should be made from the same material. However, the best dielectric substrate materials are not necessarily the best for active devices.

The second consideration is the high cost of gearing for monolithic production. The quantities to be produced must be great enough to justify the additional expense and must cover the cost of expected higher production losses.

"Calculations have shown that semi-insulating gallium arsenide and silicon of resistivity greater than 1000 Ω/cm have a loss sufficiently low to fabricate microcircuitry," Gelnovatch said.

Texas Instruments, for one, reports that in addition to 500-MHz amplifiers, it has made X-band balanced mixers and TR switches, using silicon as a substrate.

Hyltin reports that a number of basic problems must be solved when monolithic techniques are used. He lists these as:

- Conductivity modulation of the silicon substrate by dc currents. This introduces rf leakage to the ground plane and leads to excessively high insertion loss.
- Difficulty in obtaining low resistance contacts between the microstrip conductor and active devices.
- Unwanted diffusions of metals into the substrate, as a result of high processing temperatures. ■■

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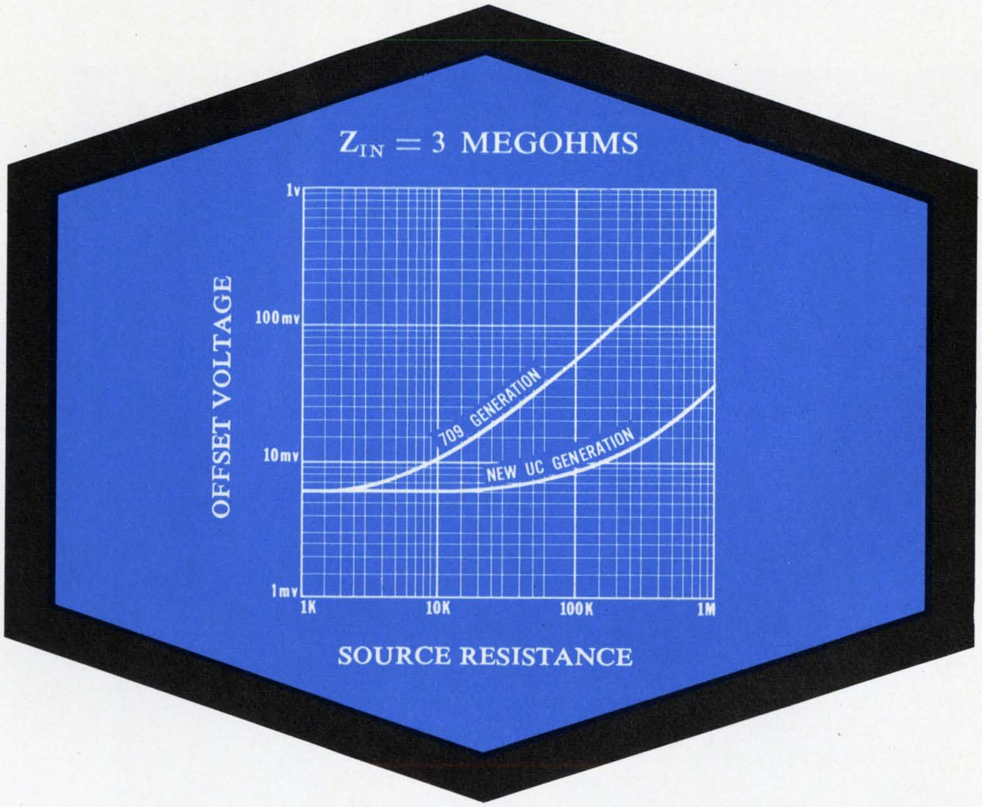
Hyltin, T. "Microstrip Transmission on Semiconductor Dielectrics," *IEEE Trans. on Microwave Theory and Techniques*, Vol. MTT-13, No. 6 (Nov. 1965), 777.

Wheeler, H. A. "Transmission Line Properties of Parallel Strips Separated by a Dielectric Sheet," *IEEE Trans. on Microwave Theory and Techniques*, Vol. MTT-13, No. 2 (March 1965), 172.

New Generation



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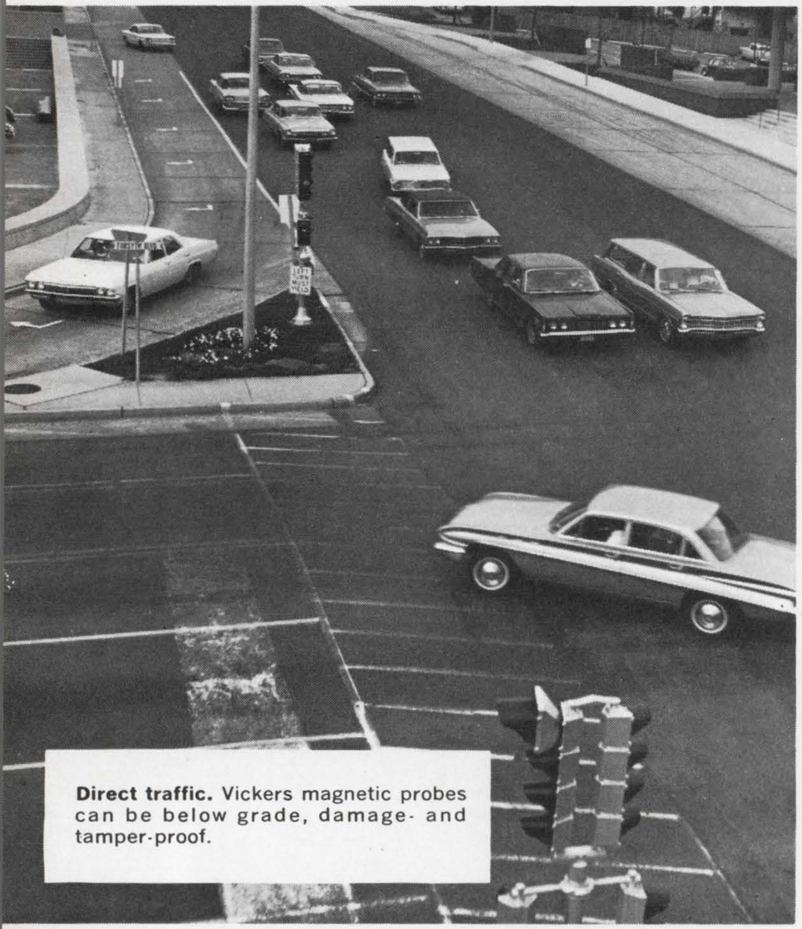

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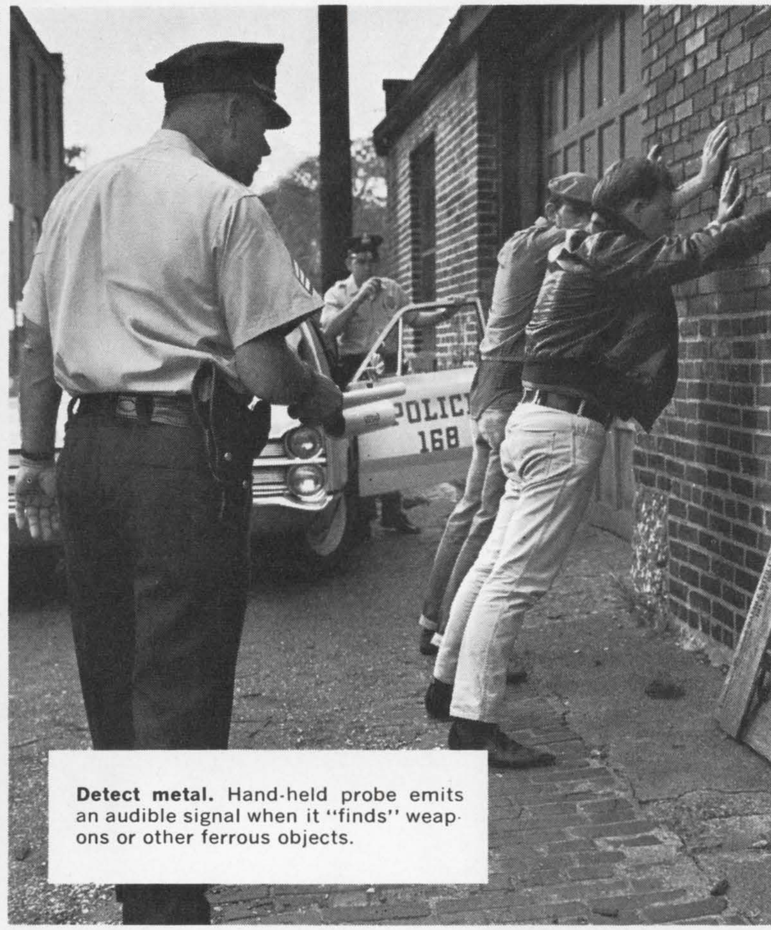
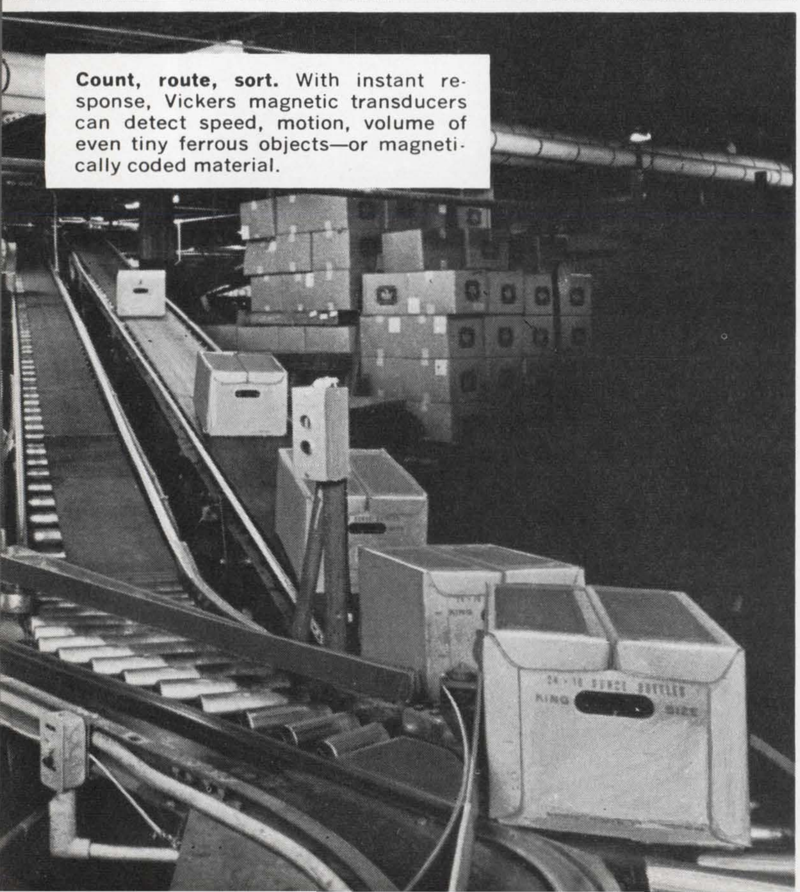
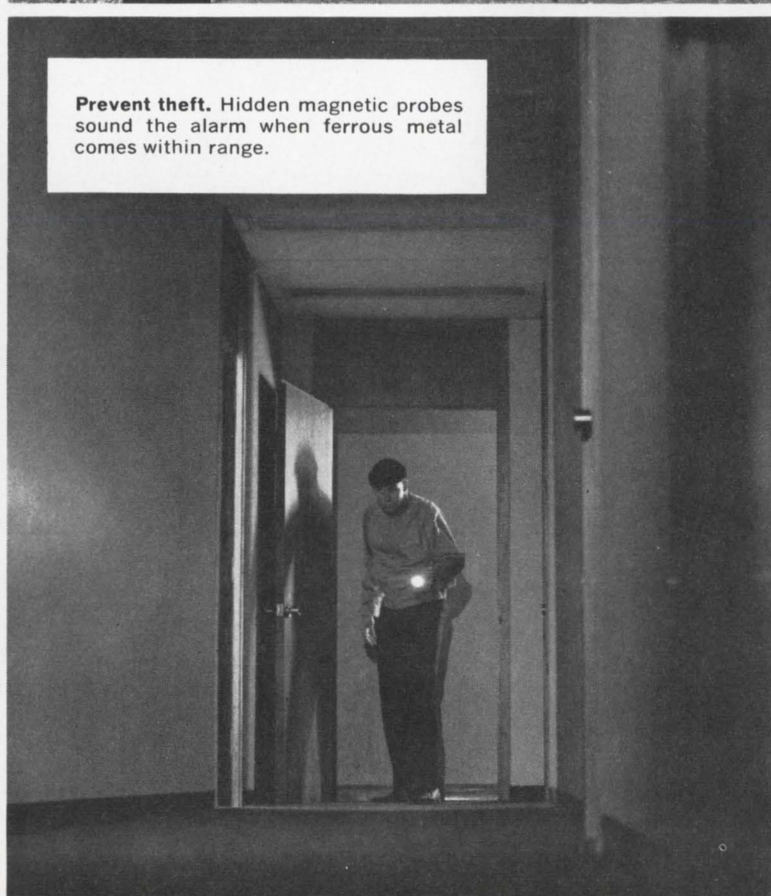


Detect metal. Hand-held probe emits an audible signal when it "finds" weapons or other ferrous objects.



Count, route, sort. With instant response, Vickers magnetic transducers can detect speed, motion, volume of even tiny ferrous objects—or magnetically coded material.



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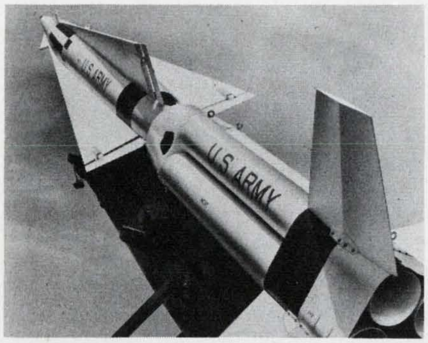
ON READER-SERVICE CARD CIRCLE 27

Congressman sees Soviet ICBM danger



Washington Report

CHARLES D. LAFOND
WASHINGTON BUREAU

ICBM parity predicted by 1970

With clarity and frightening logic, Rep. Craig Hosmer (R-Calif.) gave to the House, and later to the Subcommittee on Military Applications, a statement describing the present and future balance of strategic power between the U.S. and the Soviet Union.

On the basis of Pentagon statistics on U.S. and Soviet strategic-missiles strengths, Rep. Hosmer predicted that the U.S. total of 1454 land-based ICBMs and on-station sea-launched IRBMs could be surpassed by the Soviet Union by 1970. The U.S.S.R. could then have 1540 comparable missiles at its present rate of adding 300 weapons a year to its arsenal. He cited these estimates as evidence that Defense Secretary Robert S. McNamara's reliance on massive retaliation to destroy Soviet war capability completely was not necessarily sound. Present U.S. deployment plans count on 1054 operational land-based missiles and approximately 400 of the nation's 656 Polaris or Poseidon missiles to be on station at all times. Since these figures are to be essentially stable between now and 1970, said Hosmer, it can be presumed that parity will occur. It can also be assumed, he said, that, as Soviet technology improves, missile accuracy will fall within a 2000 foot CEP (circular error probability). Based on these figures, he reported that the Rand Corp.'s "bomb damage effect computer" had calculated a 92 per cent destruction probability from a first Soviet strike at U.S. land-based ICBMs—that is 970 of the 1054 would be destroyed leaving only 84 missiles available for retaliation. Of the 25 Polaris submarines at sea, 79 per cent should survive, leaving 316 missiles available for use.

Of the 400 surviving missiles, 200 might get through to their targets if the Soviet ABM defense is only 50 per cent effective. Hosmer estimated the total actual damage to the Soviet Union would be only 16.8 per cent: it would not be totally incapacitated. He then pointed out that purges of the Thirties accounted for up to 15 per cent of the Soviet population and in World War II the Russians lost 40 per cent of their industrial capacity, yet the U.S.S.R. survived. A 16.8 per cent loss would be a "bargain basement price for world domination," Hosmer declared.

FOBS impact only partially disclosed

Defense Secretary Robert S. McNamara's recent announcement of the Soviet FOBS (Fractional Orbital Bombardment System) development revealed only part of the military capability of such a weapon, Rep. Hosmer told the House. McNamara stressed the dubious role of FOBS for attacking U.S. manned bombers on the ground; Hosmer pointed up two other major missions: the destruction of Sentinel acquisition radars, and the destruction of retaliatory U.S. ICBMs in their silos.

Full details of the Russian Scrag were given in a May 29, 1967, issue of the *Washington Report* of the American Security Council by Dr. Stefan T. Possony, director of the Hoover Institution on War, Revolution, and Peace at Stanford University. Possony stated that FOBS's Scrag (roughly meaning garrote in Russian) warhead in orbital configuration could be in the 30-megaton class. McNamara insisted, however, that Scrag orbital-warhead yields are only in the one-to-three-megaton range.

More importantly, Possony suggested that Scrag could offer a three-pronged attack capability: as a conventional ICBM with up to a 50-megaton warhead, as a fully orbiting space bomb, or as a fractional orbiting weapon with a 30-megaton warhead. There is also no reason to believe that any of these weapon configurations might not be provided with 20 to 30 multiple warheads or that these might not be capable of maneuvering after separation. Scrag, he declared, "provides the Soviets with a genuine capability to hit every spot on earth with very short notice." High-altitude, high-yield explosions by suborbital or orbital Scrags detonated sequentially could establish and maintain an X-ray screen and could keep U.S. electronics and communications inoperable, Hosmer said. Scrag, he emphasized, represents the the first genuine global weapon.

Need for on-board processing critical

NASA's Goddard Spaceflight Center at Greenbelt, Md., is pressing development of a standardized spacecraft digital processor, to help reduce the incredible problem posed by the masses of data currently received at ground stations from scientific satellites. A three-module unit to perform in-orbit reprograming and high-speed instruction execution, under development by the Space Electronics Branch, includes a central processor memory unit and an input/ouput device.

The plated-wire, random-access memory unit of the 18-bit processor is being built for Goddard by the Librascope Group of General Precision, Inc. Considered the heart of the processor, it combines woven-wire and nondestructive readout techniques with power switching to obtain a word cycle time of 2 microseconds at a power dissipation of 6 to 7 watts. The memory may contain up to eight storage modules with each six-pound unit having a capacity of 8192 eighteen-bit words. Power does not increase with added modules.

The central-processor module employs low-power integrated circuits, requires 5 watts, and weighs about 4 pounds. The input/output module interconnects all applicable spacecraft sensors and electronic subsystems with the memory unit.

Apollo systems pass rigorous test

The highly intricate mission of the recent Apollo/Saturn V test flight provided a comprehensive and practical exercise for the Apollo guidance and control systems. Both apparently lived up to expectations. During the early part of the mission, the guidance system in the Saturn V vehicle was in control with the Apollo guidance system serving as a continuous monitor and backup system.

Following the second burn of the Saturn's third-stage engine, to boost the Apollo into the long, 11,330-mile elliptical orbit, and that stage's separation from the Apollo spacecraft, the Apollo guidance and control system took over. Working together, the AC Electronics guidance and navigation system and the Honeywell stabilization and control system provided steering and attitude orientation, service engine iginition, and full control for reentry sequences.

The flight profile was intricate and provided the first attempt at skip reentry. After four hours in the elliptical orbit, the service engine fired, boosting speed to 25,000 mi/h for the earth-atmosphere intercept. At about 400,000-ft altitude a partial reentry was effected and then the spacecraft skipped back out of the atmosphere, simulating the method that would be used on return from a lunar mission to reduce spacecraft velocity. The planned full reentry brought the spacecraft down within six miles of target in the Pacific. The near perfect launching may result in the first manned Apollo flight's being moved up from some time in 1969 to late next year.

EIA to review foreign electronic market

A new monthly publication by the Electronic Industries Association will be available hereafter on a subscription basis to provide marketing data on a country-by-country basis. It will review trends in worldwide trade in electronics and analyze the current state of business within individual nations, EIA disclosed.

The first issue carrying an October date covered Sweden; November and December editions will cover Japan in a two-part series. The report, called *Electronic Trends/International,* will regularly provide up-to-date information on all nations previously reported in depth, EIA said. Subscriptions are available from EIA's Marketing Services Dept., 2001 Eye Street, N.W., Washington, D.C. 20006, at $250.00 per year.

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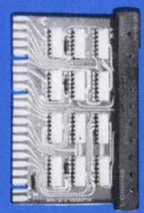

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ON CAREER-INQUIRY FORM, PAGE 111, CIRCLE 909

AN ELECTRONIC DESIGN SPECIAL REPORT

Dolphins challenge the designer

Animal's echo-locating outperforms sonar, while sound outputs push limits of detection electronics

Richard N. Einhorn
News Editor

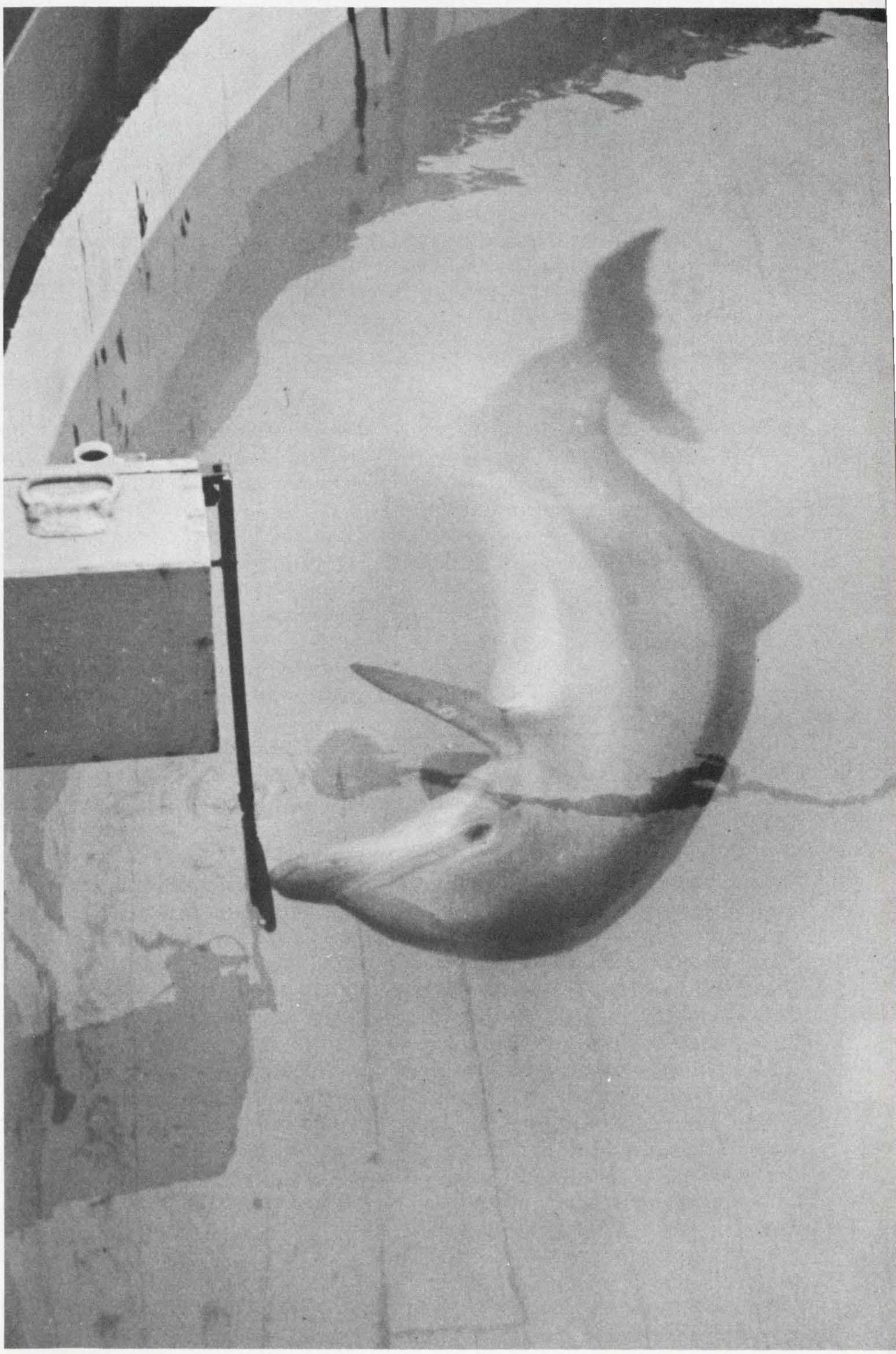
In the Fourth Century B.C., Aristotle began to observe the dolphin. He noted its intelligence, social organization and apparent friendliness toward man. In the intervening 23 centuries very little else was learned about this intriguing animal. Recently, however, scientists in various disciplines have converged on it. The application of electronic equipment—the hydrophone to penetrate the dolphin's environment, the tape recorder to accumulate data and computers to analyze it—has enabled them in the last 15 years to make the first real advances since Aristotle's original observations.

The scientists are seeking answers to such questions as:

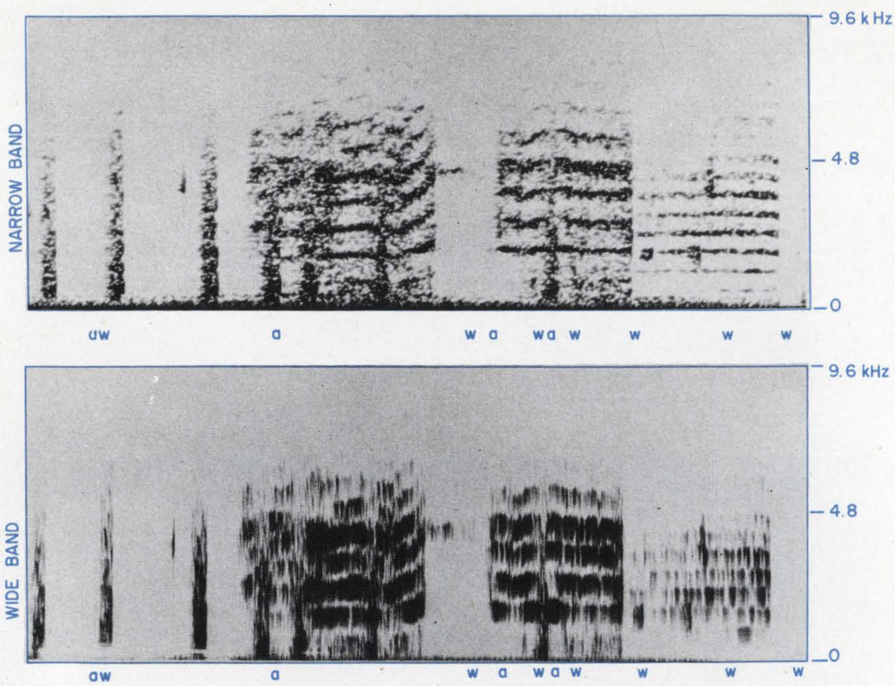
- Does the dolphin have a language comparable to a human one?
- Can the dolphin be taught to communicate with man and vice versa?
- What lessons can we learn from the dolphin as a bionic model—for example, can engineers learn how to design improved sonar from the dolphin's echo-location techniques?
- Will dolphins become the "Eskimo dogs of the deep" to aid man in his explorations under the sea?

It is a truly international venture. Research is being carried out in laboratories on both coasts of the United States, as well as in the Caribbean, Mediterranean and Black Seas. In this country there are several major research centers:

- Naval Missile Center, Point Mugu, Calif. (about 60 miles up the coast from Los Angeles).
- Communication Research Institute, Miami, Fla.



Dolphin pushes paddle with beak during test of its hearing response. This triggers automatic fish feeder.



1. **Dolphin's sounds produced in air** (a) **and under water** (w) alternately are displayed on sonagram. Vertical axis represents frequency and the horizontal, time. The two traces represent the same information recorded with a 45-Hz bandpass filter (top) and a 300-Hz filter (bottom). The broad traces represent a banjo-like sound and the narrow ones barks, according to Dr. John C. Lilly. (Reprinted from *Proc. Amer. Philo. Soc.*, CVI, No. 6 (December 1962), 523)

- Oceanic Institute, Sea Life Park, Oahu, Hawaii.

In addition, delphinologists (as experts on dolphins are known) use the facilities of such aquaria as Marineland in St. Augustine, Fla., and Marineland of the Pacific in Palos Verdes Estates, Calif., after visiting hours.

Research with dolphins is more than just a matter of scientific curiosity. It involves the most sophisticated electronic technology used by natural scientists. Already the inventory of equipment includes hydrophones, transducers, instrumentation tape recorders, spectrum analyzers, oscilloscopes, telemetry equipment and computers. It also includes such specialized equipment as man-to-dolphin and dolphin-to-man translators (devices with which scientists attempt to make the English language more comprehensible to dolphins and delphinese more so to them).

But this is only a beginning. What is learned about the limitations of existing equipment—especially the wide-band hydrophones, which many scientists have criticized—will spur the design of a new generation of instruments for field work. It embraces the dolphin (a system), the sensory apparatus (subsystems) and the environment. Many of the signals cannot be seen or heard. Improved instrumentation is essential.

Often the data gathered cannot be reduced to real-time observations. At present the scientists struggle with jerry-rigs. Most of the fallout from the aerospace program has proved overly expensive and overly complex. The delphinologists need help from the systems engineer.

Dolphins are toothed whales

What is a dolphin? The question is by no means obvious, for there seems to be a great deal of confusion among nonscientists. A dolphin is any one of more than fifty species of small, toothed whales that range from the killer whale down to the freshwater dolphin of the Amazon. They are air-breathing mammals that live in the ocean but must surface every few minutes. If kept out of water for prolonged periods, they would die because they cannot support their own weight on land. The porpoise is only one variety of dolphin, although many Navy men call all dolphins "porpoises." In this report, by dolphin is meant the Atlantic bottlenose dolphin (Tursiops truncatus). This species is bright, articulate and docile, and thrives better than most in captivity.

Dolphins have large brains that compare favorably with man's in size (20 to 40 per cent larger) as well as in degree of convolution. They are thought to be intelligent, though only the most foolhardy scientist would try to assign an IQ range to them now.

They are friendly to humans, and will endure more abuse from a person without biting than they will from another dolphin. In captivity, even the killer whale is gentle and can be trained for circus performances. They appear to be noisy and gregarious, with an active social life.

Since they are vocal animals, anyone studying them needs a hydrophone and tape recorder at the very least. At times the instrumentation must be highly complex. Many studies have been performed on the dolphin's sound production. Among the abilities discovered by scientists are the following:

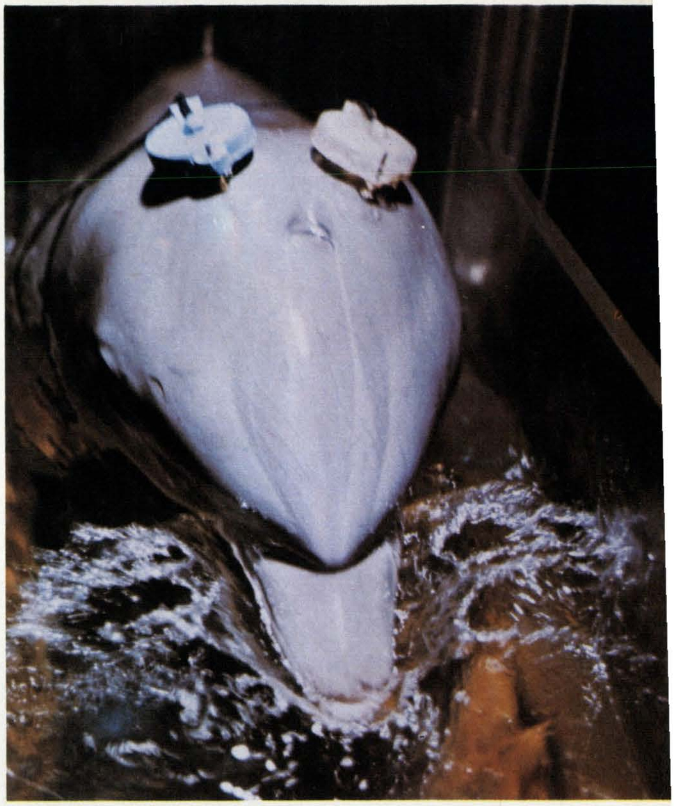
- The dolphin emits sounds in a spectrum from about 200 Hz to 150 kHz. Waveforms range from steep pulses (clicks) to almost pure sine waves (whistles).
- The dolphin has at least two (possibly three) independent sound sources and can use them separately or in conjunction.
- The dolphin apparently knows how to beat waveforms to produce sum and difference frequencies that are useful in echo-location as well as communication.
- The dolphin can convey not only emotion but also information about the environment to other dolphins.
- Each dolphin has its own signature whistle (like call letters).
- The dolphin naturally emits sounds underwater, and in captivity learns to vocalize in air.
- The dolphin can mimic human speech in a "Donald Duck" fashion.

I. Sound-production

At Communication Research Institute, where Dr. John C. Lilly is the director as well as the principal scientist, a great deal of electronic equipment is brought to bear on the dolphin's sound output.

Sounds in the dolphin's repertoire are variously described as whistles, squeaks, clicks, buzzes, racks, squawks, barks, yelps and chirps.

1



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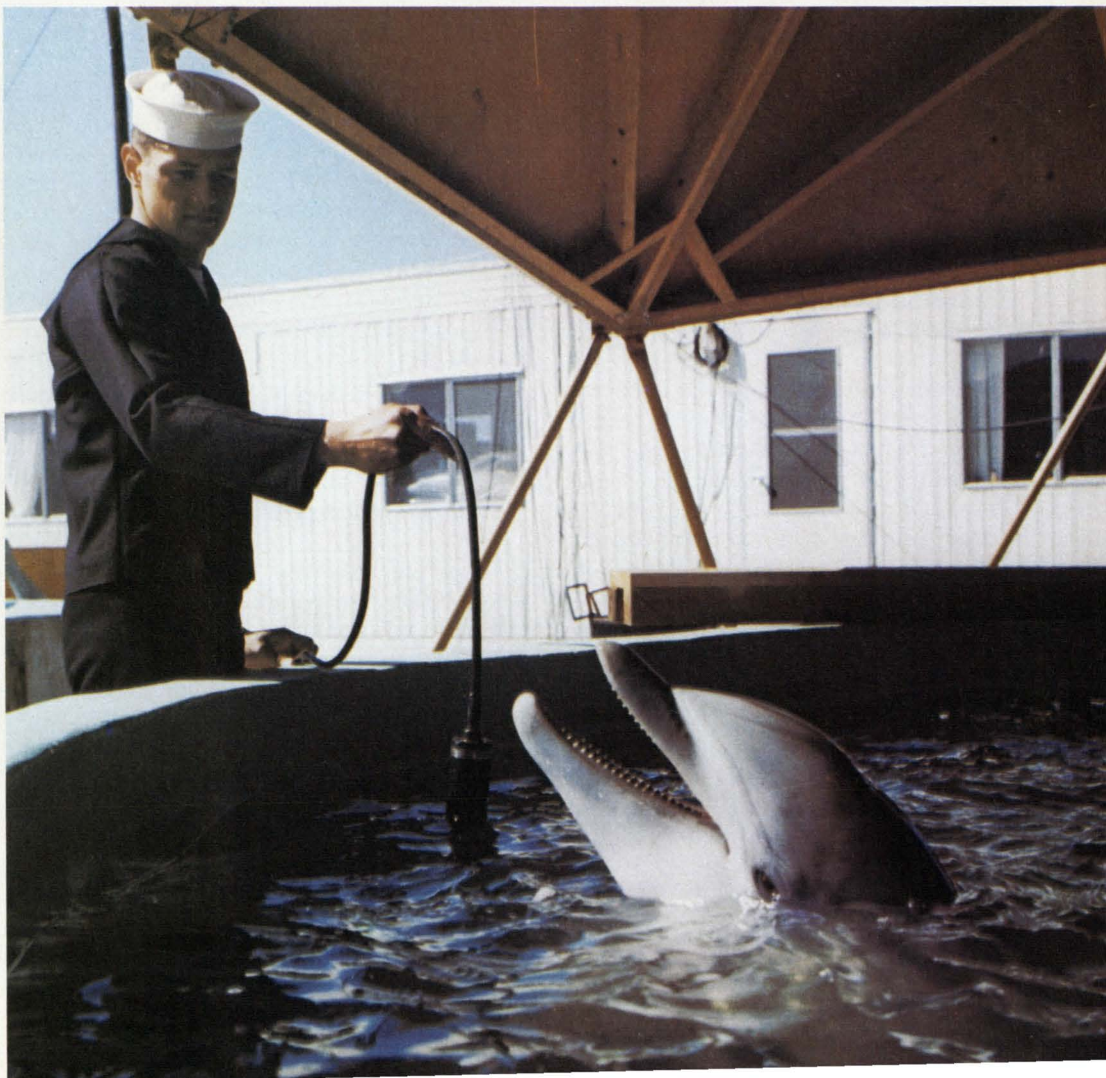
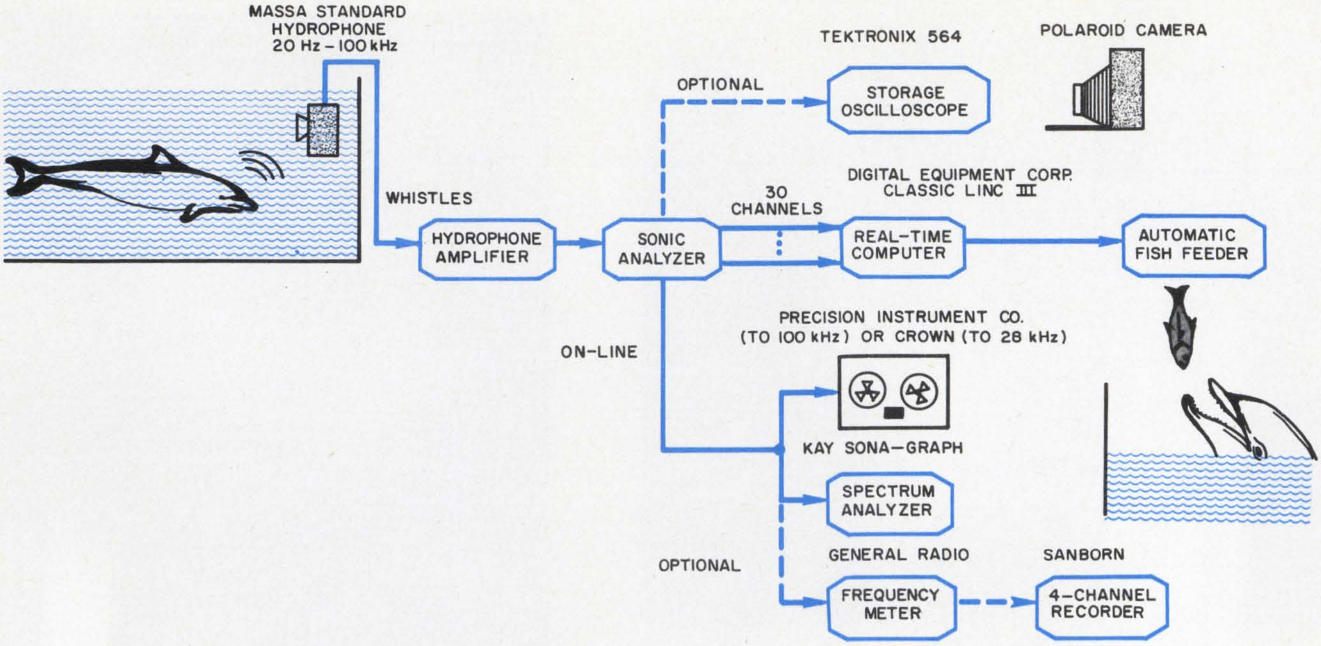


3

1 *Echoless mud bottom of Hawaiian inlet favors tests from houseboat laboratory.*

2 *Lady playfully splashes Hasselblad from tank where dolphin voices are recorded.*

3 *Doris vocalizes into hydrophone held by Airman Brian Bates at Point Mugu.*



2. **Dolphin undergoes programed tests** of its vocalization. If the computer determines that the animal has given a correct response, it actuates an automatic fish feeder that plops a thawed fish into the tank. Sonic analyzer divides spectrum into 30 bands in real time. Computer sorts frequencies to form bar graph of their distribution.

But these terms are as subjective as "moo" or "meow." Delphinologists recognize this and generally include oscillograms and sound spectrograms in their papers.

Form sonic spectrograms

Exchanges between two dolphins or between a dolphin and a human can be displayed on sonagrams (Fig. 1). The Sona-Graph is manufactured by the Kay Electric Co., Pine Brook, N.J., under license from Bell Telephone Laboratories. It analyzes sound signals in the range from 85 to 8000 Hz and provides a graphic contour on facsimile paper. Any portion of this frequency range may be examined on an expanded scale. The frequency response can be extended by slowing down the playback of any magnetic tape that is used as an input to the Sona-Graph. Bandpass filters permit analysis of 45- and 300-Hz bands. The output of the analyzing filter is then recorded on dry facsimile paper, which is wrapped around a smooth drum. A high-frequency current applied to the stylus is varied according to the amplitude of the signal. Time is displayed on the abscissa, frequency on the ordinate, and intensity as shades of gray or black.

In one setup (Figs. 2, 3), the dolphin's outputs are divided into frequency bands by a sonic analyzer (Kay Sonalyzer) which operates in real time. The Sonalyzer routes these signals simultaneously to a tape recorder, a spectrum analyzer, a storage oscilloscope with Polaroid camera attachment, a four-channel recorder and a digital computer that operates in real time.

A relatively wide-band ammonium dihydrogen phosphate crystal hydrophone is used to pick up the dolphin's outputs. Dr. Lilly complains that his Massa M-115C Standard hydrophone has a poor signal-to-noise ratio and rings at 130 kHz. At this frequency it can be shock-excited by the dolphin's sonar emissions, and an input attenuator has to be used to prevent overload. Because the amplitude of the dolphin's signals is high, the hydrophone is run at a level of –30 dB.

Hydrophones are criticized

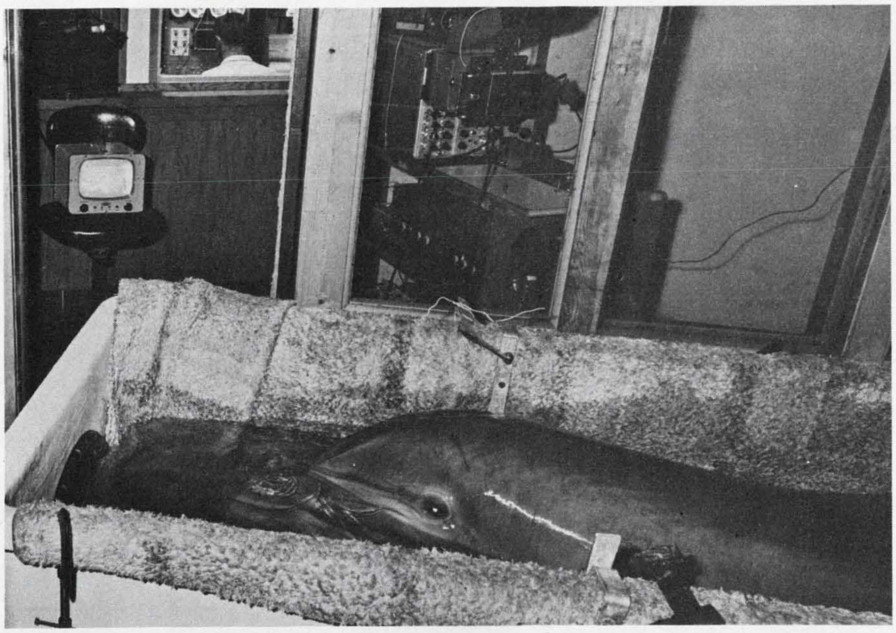
"We very definitely need a better wide-band hydrophone, he says. "We have other hydrophones, smaller ones, that can go up to 150 kHz. But I think commercial ones in general have too high a noise level."

Another investigator, the late Dwight W. Batteau, agreed with Dr. Lilly that dolphins can produce ringing in wide-band hydrophones. (These criticisms of equipment, like many others made, are specific to dolphin research. While the instruments may be adequate for their intended applications, the intensity and wide bandwidth of the dolphin's sound emissions, coupled with stringent environmental demands, often require special-purpose devices that simply are not available. In some cases the cost of suitable electronics far exceeds the budget of the delphinologists.)

Asked about Dr. Lilly's problem, Batteau, who was a professor of mechanical engineering at Tufts University, Medford, Mass., and president of Listening, Inc., at nearby Arlington, said:

"He shouldn't be using that hydrophone if it's the same type of Massa hydrophone we were using. It has a poor signal-to-noise ratio, and it may be too large for this application. I think that for the extremely broad-band frequency analysis Lilly is trying to do with rack (click) sounds he needs a 1/10-inch hydrophone, like the Atlantic Research instruments that go up to 500 kHz. The use of FET preamplifiers mounted as close as possible to the hydrophones would cut down on cable-induced microphonic noise. The cable is capacitive. It eliminates hum pickup from fields in the wire. There are 2 feet of cable to the preamplifier. There may now be some hydrophone units available with an integrated preamplifier."

Other delphinologists, however, complain that small hydrophones generally fall off at the lower end,



3. **Dolphin rests in isolation tank** for study of the sounds produced in its head. Either a hydrophone suspended in tank or small transducers mounted on its head may be used. Behavior is monitored over TV. Toweling reduces echo.

that is, frequency response is inversely proportional to size. Also, they tend to be less sensitive than the larger units.

Dr. Lilly also uses transducers with telemetry transmitters that are held on the animal's head with suction cups (see cover). They pick up sonic and ultrasonic outputs directly from the dolphin's head, thus avoiding echoes and giving more accurate timing. In addition, the tighter coupling causes less loss of amplitude than the path through the tank to a receiving hydrophone. The devices are made by Sensory Systems Inc., Tucson, Ariz.

"They're useful for certain special things, for example, if you want to know when the dolphin is transmitting in the human-speech bands," Dr. Lilly comments. "The bandwidth is 500 Hz to 60 kHz. The hydrophone in the tank can pick up higher frequencies."

Dr. Lilly is not satisfied with the transmitting hydrophones used for projecting sound into the dolphin tanks, either.

"A separate hydrophone is needed for active use," he says. "It requires 50-watt peaks to give effective transmissions. The dolphins, by the way, are very curious about the transmitting hydrophones. If the amplitude is too high, they will try to throw the hydrophones out of the tank."

One approach to remedying the deficiencies of transmitting hydrophones has been tried by William Evans and Jarvis Bastian, two scientists at the Naval Missile Center at Point Mugu. They use an array of hydrophones connected like a multiple-loudspeaker hi-fi audio system. Crossover networks divide the sounds among the hydrophones, each covering a specific band. This gives equal intensity of signals over a wide band. Its only shortcoming is that it does not present a point source to the dolphin, but even that problem exists only in the near sound field.

Filters distort nonlinearly

Dr. Lilly is also critical of the commercial filters used in his laboratory.

"Both the active and the passive filters leave something to be desired," he says. "The Spencer-Kennedy variable electronic filters that we have give too high a noise level for large-amplitude signals. They are nonlinear. Not only do they go into harmonics, but they also change the waveforms."

Referring to Allison Laboratories narrow-passband nickel magnetostrictive filters, he says, "We must use a matching transformer, which introduces 60-cycle hum. What we really need is a filter with high input-output impedance, with no noise or microphonics."

The filters are necessary to cut out any portion of the dolphin's emissions that may act as a noise source in a given experiment. Variable skirts in cascade therefore are needed to change the slope of the filter. They have to be sharp—something like 45 dB per octave, Dr. Lilly says.

Working with the miniature dolphin-mounted transducer pickups, Dr. Lilly was able to make discoveries about what he calls the dolphin's stereophonation. If the transducers are positioned correctly, a listener with stereo headphones (Fig. 4) can notice the sounds moving back and forth from left to right. The apparent sound source seems to move through the listener's head.

According to Dr. Lilly, the dolphin's blowhole (an orifice just in front of its forehead) is used both for breathing and for emitting sounds. Like the human nose, it is divided internally. The right nasal passage is usually slightly larger than the left. Air sacs in the nasal passages function as sound emitters.

Dolphins blow in stereo

How does the dolphin use this system? Dr. Lilly speculated that because of the asymmetry of the nasal passages, there are frequency differences: the right channel is slightly lower in pitch.

The dolphin might use the left side to generate a sound that rises in pitch with time, and the right side to generate one that falls in pitch with time. Since the rise and the fall start and end simultaneously, the change in pitch for both channels resembles a less-than sign (<).

The two straight-line outputs that form the (<) output beat to form sum and difference frequencies. Since the algebraic sum of corresponding values along the left and right traces is always twice the initial frequency, the slope of the sum frequency line is zero, so the output looks like a dash (——); Dr. Lilly calls this the "bar call." The difference frequency, however, increases with time, starting with zero and ending with the initial freuency value. The difference output resembles a slash (/); Dr. Lilly calls this the "slash call."

For example, if the dolphin emits one call in the left nasal passage starting at 10,500 Hz and rising to 15,000 Hz, and another in the right channel starting at 9500 Hz and falling to 5000 Hz, the sum frequency is always 20,000 Hz (a straight-line trace). The difference frequency starts at 1000 Hz (10,500 — 9500) and ends at 10,000 (15,000 — 5000).

The effect is to put the difference frequency trace (the slash call) entirely within the human hearing range (below 10,000 Hz) and the sum frequency trace (the bar call) entirely out of the sonic range (20,000 Hz throughout).

This beating of frequencies causes no problems for the dolphin: it can recognize the three sounds (<), (——), and (/); in fact, to the dolphin (<) is equivalent to (——/), the sum and difference frequency components taken separately.

The human, on the other hand, can hear the slash (/) call easily, the (<) call faintly and the (——) not at all, since it is out of his hearing range.

Computer rewards dolphin

In analyzing the dolphin's output, Dr. Lilly uses the Classic Linc (Laboratory Instrumentation Compiler), a small digital computer developed specifically for biomedical research. It is produced commercially by Digital Equipment Corp., Maynard, Mass. It generates stimuli under program control, digitizes the dolphin's analog responses (sound outputs), stores data on tape, calculates distributions, performs correlations and compiles histograms.

Frank Grissman, Dr. Lilly's engineer, says that the Linc computer "in effect gives a survey of where the sound components lie. It is a new way to look at it in real time—we aren't concerned with amplitudes."

In essence, the outputs of a sonic analyzer are fed into the computer. There are 30 channels of inputs. In real time, the computer tracks a pulse traveling through the sonic analyzer and gates each channel. The serial outputs are stored. Each time a threshold for a channel is reached, a 1 is stored.

The output of the computer is a bar graph, not of amplitude vs frequency of the dolphin's outputs, but of the distribution of the frequencies. The height of each bar depends on the number of times the threshold amplitude for that frequency is reached. Values below the threshold are rejected and do not appear.

Since the outputs of the sonic analyzer are computed and displayed in real time, it is possible to run tests on the dolphins without human intervention. The Linc computer is programed to deliver a sound or other stimulus (making use of the other electronics shown in Fig. 2). If the computer recognizes the proper response, it triggers an automatic fish feeder, which plops a thawed fish into the tank.

Frank Grissman says that the Communication Research Institute plans to replace its Classic Linc with Digital Equipment Corp.'s PDP-8, an advanced model with a more flexible memory that converts from the user's mnemonics to machine language. Neither model is a high-speed device, but Grissman thinks that versatility is more important for this application than brute calculating power.

Dr. Lilly described another use of the computer — analysis of tapes made during the experiments. He uses a Precision Instrument Co. tape recorder with an upper limit of 100 kHz.

"We really need 150 kHz because the dolphin's clicks go up there," he says. "On the other hand, with this machine it is convenient and relatively easy to decrease playback speed to one-tenth by turning a switch."

A tape loop that repeats selected segments is used when the computer is required to scan data with different parameters, such as different bands of frequencies.

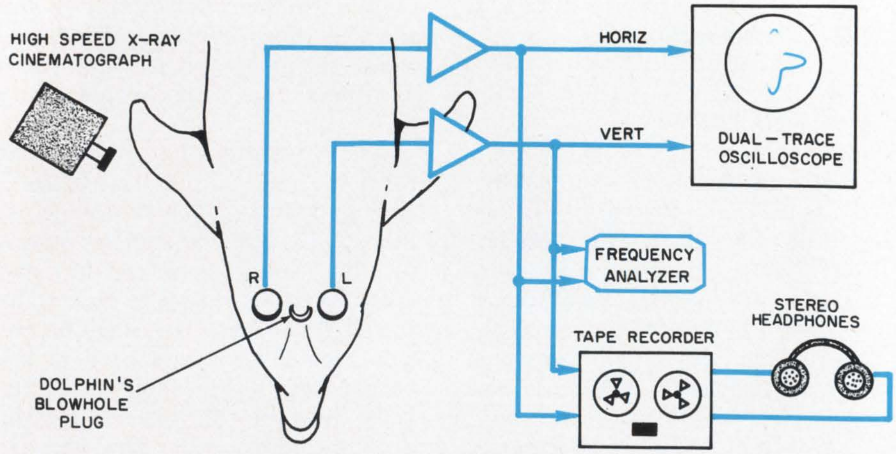
"With a single click, you have to determine what band you are in," Dr. Lilly points out. "You record the click on tape, and put it through the Sonalyzer, which gives the frequency-vs-amplitude plot of the click.

"Then the computer provides outputs which are the distribution of frequencies within a narrow band of frequencies. The computer looks at each band and detects the number of above-threshold signals. By such means you can show the dolphin's control over the frequency of click trains. As you go from one segment of tape to another you can show the peaks shifting. It is possible to see that during a click train, the peak or dominant frequency can shift up or down dramatically. We have been doing this for only the last two years."

A General Radio frequency meter is used in the analyses.

"It is especially good for whistles," Dr. Lilly says. "We can plot the frequency of the fundamental very rapidly from a tape. The output is put on a four-track Sanborn recorder. This recorder has a nice black trace that is good for photography."

Asked what he would be able to do with more nearly ideal equipment in general, Dr. Lilly said: "Eventually we will be able to specify the physics of the dolphin's voice pro-



4. **Dolphin can produce sounds in "stereo,"** Dr. Lilly asserts. If it clicks or whistles only with the left side, only a vertical trace appears on the oscilloscope. If only with the right side, there is only a horizontal trace. If there are two separate emissions, a cruciform pattern (shown in diagram) results. When the two sound sources are coupled, there are complex, shifting ellipses. Listener with stereo headphones senses apparent sound source shifting. Cinematograph takes high-speed X-ray motion pictures of the blowhole to reveal the dolphin's independent control of two emitters.

duction. I predict this will take place in less than five years, but in more than one year. However, improved equipment is not the whole answer. We have to know more about our own human perception of these sounds."

II. Echo-locating

One area in which human perception very definitely takes a back seat to instrumentation is the study of the dolphin's echo-locating. The sounds are emitted under water and the peak energy is out of the human sonic band.

Several unusual features have been discovered about the dolphin's sonar:

- The dolphin can vary the repetition rate and frequency, to select general-environmental-scanning and fine-discrimination modes.
- The dolphin can use some of its anatomical structures to beam its sonar.
- The dolphin takes advantage of beat frequencies to gain information.
- The dolphin can discern differences between dissimilar materials, even when they give returns with the same sound intensity.

Man has yet to produce the multi-function, omnidirectional sonar set. But nature, in the form of the dolphin, seems to have solved the problem in a highly compact apparatus.

At present, engineers are forced to design specialized sonars because of the conflict between power and frequency requirements. Thus they end up with various kinds: low-frequency, high-power for long-range search; high-frequency for short-range, high-resolution identification; and intermediate frequencies for sea-floor contour-mapping.

The mechanical and electrical properties of transducers are an obstacle to the operation of sonars over broad frequency ranges. The dolphin is versatile: it can vary the frequency, propagate energy either in a beam or omnidirectionally, and couple its sound sources to produce either pulsed or modulated signals. Mechanical transducers simply cannot match the characteristics that the dolphin can produce merely by flexing its muscles.

How important is the dolphin's echo-location? Take it away and it cannot survive. At night or in murky water it can't see more than a few inches in any direction. How can the dolphin tell what's up ahead while cruising at 10 knots? Is it another dolphin, something as unsavory as a shark or sawfish, the keel of a boat, the sea bottom? How can the dolphin locate a school of fish, or surface in the trough of a wave (not its crest) to breathe?

Poker faces are out

Dr. Lilly tells what it might be like if men were dolphins and looked at one another underwater by means of sonar:

"Sound waves in water penetrate a body without much external reflections or absorptions. Skin, muscle and fat are essentially transparent to the sound waves coming through the water. The internal reflections are from air-containing cavities and from bones. Thus we see a fuzzy outline of the whole body plus the bones and teeth fairly clearly delineated; the most sharply delineated objects are any gas-containing cavities."

In other words, we could "read" a person's emotions from the bubbles in his stomach. We wouldn't need facial expressions, which we couldn't see anyway. In fact, in the course of evolution dolphins have lost the ability to vary their seemingly perpetual smiles.

The dolphin's sonar signals serve two main functions: orientation to the general features of the environment, and discrimination of objects that have already been located. The signals vary, depending on what is going on.

Scans its environment

As a dolphin swims in the ocean, even in the clearest, most sunlit parts, it generates short, plosive pulses with a lot of air pressure behind them. We would hear them as loud clicks. If these clicks are recorded on magnetic tape and analyzed, it could be seen that they vary widely in repetition rate — so much so that they appear sporadic. Individual clicks last a millisecond or more, and may be uttered singly or in short series.

These are orientation clicks. With them the dolphin gets a quick-and-dirty look at large objects in its vicinity. The captive dolphin does this even in its own tank, which it may have traversed a million times.

When it detects a target of interest, say, a mackerel thrown into its tank, the pulse repetition rate increases from the 20 or 30 or 80 pps the dolphin was using for orientation to several hundred a second. The plosive clicking signals become so closely spaced that in aggregrate they sound like a creaking door or a rusty hinge.

The dolphin is now operating in its discrimination (fine-resolution) mode. The trains last anywhere from 1 to 10 seconds, depending on the difficulty of discrimination. To a human observer at poolside, the intensity of the clicks seems to drop when discrimination starts. This happens because the animal is displacing much of the energy from the (human) sonic region to the ultrasonic.

Kenneth S. Norris, a professor of zoology at the University of California, Los Angeles, who has spent years studying the dolphin's echo-location capabilities, both in the laboratory and at sea, says that the clicks have a broad energy band. The majority of the energy in a typical click lies below 30 kHz, but there are significant outputs up to 80 kHz, and some outputs well above 100 kHz. The discrimination clicks are very short—typically, 0.2 to 0.7 ms—and have a rise time as steep as 10 microseconds.

Only the rapid click trains are involved in echo-location, Norris says. As far as is known, true echo-location trains are produced with a closed blowhole in water. The open-blowhole sounds may be related to communication and are largely of frequencies audible to humans.

An echo-locating dolphin scans the environment by swinging its head, Norris says. While this enables the animal to scan with trains of directional sound pulses, it also changes the position of the dolphin's ear for fine direction-finding. Another possibility is that the dolphin might be scanning with some other pickup structure as well. Norris and others suggest that the dolphin's lower jaws may serve as sound pickups and waveguides.

Dr. Lilly theorizes that the dolphin scans with two separate sound sources and can move back and forth between them. More precisely, it can shift its sound source anywhere it desires between the two outer limits. It may thus be introducing a Doppler effect into its own sound production, and may be controlling its near-field and far-field amplitudes as it shifts from monopole to dipole modes.

In echo-location, this could be extremely useful. With this angular information, however slight, the dolphin could triangulate for more accurate target-location.

The gist of Dr. Lilly's theory is that, unlike a frequency-modulated radar, the dolphin emits two signals simultaneously, one rising in pitch with time, the other falling. The dolphin is able to use the beating of these two signals to gain information.

The dolphin's slash call is most likely used for the omnidirectional long-wavelength orientation sonar, Dr. Lilly says. What evidence is there? Dr. Lilly reports that when he placed dolphins in new surroundings, they emitted the slash call. But once they had mapped their environment, they stopped, or at least emitted it less frequently. This agrees with Norris' observations on orientation. Dr. Lilly also claims that the dolphin uses its larynx as a third sound source to produce a narrow, fan-shaped beam of high frequency (about 100 kHz) sonar. The beam is shaped by the dolphin's head, which serves as a variable acoustic lens, and is used for fine discrimination.

Discrimination is fine

How good is the dolphin's sonar? Several recent experiments have tested it. Two of the most active investigators have been Norris and a former student of his, William E. Evans, now working for the Naval Undersea Warfare Center.

Norris and Evans blindfolded a captive dolphin with suction cups that fitted over the eyes. Next they trained the dolphin to close in on two nickel-steel bearings and to specify which of the two was larger by pressing a lever on the correct side.

Their dolphin achieved a perfect score when one sphere was 2-1/8 inches in diameter and the other was 2-1/2 inches, but it was right only 77 per cent of the time when the spheres were 2-1/4 inches and 2-1/2 inches, respectively.

At one stage they tried to make the dolphin choose between two identical bearings, but the animal wasn't stupid. It would simply turn away from the problem.

How did it know that an impossible problem had been presented, yet know at other times that it was faced with a possible but difficult problem? One explanation is that a single click might return from both ball bearings with a mixture of two different lower frequency limits and different intensities. Then the dolphin would at least know that it had a problem.

During these tests, the scientists recorded the dolphin's sound production, so that they could correlate it with the dolphin's successful discriminations. They verified that most of the energy is concentrated between 16 and 30 kHz. They found that for the simplest discriminations the click trains were uniform and ranged from 1.1 to 2.9 seconds. For more difficult tasks, the longest train was 4.7 seconds. The dolphin usually started a test at a repetition rate of from 80 to 100 pps and went as high as 230 pps.

Detects different materials

Evans went on to prove that dolphins can distinguish between different metals, even when they exhibit the same reflectivity to sound waves and therefore have echoes of the same intensity. (The two ball bearings of different sizes varied the frequency content of the reflected pulses as well as the intensity.) He and Bill A. Powell of the Naval Undersea Warfare Laboratory prepared target disks of different metals of various thicknesses. They had plotted the reflectivity of these metals with a computer and determined that 0.22 cm of copper could be used as a standard target.

They trained a female dolphin named Scylla to swim blindfold down a runway and select the standard target in preference to comparison targets of copper, brass and aluminum. Scylla was unable to distinguish copper or brass targets that were close to the standard in thickness, but she could distinguish a 0.64-cm copper target from the 0.22-cm standard with an accuracy of 85 per cent. With much thicker aluminum targets, she always scored better than 90 per cent, even when the reflectivity was theoretically identical to that of the standard.

This puzzled them until a coworker, C. Scott Johnson, deduced that the dolphin must be using information other than relative echo intensity. He concluded that phase differences, produced by reflections from the back of the target by sound waves entering the front, supplemented the dolphin's information.

Norris and Evans say that the dolphin uses time relations within click trains to derive information about targets. The rate change of the repetition rate itself can become a measure of gross closing rate. A much more precise measure is the time interval between the end of an outgoing click and the beginning of reception of the echo. Knowing its own speed within reasonable limits, the dolphin should be able to gauge the relative speed of the target by assessing the rate of change of echo placement.

Evans thinks that the dolphin uses built-in mechanisms to overcome noise and jamming signals. He says the animals single out important echoes in a complicated ensemble just as easily as human beings can pick up one conversation at a party or one stringed instrument in a quartet. Well-developed directional hearing and the ability to emit sound in a narrow, fan-shaped beam from its forehead could account for the dolphin's success even in noisy environments.

Dolphin wears antenna

Recently Evans demonstrated his equipment (and his star, Scylla) to ELECTRONIC DESIGN. Evans maps the sound fields around Scylla's head by telemetering the outputs of miniature hydrophones fastened to her head by suction cups. The hydrophone is an Atlantic Research Corp. LC-10 lead zirconate titanate device. The telemetry units are solid-state fm transmitters designed by Gary Blanc of the Naval Weapons Center, China Lake, Calif. Each transmitter is housed in a little hinged plastic parts box. The transmitter box and the hydrophone are both cemented directly to the suction cup (Fig. 5).

The unit consists of three stages of amplification (FETs are used in the first two) and a modified Colpitts oscillator stage tuned to 55 MHz. The amplified signals from the

1 *Dolphins lug tools and messages on Navy's Sealab project and can be summoned by acoustic signals.*

2 *Frank Grissman studies frequency distribution of dolphin's output with aid of Linc digital computer.*

3 *Curious, Pequod surveys scene at Communication Research Institute after splashing the author.*

1

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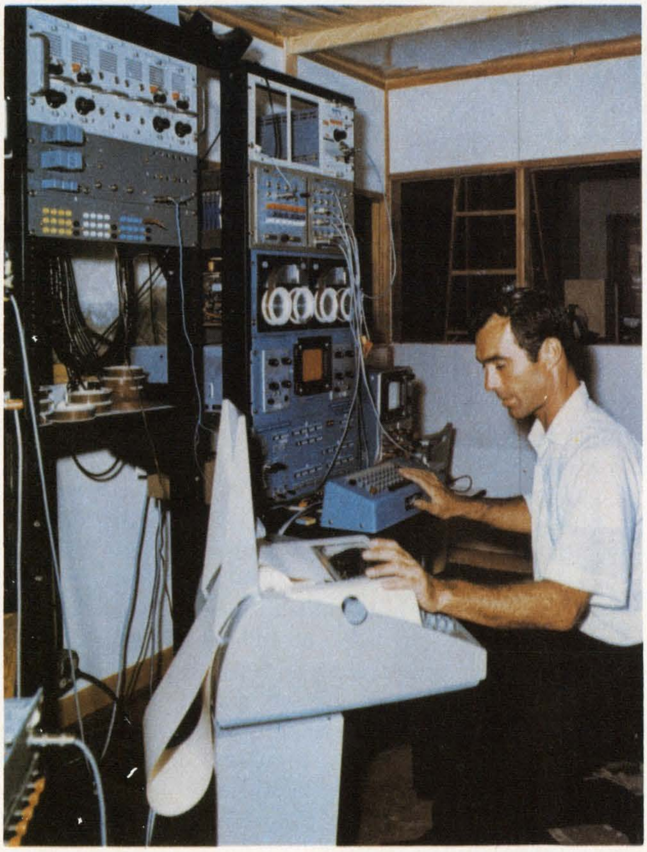

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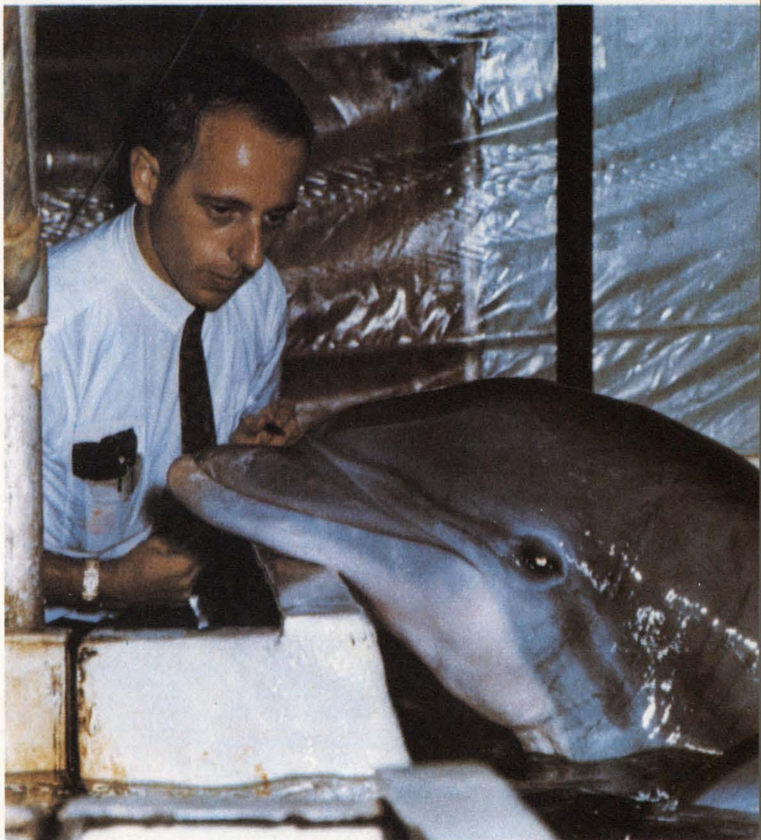
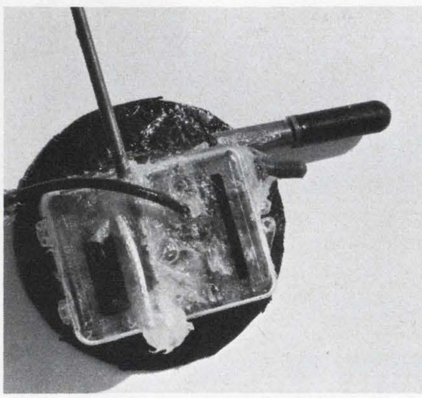


hydrophone frequency-modulate the output of the oscillator. Use of a 55-MHz carrier necessitates a monopole antenna that is always in the air even when the dolphin is submerged. Otherwise, the high-frequency signals would not penetrate the water.

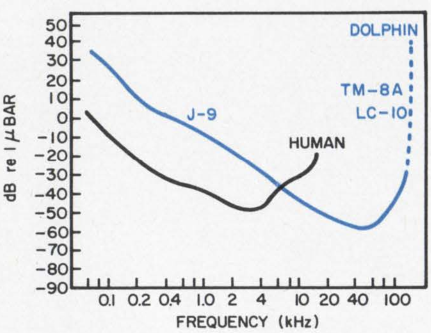
Blanc says that he selected a 55-MHz operating frequency because it can be accommodated at the lower end of the high-quality wide-band telemetry receiver available for the experiment. He says that a much lower transmitting frequency would be desirable, since then the rf could be transmitted directly through the salt water medium. This would eliminate the antenna, which Evans feels is objectionable.

Blanc has the basic design down to the point where he can build transmitters in about half a day. He is currently designing a transmitter to operate at an fm carrier frequency of about 1 MHz, but he points out that no commercial receiver can handle the signal because the dolphin's pulses have such broad frequency spectra (at least 150 kHz). Therefore, he must either design a receiver or modify an existing one.

"We have to make compromises," Evans says, "but all in all, it works nicely with the animal."



5. **Dolphin's sonar pulses** are telemetered with unit designed by Gary Blanc of U.S. Naval Weapons Center. Hydrophone and a transmitter packaged in a plastic box are cemented to suction cup that fits on the animal's head. Monopole antenna sticks up out of water even when dolphin is submerged.



6. **Hearing of dolphin is mapped** with sine waves. Three hydrophones (Atlantic Research LC-10, Apelco TM-8A and U.S. Navy J-9) are used because no one projector covers the band.

Receiver bandwidth poor

Evans also uses a larger hydrophone suspended in the tank. Since no telemetry link is used with this hydrophone, the output goes directly to an amplifier. The telemetered outputs of the miniature transducers (Evans uses two or four of them positioned to provide phase information as well as frequency and amplitude) first have to be demodulated by an fm receiver.

"I would like to be able to use fm at 1 MHz because I could feed the output directly into a tape recorder like the Ampex FR 1400, which has a 1.5-MHz bandwidth," Evans comments. "I could simply slow down the fm tape to get it digitized. That way I can avoid some of the noise pickup, because 1-MHz receivers usually aren't much good."

Evans doesn't have an FR 1400 predetection tape recorder in his inventory, although he wishes he did. In his usual setup, the amplified hydrophone or transducer signals from the receiver are amplified and filtered with a Krohn-Hite variable filter, model 3202R.

"We also have a Spencer-Kennedy filter," Evans says. "The Krohn-Hite does the same job, only with slightly less noise."

From there the signals are applied to an Ampex FR 1300 tape recorder operating on multiple tracks at 60 in./s. This machine goes up to at least 300 kHz and can accommodate every signal of interest. Sometimes the signals are also displayed on a storage oscilloscope.

"We're fortunate in being able to get some time on a large computer for analyzing the runs on a target. We really need this computer because we're dealing with very short duration transients that are difficult to analyze. We also run the hydrophone signals through a sound spectrum analyzer like the Kay Sona-Graph. This doesn't give the full frequency response, but it's handy as a sort of index to what I want to look for later on. I paste the sonagrams right into my data book.

"We send the tapes from the instrumentation recorder to China Lake. The tapes are records of the animals' sounds as a function of time. We enter timing pulses on the tapes using IRIG format-B range timing, as in space telemetry. There is a modulated 1-kHz time base that gives Greenwich Mean Time from the month down to the millisecond."

Digitize sonar sounds

At China Lake, an engineer by the name of Robert Stirton uses a NODAC analog-to-digital converter to digitize the signals for analysis by a Univac 1108 computer.

Stirton commented: "We sample the tapes with NODAC, which was developed at the Naval Ordnance Test Station. The computer does a Fourier analysis of frequency and transforms it into spectral density. The output shows the energy in the signal as a function of frequency. This analysis is similar to sonagrams, except that it is done on a computer."

Asked about the cost of such a procedure, Stirton said, "The amount of computer time varies. A typical recent run might be 0.2 or 0.3 second using a high-speed Fourier analysis method. It takes only a few minutes of human labor. It is extremely economical, and probably less expensive than making sonagrams for this program."

There is one decided advantage to this method: the full bandwidth of the transducer can be captured and analyzed, whereas sonagrams are limited in frequency response to 8 or 16 kHz, depending on the model.

Despite his success in recording echoes, Evans is not totally satisfied with the instruments at his disposal.

"By now I'm used to the concept that what I have to work with is usually the fallout from the defense and aerospace field. And that fallout isn't always useful to the people doing biological or medical research because industry doesn't do anything to help them.

"For example, when Ampex or

Lockheed builds a recorder or amplifier, they don't tell you what transducer to use and how to match equipment. They leave it up to you. Well, this may be all right for engineers who work with missiles, but the biologist, the veterinarian, or the physiologist needs help from the systems engineer."

Evans outlined the improvements he wanted. "We need a wider range of underwater transducers and hydrophones. I mean both in frequency response and in physical size.

"Then, we need improved sensitivity of the smaller barium titanate devices. When a transducer is made so small that it can fit in the dolphin's blowhole, the sensitivity tends to be extremely poor. So far, the animals have produced enough sound, but I am thinking about other research where this sensitivity is needed.

"A really big need is for good, high-quality battery-operated field equipment at a reasonable price: recorders, amplifiers — not only for scientists studying dolphins and sea lions, but also for the bird people and the bat people.

"As a minimum, I'd like to see two- and four-channel, reliable instrumentation - quality tape recorders with good response up to at least 100 kHz, with matched amplifiers.

"Lockheed makes a very fine battery-operated instrumentation recorder, but it costs 12 to 14 grand, almost as much as a Rolls Royce. These may be realistic prices for the quality, but let's hope that the price can come down some day to where we can afford them.

"Field units like the Uher, which have a response up to about 20 kHz are all right for recording whistles and hearing them, but for analyzing the signals from 20 kHz up, where much of the signal energy lies, we need something like the Lockheed.

"On field trips with a special glass-bottomed boat we got usable readings with the Ampex FR1300, but we had batteries with a converter on board and we picked up converter noise. The Ampex sopped up half a kilowatt and the batteries were used up quickly. It's equipped with handles, but you need two very strong guys to lug it. It is portable only in the sense that it isn't cemented down. A unit I could carry by myself would be useful."

Prof. Batteau commented that equipment used in this type of environment should be rugged.

"One of the severe problems of working in sea water is that it gets into everything," Batteau said. "We have to be careful that cables don't leak and short out. And the sea air is full of salt, which corrodes equipment. Besides, the dolphins chew on the hydrophones and the cables, and they have sharp teeth.

"Our tape recorders are subject to water damage. A tape recorder that is immune to salt spray and water damage and records to 30 kHz would be adequate for our immediate purposes, although we have used Ampex machines that go up to 300 kHz for recording racks (clicks)."

If dolphins are to use these echolocation techniques, they must be able to hear and interpret a range of signals over a wide frequency band.

Map hearing curves

C. Scott Johnson, a physicist working for the Naval Undersea Warfare Center at Point Mugu, has been plotting threshold hearing curves for the Atlantic bottlenose dolphin, much like the audiometer hearing curves used in human hearing.

Johnson treats the dolphin as a black box, say, like an amplifier. His basic technique is to measure thresholds, determine the minimum sound fields the dolphin can detect, and then make the tones shorter and shorter in duration to see what happens to the thresholds. Of course, the amount of energy decreases as the pulse is shortened.

Johnson says: "I use pure sine waves and try to duplicate the results logged with humans because we're the animal that scientists know best. When these tests are completed, the dolphin will be the animal with the second best-known hearing curve."

According to Johnson, dolphins can hear sounds in water with approximately the same sensitivity as human hearing in air, except that the upper frequency limit is about ten times higher than the point where our hearing cuts off — about 150 kHz as compared with 15 kHz for humans. The lower cut-off is about 75 Hz compared with about 20 Hz for humans (Fig. 6).

Johnson qualifies this by pointing out that all his work has been done with one animal. However, he finds reasonably good agreement with results of other tests published in the 1950s. Johnson thinks that his own results are the most reliable because he uses up-to-date equipment, and because his dolphin is trained to listen for the signals.

In general, it's an exacting process to measure the hearing thresholds of aquatic animals, Johnson says.

One reason is that it is difficult to determine the sound field accurately. Since a high background noise level is present and even redwood-lined Fiberglas tanks reflect sound waves, the only way to hold the sound field relatively constant (within ±5 dB) is to induce the animal to stay still in one spot. Another problem is that at low levels, the farther the subject is from the sound source, the greater the loss. Therefore, for a uniform sound field, the dolphin has to be stationed as close as possible to the projector, but not so close as to cause problems with the near field.

Still another problem is to know unambiguously when the animal has detected the sound — he may be hearing but not responding.

The final problem concerns the limitations of existing equipment, Johnson says. Hydrophones are built mainly for underwater detection, not sound projection. It's not easy to find one that covers the frequency range from 200 Hz to 200 kHz. Barium titanate piezoelectric devices, which offer superior performance at high frequencies (they generally resonate at about 200 kHz), fall down badly at the low-frequency end. On the other hand, many magnetostrictive hydrophones have a resonant frequency that is too low to test the upper range.

Johnson finds one hydrophone particularly useful as a projector. That is the J-9, a moving-coil transducer that was developed by the Navy's Underwater Sound Reference Laboratory, Orlando, Fla. Several companies are licensed to manufacture the J-9 (including Chesapeake Instrument Corp., Shadyside, Md.).

"The response is supposed to be 40 Hz to 20 kHz, but I've used it up to 100 kHz. Above that, I've got to go to the barium titanates."

Johnson has also used a circular-piston barium titanate transducer (Apelco TM-8A) and a cylindrical barium titanate transducer (Atlantic Research LC-10). William Evans says the LC-10 performs well as a pickup device that can be attached to the dolphin, but Johnson has been using it as a projector, an application that Atlantic Research Corp. did not intend.

Johnson points out that it is all right for him to use a variety of projectors. "I use pure tones, and I use them one at a time," he says. "All I have to do is calibrate at each frequency. I'd run into problems if I were feeding in click trains, which are extremely broad-band pulses."

Johnson's experiment was set up as follows (see photo on p. 49). The dolphin, a nine-year-old male named Salty, swims into a stall-like enclosure in his tank. When a light comes on, he pushes a paddle with his beak and hears a tone — a 1-second series of sine waves. Now the dolphin has to push another paddle in order to hear another tone. By varying the intensity of a sound at a given frequency, it is possible to tell from his responses whether he is hearing anything. Meanwhile, Johnson watches the action over closed-circuit television.

In reality, what is being measured is the sound level at which Salty is willing to respond. How closely this approximates the true threshold one cannot say.

There are times when Salty just won't work. He hears the tone but doesn't respond.

"There's nothing you can do about it except put him through a training session where you know he can hear every tone," Johnson said.

"If he doesn't respond to a tone you make him sit there for 5 minutes until the next tone comes on, which he doesn't enjoy very much," Johnson explained.

III. Communicating

"Eventually it may be possible for humans to speak with another species." So said Dr. John C. Lilly in 1961. And what better place to tackle the problem of communication with an intelligent species than here on earth with dolphins?

Communicating with dolphins requires electronic compensation for disparities in sound frequencies and modes, in hearing and in environment. Two approaches in electronic converters are:

- Voice coders that shift human speech upward in frequency to lie more comfortably within the dolphin's hearing range, and vice versa. With these devices, the delphinologists speak in English to the dolphins and hear the dolphin's natural responses shifted down in frequency to the human speech band.
- Man-to-dolphin translators that convert human speech into sine-wave whistles of different pitch. The dolphin, in turn, learns the meaning of each whistle and is taught to reply with similar whistles. What the human hears is synthetic speech (selected "nonsense" words) that are the "translation" of the whistles.

The inherent physical problems in communication—underwater versus in-air modes, and differences in hearing range and sound production—result in subtle difficulties. The meaningful portions of the human voice lie below 3500 Hz; fundamentals and harmonics above this frequency (over which humans have less control) tend only to confuse the dolphin. For example, Dr. Lilly says, humans have an appreciable output in the ultrasonic range. Men cannot hear it and it is of no use to them, but dolphins can hear it. How can you explain to the dolphin that you don't want it to pay attention to these harmonics?

In Dr. Lilly's experiments he prefers operating in real time so that he can relate responses to events and cues. While it is possible to figure things out from the retrospective analysis of tapes, it is like listening to someone on Mars over an rf link—a lot can happen during a pause.

Dr. Lilly therefore uses electronic speech translators that enable the two species to communicate on more even terms. These devices are variants of the Vocoder (voice coder) developed by Homer Dudley of Bell Telephone Laboratories in 1936 to permit the compression of speech for transmission and the reconstruction at the other end of the line.

A typical setup is shown in Fig. 7. Dr. Lilly sits in an observation booth and speaks into a microphone. His voice signals are stepped up in pitch by a factor of 10 in a man-to-dolphin coder that was designed for him by Will Munson. (He is one half of the duo that published the Fletcher-Munson curve of human hearing while at Bell Telephone Laboratories.) Only the band of speech between 200 and 3500 Hz is processed by the coder (that portion of the spectrum over which humans have most control and which is therefore most meaningful to the dolphin). At the same time, his original speech is recorded directly onto one track of a four-channel tape recorder.

10-channel Vocoder used

The voice signals are divided into 10 channels by bandpass filters, amplified, the pitch extracted, rectified and low-pass-filtered. At this point the signals are modulated by a pitch-rate chopper. A pitch circuit provides the timing for the switch that does the chopping. The modulated human voice signals are amplified and bandpass-filtered once again. The final output to the dolphin consists of the intelligence in the band from 200 to 3500 Hz, only shifted upward in frequency by a factor of 10.

The reverse process is used with the dolphin's vocalizations. The same 10 high bands are used, the envelope is stripped, and the signals are used to modulate 10 lower bands. Thus two 10-channel Vocoders are used back-to-back to present the dolphin with high-pitched signals and the human with low-pitched ones.

How much is lost in translation? This can be ascertained by leaving the dolphin out of the loop. The receiving hydrophone in the tank picks up the output of the underwater loudspeaker and feeds the stepped-up human speech frequencies into the dolphin-to-man translator, which reconstructs the input with synthetic speech. Dr. Lilly estimates intelligibility to be 95 per cent.

"It's good enough for you to be able to recognize whether a man or woman is speaking," he says.

A completely different approach to communicating with dolphins was taken by Prof. Batteau. He reasoned that dolphins are equipped to cope with whistles much better than they are with words. Therefore, instead of giving them commands in English, why not in the more familiar whistle format? He chose whistles over clicks "because whistles are easier to produce."

Batteau went to work with Stephen L. Moshier, chief electronics designer at Listening Inc., Arlington, Mass. They devised instrumentation with which human voice sounds are converted into frequency-modulated whistles—a man-to-dolphin translator (Fig. 8) that translates into quasi-delphinese instead of shifting English words up in frequency, as the Vocoder does.

The speaker's words are picked up by a microphone and routed to two sections of the man-to-dolphin translator: the vocal pulse detector and the voice-to-dc converter.

"We measure the time delays in speech rather than the frequencies," Moshier says. "Speech is produced when the vocal cords chop the air flow from the lungs into a series of sharp, acoustical pulses or clicks with fast rise times and relatively long decay. These pulses are reflected — bounced around in the mouth and throat cavities. Information is put onto the pulses as a series of time delays depending on the length of the throat, the position of the tongue and lips, and so forth. The resultant speech signal is a series of exponentially decaying wave trains."

The first step in the analysis of this signal is to extract the time at which the vocal-cord click (as distinct from the reflections) occurs in each wave train. This is done in the vocal-pulse detector, which generates a series of positive-going pulses that correspond to the detected vocal-cord clicks.

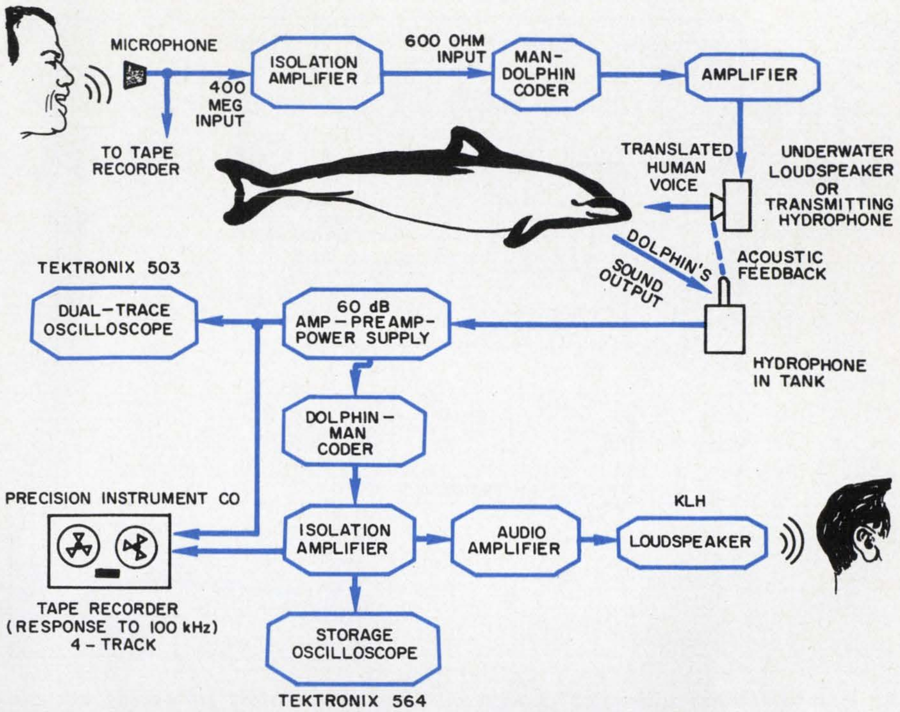
The voice-to-dc converter measures one particular time delay in the speech output—the first formant, lying in a resonance band of roughly 500 to 800 Hz. It is produced by the portion of the vocal tract that extends from the back of the throat to the middle of the tongue. The rest of the speech signal is removed by a 1-kHz low-pass filter. The output is a dc voltage proportional to the measured interval.

The whistle generator is a voltage-controlled oscillator that transforms the dc level into a tone with a frequency that depends on the characteristic time interval of the first formant. The logic and whistle gate defines a minimum and maximum interval between successive vocal pulses for which the whistle output will be gated on. This ensures that a whistle will be produced only when there is a voice input. The gate is turned on as soon as the pulse detector recognizes speech. The whistles are amplified and coupled into the dolphin's tank through a transmitting hydrophone. The whistle amplitude is approximately constant, but the pitch is modulated.

The whistle outputs have been formed into a language of sorts by Batteau. There is a definite, repeatable pitch that corresponds to each acceptable sound. The functional relationships for the sounds in Batteau's language are given in the above table.

Batteau (who passed away in October) and his trainer worked with several dolphins at Coconut Island, Haw., because the sea bottom there is muddy, without much echo. The dolphins respond to a number of words that they learned by means of simultaneous exposure to the word and to the appropriate object or action.

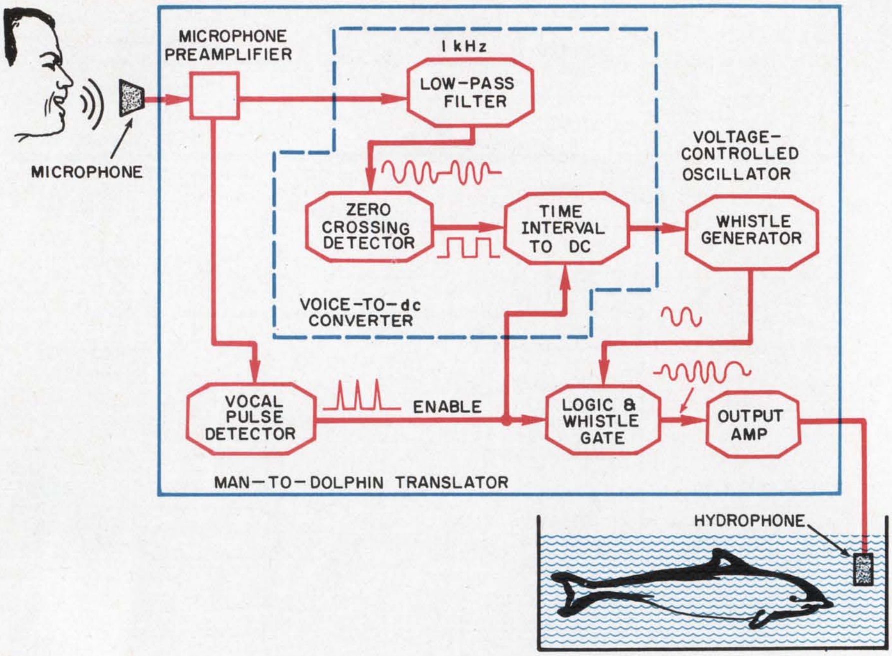
Whenever the dolphin repeats the whistle word (or gives a reasonable approximation), it hears "BIYIP" (the word of acknowledgment)



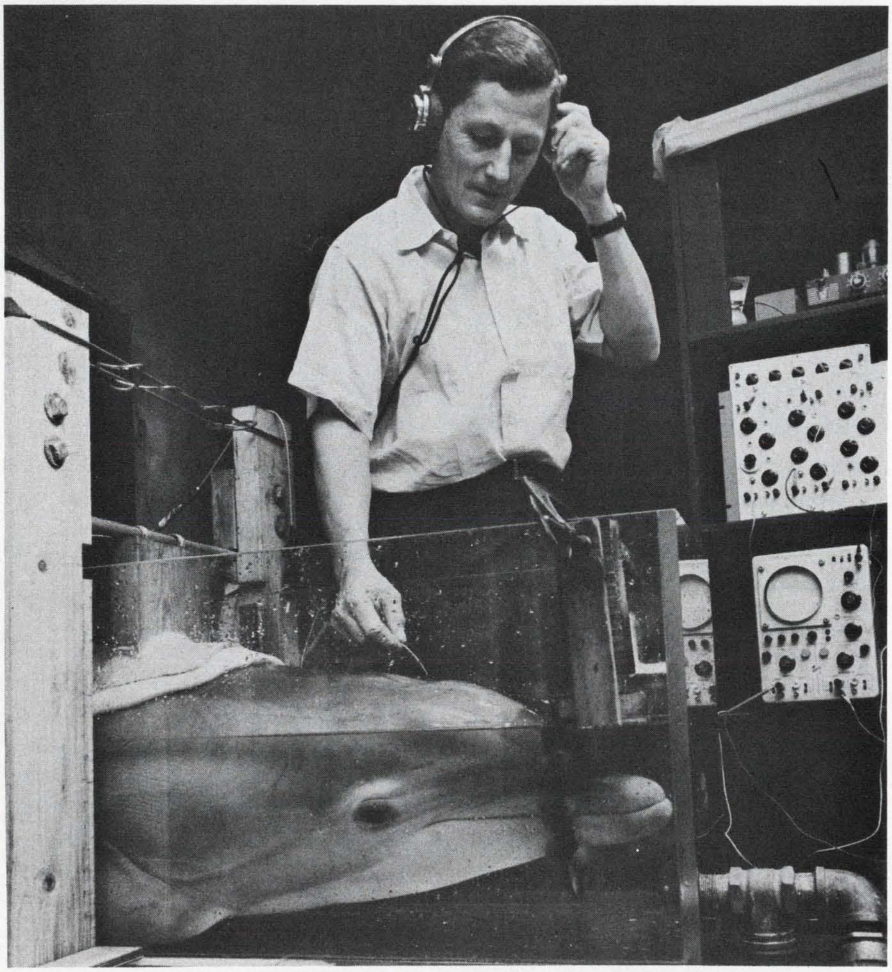
7. **Electronic frequency converter "translates"** human band of speech into higher frequency band. Reverse is done with dolphin's output. Four-track recorder tapes unmodified human speech, translated dolphin output, and unmodified dolphin output on separate tracks.

Table: Relation of whistle and phonetic sounds

Sound	Symbol	Whistle frequency (Hz)
ah	A	7000
a as in bait	E	10,000
i as in sit	i	11,000
r as in burr	R	11,500
oo as in boot	U	12,000
ee as in beet	I	14,000
i as in Spanish sí	Y	15,000
b as in boy	B	(B and P used for distinct beginning and ending of words)
p as in tap	P	



8. **Man-to-dolphin translator** converts artificial vocabulary to whistle outputs separated in pitch. The device, developed by Listening Inc., Arlington, Mass., detects speech and measures time delays of vowels in real time. Dolphin's own whistles are converted into synthetic speech by dolphin-to-man translator.



9. **Dr. Lilly stimulates a dolphin's brain electrically** to induce it to emit a variety of sounds. The operation, which is not dangerous to the animal, has also been performed on monkeys and on men ("Probing the Mind's 'Computer'," ED 11, May 24, 1967, p. 36). The sounds are picked up in air by a microphone.

from the trainer—in the whistle language—and it is given a fish to eat. The vocabulary is limited and artificial. If too many words are used, the human observers might be unable to recognize what the dolphin is saying.

In one experiment a male dolphin named Dash was tested on how well he could identify two objects, a ball and a hoop floating in his pool. He picked out the object named in 85 per cent of the trials. Later, he learned to use the correct whistle word himself in 74 per cent of the trials.

Other words for which Dash learned the whistle equivalents were BAEP, begin echo-locating; BURRAP, wait at the other side of the pool; UEIAP, go through the hoop.

Listening Inc. has also developed a dolphin-to-man translator and a spectrum analyzer.

The dolphin-to-man translator converts the dolphin's whistles into synthetic speech that corresponds to the artificial language—the reverse of what the man-to-dolphin translator does. It has been breadboarded, but not refined.

Batteau was asked whether he had encountered any difficulty in recognizing the repetition of whistles by the dolphin as they come through the speech synthesizer.

"Yes, but not nearly as much as three years ago, when we used only two pulses. You get used to it after a while. I can recognize BAIEP and BIYIP and all the rest, but it's still a far cry from human speech."

Moshier interrupted to say: "We've programmed dolphins in sequences in which the initial command was to repeat the word the trainer spoke. So here's the trainer's word BAIEP and the dolphin immediately replies with a whistle. It's lower than the trainer's but the shape has been reproduced. As you sit with the spectrum analyzer in the training session, you see immediately what the dolphin's saying from the tape spilling out. This is done in real time, which is why we've developed the analyzer."

The spectrum analyzer is a 30-line analog frequency meter and multiple-pen recorder. Each line is traced by one of the 30 pens. Since all the pens move horizontally, the contour lines are not joined, and the over-all impression is gray. Batteau said that this spectrum analyzer is more useful than commercially available apparatus.

The analyzer has two channels. One channel includes a 4-to-20-kHz bandpass filter, which minimizes noise. The second channel is unfiltered and is normally connected directly to the output of the man-to-dolphin translator, to obtain an undistorted record of the transmitting hydrophone signal.

Do you read me dolphin?

Despite the responses Batteau has elicited from his test dolphins, some question remains whether he was communicating with the dolphins or conditioning them to exhibit a type of behavior. In other words, it leaves unanswered the question whether the dolphin is a bright animal that can learn tricks extremely rapidly or an intellect comparable to the human mind.

The criterion would appear to be this: Are the problems interesting to the dolphins in that they engage their intelligence and curiosity, and meaningful in that they involve the right symbols, frequencies and environments? Or is the experimenter unconsciously training to a higher grade of stereotype?

For a clearer picture of the problems that the dolphin's sound emissions pose for the electronic designer, it is helpful to know something about the animal's physics and anatomy.

In the wild, most of the dolphin's sounds are produced under water. The animal generates them with a vocal apparatus that is unorthodox by human standards. To begin with, it talks and breathes through its blowhole. The mouth is for eating and grasping, and serves the dolphin in place of a hand.

When the dolphin is submerged the blowhole is covered by a crescent-shaped plug. The two sides of the plug (called tongues) can be used independently. Not only can the two nasal passages be used separately to emit complex pulses and near-sine waves in the range roughly from 400 Hz to 150 kHz, but the dolphin can also intermix the two simultaneously.

"The sounds are used for both sonar and communication," Dr. Lilly says. "We no longer separate the two."

The dolphin's whistles consist of a sine-like fundamental in the range from 4 to 22 kHz, and a number of harmonics. The clicks, on the other hand, are short pulses with steep leading edges. Since the dolphin can vary the repetition rate, and since the pulses have both sonic and ultrasonic components, the emissions are rich in signal content.

Kenneth Norris suggests that, to imitate dolphin clicks, you try this:

Press your lips tightly together, then force air out as a stream of small bubbles. The tighter your lips, the shorter and sharper the signals, and the richer the high frequencies. Also, the harder you blow, the faster the repetition rate.

Peter Purves, a zoologist from the British Museum of Natural History, London, reports that all of the noises belong to a particular class of vibrations known as relaxation oscillations. Frequency is dependent not on the customary ratio of elasticity and mass, as in the human vocal cords, but on some form of resistance, which, on reaching some critical value, suddenly relaxes and builds up again. The human counterpart is the raspberry or Bronx cheer — made by blowing air through tightly pursed lips.

Bottlenose dolphins "talk" to each other, Dr. Lilly reports. During these formal conversations they exchange whistles and clicks. According to Dr. Lilly they always answer in the mode in which they are addressed and they are very "polite." Each animal waits until the other stops, in the case of the whistles, or there is opportunity to alternate within the train in the case of the clicks.

Whistle sweet nothings

There is also a special phenomenon that Dr. Lilly calls a duet, in which the animals whistle simultaneously. They have the uncanny knack of synchronizing these whistles so accurately that one can hear a beat signal.

Dr. Lilly says that the two sonic modes—whistles and clicks—do not occur at the same time. This means that dolphins can talk with whistles and click trains, so that the whistles and clicks are completely out of phase with each other. Thus dolphins can fill the silences of the whistle exchange with a click exchange and the gaps in the click train with whistles—without interrupting in either mode. To the uninitiated a pair of dolphins gabbing away can sound like four.

Dr. Lilly speculates that dolphins communicate information about objects to other dolphins by transmitting the proper frequency pattern in clicks and whistles. In other words, they can describe a size of shark, say, at a given distance.

"If we are ever to break delphinese and convert it into human language," Dr. Lilly says, "we thus have many hints on which to proceed. At least we have testable hypotheses to either bear out or disprove."

Jarvis Bastian, a psychologist at the Davis campus of the Univ. of Calif., decided to test the hypothesis that dolphins could convey information about an artificial environment to one another.

He partitioned a tank so that two dolphins, a male named Buzz and a female named Doris, could hear but not see each other. He trained them to perform tasks in cooperation when a pair of lights came on. Doris could see both lights, but Buzz only one. The dolphins worked out a signaling system so that they could get their rewards.

Bastian analyzed tape recordings of their vocal outputs and found both clicks and whistles. He concluded that, although the whistles seemed to hold emotional context for Buzz and Doris, they did not account for the correct performance. The state of the lamps was conveyed by click trains. Thus Bastian seemed to prove that dolphins can communicate arbitrary environmental information.

But what of all the other sounds that the person who spends a great deal of time near the dolphin tanks eventually gets to hear?

Dr. Lilly says that barks, blats and the like are common only during intense emotional excitement on the part of the animal. He has tried electrical stimulation of the dolphin's brain to induce the animal to emit a variety of sounds (Fig. 9).

When dolphins have been in close contact with man for a length of time, they somehow learn to vocalize in air with an open blowhole.

Dr. Lilly is convinced that this transition from making sounds under water to making sounds in air is in response to hearing humans' consistent use of air sounds.

"If we talk to them under water, they answer us under water," he says. "If we talk to them in air, they answer us in air."

Dr. Lilly reports that the best humanoid sounds he recorded were made with the slash call. If so, then the dolphin deliberately produces these difference frequencies in order to imitate human sounds in air.

Thus, he concludes, when dolphins learn to make humanoid sounds, they are definitely trying to communicate with us in our own mode.

Dr. Lilly made tape recordings of dolphins mimicking humans by means of sounds emitted from the blowhole opened in air. When he played the tapes back to other scientists, he failed to convince them that they were hearing mimicry. He contends that the skeptics were honest, but that they were not accustomed to these sounds.

If Dr. Lilly is right, then the ability can be learned, just as one can learn to make sense of distorted voice transmission on an aircraft radio in a noisy background.

Since his first attempts, Dr. Lilly has spent considerable effort on "shaping up" the vocal behavior of his dolphins so that they become more and more humanoid. He devised lists of nonsense syllables that he emits in sequence. The dolphin listens and then repeats the list in a Donald Duck sort of voice. Dr. Lilly claims that in tests the dolphins matched the number of sounds made by the human, either exactly or plus or minus one, in 92% of the trials.

How does the dolphin know it is its turn to vocalize? Dr. Lilly surmises that it discerns a change of inflection whenever the reader comes to the last word. This, he says, "is a convincing demonstration of the quality of the mind listening at the other end of this system."

While he does not claim to have cracked the dolphin's own language, or proved that the dolphin understands us, Dr. Lilly asserts that at least he has proved that dolphins are trainable.

"The next step, a long one, is demonstrating that the dolphin can meaningfully use these sounds as we use language and speech," he says.

Dr. Lilly's views are shared by few other investigators. Some scientists openly sneer at his theories. Yet he persists. He has not succeeded in making the dolphins learn English, but he has discovered many surprising things that shed light on dolphins and men.

IV. The future

What is the future of this research? It will become more and more ambitious as existing programs are completed. Already psychologists and social scientists are involved as well as biologists and engineers. Several investigators have been studying the behavior of dolphins at Sea Life Park in Oahu, and at the Communication Research Institute. The animals are rewarded for every display of new behavior. Dolphins respond to this treatment because they seem to get bored by simple, repetitious tasks like swimming through the same plastic hoop. Some day psychologists may devise meaningful tests of intelligence for these animals.

It is expected that the dolphin will make significant contributions to man's progress in the development of the sea, especially of the continental shelves. This has been proved on Sealab II, the Navy's man-in-the-sea program, in which a dolphin was harnessed to carry tools to aquanauts 200 feet under the surface.

There has been some speculation in the popular press about the use of dolphins as military combatants. One hears of dolphins being trained to survey enemy waters and return with intelligence reports, to listen for the approach of enemy submarines and to fight frogmen. For example, one reporter suggests that "lethal dolphins" equipped with dynamite on their harnesses could ram submarines.

These speculations cannot be dismissed out of hand, since a knowledgeable trainer can work wonders with these animals. However, analysis of the known physical limitations of dolphins reveals:

- Dolphins are not fast enough to intercept nuclear submarines. In tests conducted for the Naval Ordnance Test Station by Thomas G. Lang, it was found that the fastest dolphin could not exceed 22 knots in a short sprint — a far cry from the 30 knots reported by many sailors. (There is an explanation for this discrepancy: dolphins know how to ride the bow waves from ships, and thus they are in part coasting with a boost from the ship's power plant.)
- Nor can they dive deep enough. The deepest descent reported was 550 feet by Tuffy on the Sealab program in a 2-3/4 minute round trip. Dolphins cannot hold their breath for more than 6 minutes.
- Their sonar is good for only a few hundred feet in horizontal layers of the ocean. Whether it could scan a sector perhaps a thousand feet down is not known.

What does seem feasible is the towing of targets for the training of sonar operators, and towing of experimental devices to test their performance. This, of course, is all speculation.

The attempt to communicate with dolphins is continually pointing up the inadequacy of electronic equipment. Present research may lead to the development of superior receiving and transmitting hydrophones, and in turn advance the technology of antisubmarine warfare.

The research should certainly lead to the development of much-needed field equipment that will aid investigators in many of the life sciences.

Finally, it may cause us to crystallize our ideas on how to communicate with extraterrestrial intelligence. We may never find it on our future interplanetary and interstellar expeditions, but we may be overlooking something right under our own noses because of our preconceptions about how intelligent beings should look.

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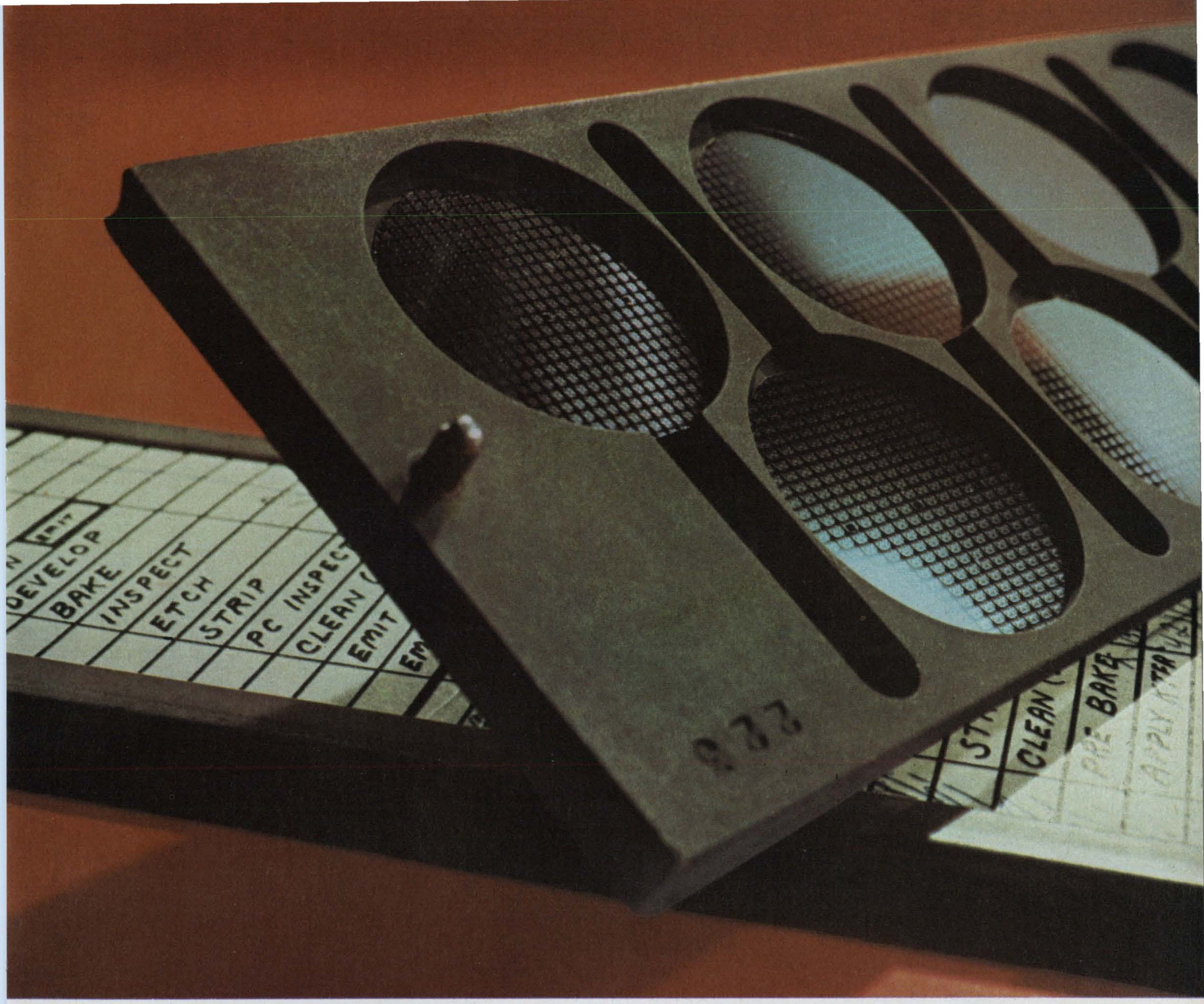
(Photographs courtesy of George Musil, Dale Beatty, Dwight Batteau, Black Star and the U.S. Navy)

Free reprint

A copy of this report, "Dolphins challenge the designer," will be sent free of charge to readers who circle Reader-Service No. **250.**



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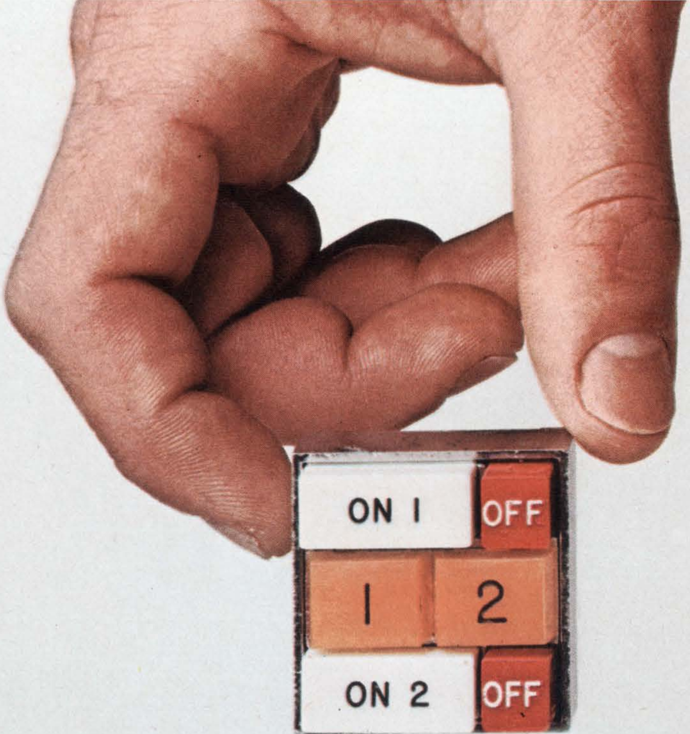

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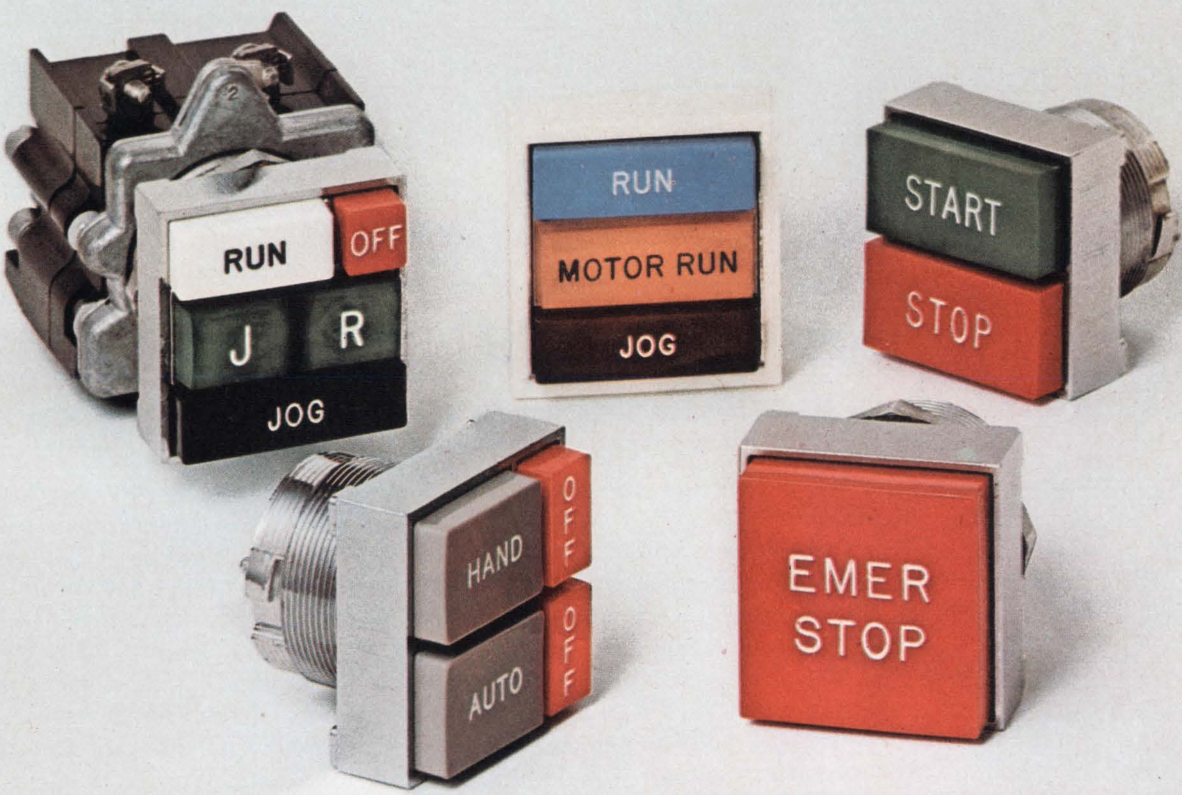
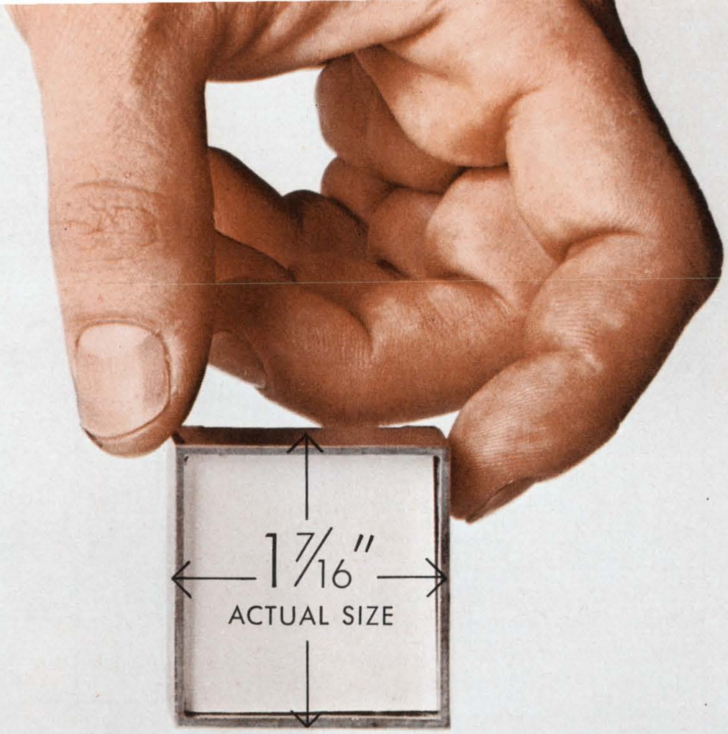


New Cutler-Hammer compact pushbuttons use the same $1\frac{3}{16}$" round industry-standard mounting holes as your present full-size oiltight pushbuttons.



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CONTROL

ON READER-SERVICE CARD CIRCLE 867

Letters

Challenge to design of random generator

Sir:

The circuit shown on p. 98 of the June 7, 1967, issue of ELECTRONIC DESIGN, "Random-signal generator uses Zener diode" [ED 12, Ideas for Design], will not operate with the voltage and Zener-diode polarity given.

To make it operate, either the Zener and power-supply polarity must be reversed, or the transistors must be exchanged and the Zener reversed from the way it is shown in the diagram.

I also found it necessary to place an 0.01-μF ceramic-disk capacitor between the collector and ground of the emitter follower in order to prevent oscillation.

C. W. Potter
Avionics Laboratory
General Dynamics
Fort Worth, Tex.

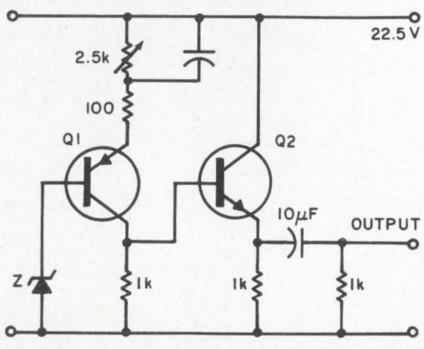
The designer responds

Sir:

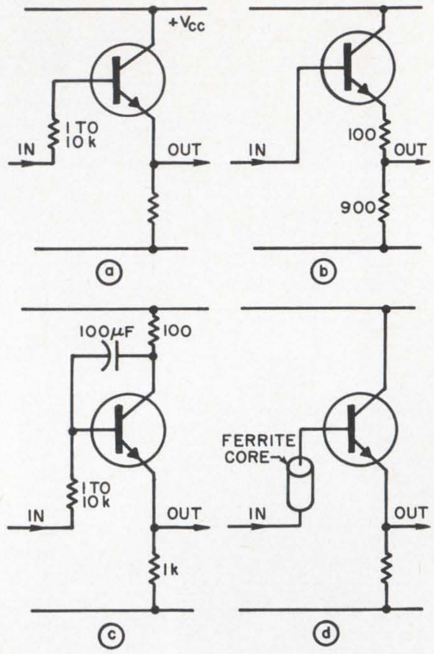
I should like to thank Mr. Potter for his comments. An error did indeed slip into the circuit diagram. The correct diagram is shown in Fig. 1. It is also possible to use an npn transistor for *Q1* and a pnp for *Q2* by inverting the power supply.

I have noted no tendency for the emitter-follower stage to oscillate. Should this occur, however, four methods of eliminating it are shown in Fig. 2.

Roger Damaye
Electrical Engineer
Fontenay aux Roses (H. de S.)
France



1. **Random-signal generator** has Zener diode as noise source.



2. **Oscillation in emitter follower** of random-signal generator can be eliminated by four methods.

'Tiny flaws' plague all instrumentation

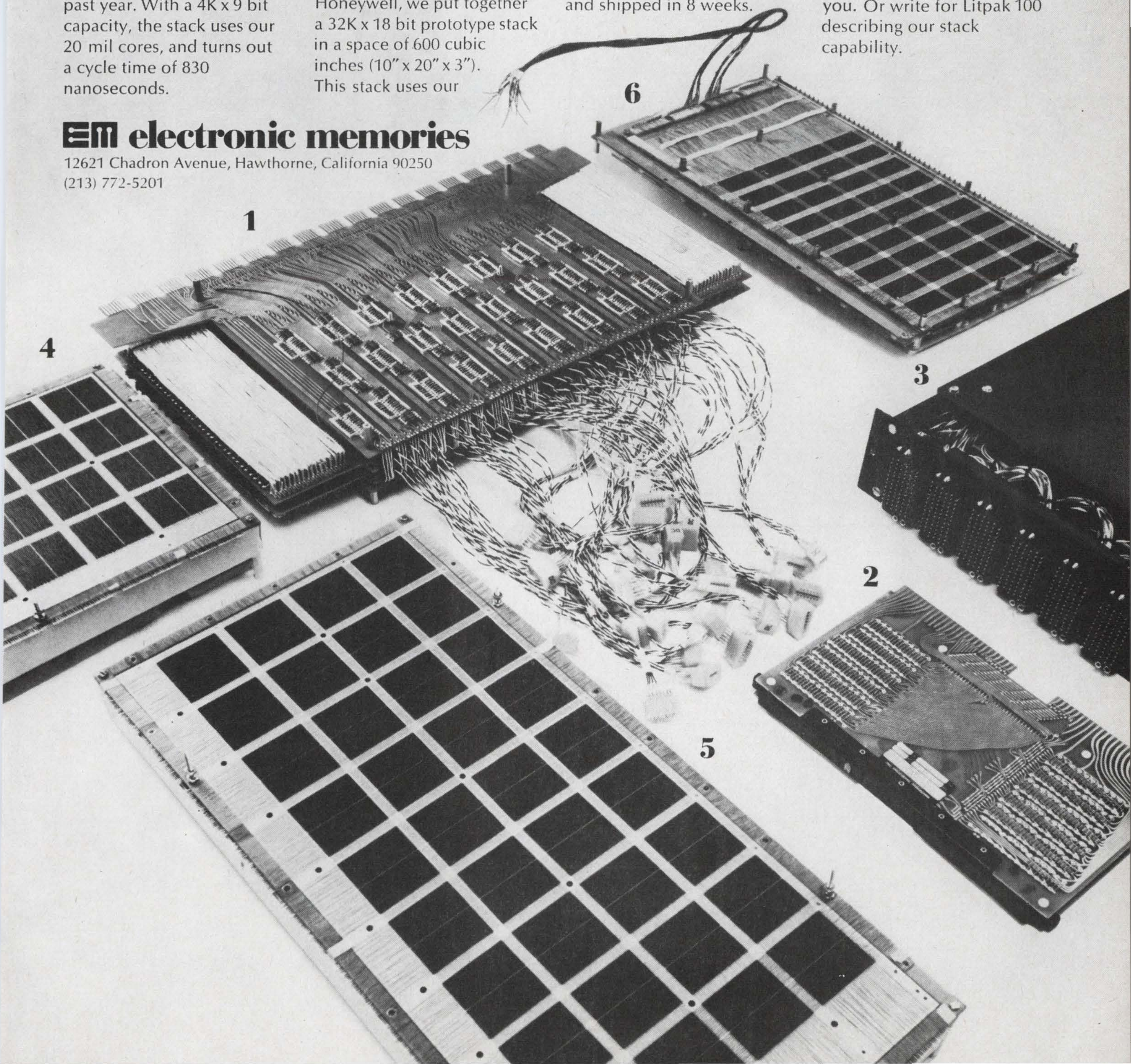
Sir:

Ron Gechman's article ["The Tiny flaws in medical design can kill," ED 18, Sept. 1, 1967, pp. 22-26], is an excellent beginning on a subject that has been ignored far too long! The problems he cites in the design of medical equipment have existed, in latent form, in general instrumentation for many years.

After more than 30 years in this field I am struck by the ability of some engineers to isolate themselves from factual knowledge of anything but their own narrow field of interest. Thus we have designers acting as though their products were operated only in solitary environments, where any tests they may make clearly show how well they work—alone!

Take a case in point. Consider the archaic practice of the bypass capacitors connected from each side of an ac line to instrument chassis (*C1, C2* etc. in the figure on p. 24 of Gechman's article). These capacitors are "carefully" chosen to limit the maximum current to a "safe value." This is fine for the solitary instrument—but sheer nonsense for a multiple system composed of many such instruments neatly in-

(continued on p. 72)


6
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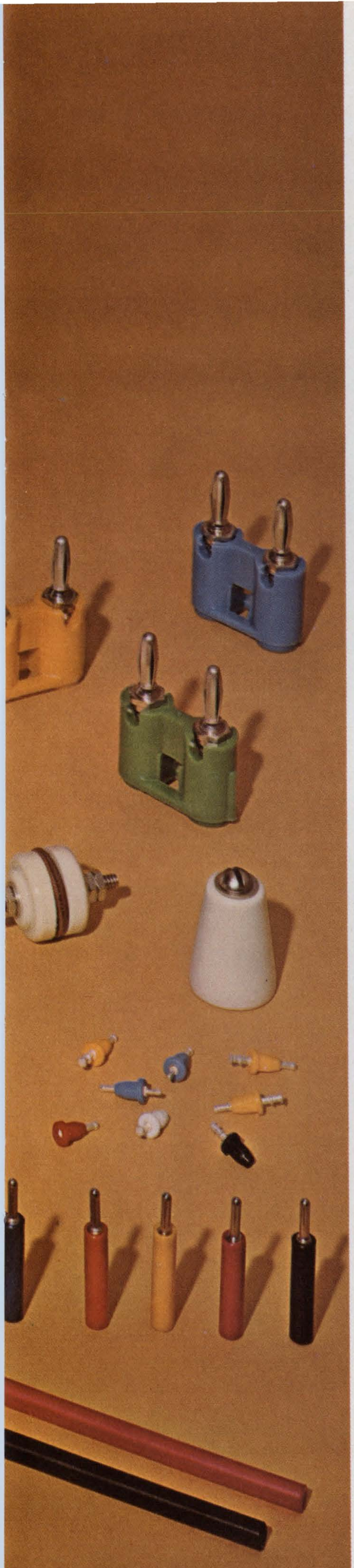
Portrait of a most reliable family



More accurately, the portrait shows only *part* of a most reliable family. The E. F. Johnson Company makes hundreds of fine quality electronic components, including:

CAPACITORS—A dozen basic series of air variable capacitors, each in a wide choice of capacity values. They range from sub-miniature machined plate capacitors with maximums of 4.2 to 24.5 pf., to larger, heavy-duty types with capacity values to 1700 pf. and voltage ratings to 9000 volts peak.

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ON READER-SERVICE CARD CIRCLE 37

LETTERS

(Continued from p. 68)

stalled in a "grounded" relay rack or metal cabinet. How many instruments (that is, bypass capacitors) does it take to build up a dangerous situation, should the "ground" actually become open or develop resistance due to corrosion, etc? Whose responsibility is this?

Old-timers will recognize this situation as the cause of "burned-out" attenuators, "ground loop" errors, and similar features.

Can we afford to continue this farce where lives are at stake? The solution is complicated by the mere existence of large numbers of such equipment, let alone by the steps necessary to correct new designs.

Charles A. Cady
Consultants Associates
Wayland, Mass.

Accuracy is our policy

In "Go-no-go comparator uses complementary addition," in the Ideas for Design section of ED 17, Aug. 16, 1967, pp. 274-276, the following errors should be corrected in the labels on the left side of the figure:

I_0 should be L_0;

G_N should be G_H (gate high limit);

G_L means gate low limit.

The following truth table mentioned in the text was omitted:

C_n low	C_n high	Result
1	0	in limits
0	0	below
1	1	above
0	1	invalid

In "Use the signal flow graph technique," ED 17, Aug. 16, 1967, pp. 254-256, author Glenn DeBella has noted five inaccuracies:

On p. 254, right-hand column:

The definition of *Forward path* should read: "A flow graph may have more than one forward path" (not "forward step" as printed).

The definition of *Feedback loop* should show as a second example: x_4, x_5, x_4 (not x_4, x_3, x_4, as printed).

The definition of *Self loop* should read: "A branch originating and terminating on the same node" (not "on the same model" as printed).

On p. 256:

In Eq. 9 the fourth equation should be:

$$v_2 = [(i_1 - i_2)R_L] - [a_o R_L v_{b'e}/R_L],$$

where R_L in the first element is a multiplier, not a divisor as printed.

In Fig. 3c, the transmittance of the branch directed to node $v_{b'e}$ from node i_2 should be $-1/C_{ob}s$, not a positive quantity as printed.

In "Push-button switches for circuit boards," in the Components listing of the Products section of ED 22, Oct. 25, 1967, p. 178, the price should read: $2.08 per unit in 1000 lots," not "$208 in 1000 lots" as printed.

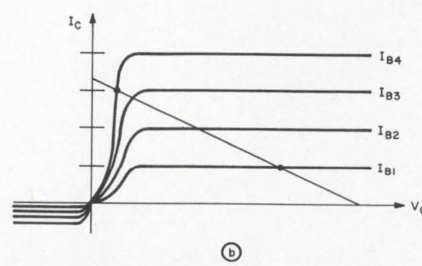
In "Computer talks to the circuit designer," ED 21, Oct. 11, 1967, pp. 58-63, author Richard McNair draws attention to the following errors:

On p. 61 left-hand column, in the list of definitions of the eight parameters that describe the transistor model, the definition of V_{SAT} should read: "the collector voltage at $Ic_{(sat)}$ and $I_{B(sat)}$" (not $I_{B(act)}$, as printed).

On p. 61, right-hand column, the third line should read: ". . . V_{SAT} is measured. A separate parameter, I_{CBO} is . . ." (inserting the dropped I).

On p. 61, Table 1, the output quantities for the TRANsistor element should read: "Base, collector and emitter currents, power dissipation, forward base-emitter, collector-emitter and base-collector voltage drops and circuit gain, I_C/I_B" (inserting the dropped words "collector-emitter").

On p. 60, Fig. 7b, the load line was omitted from the curves. The corrected figure is republished below:



(b)

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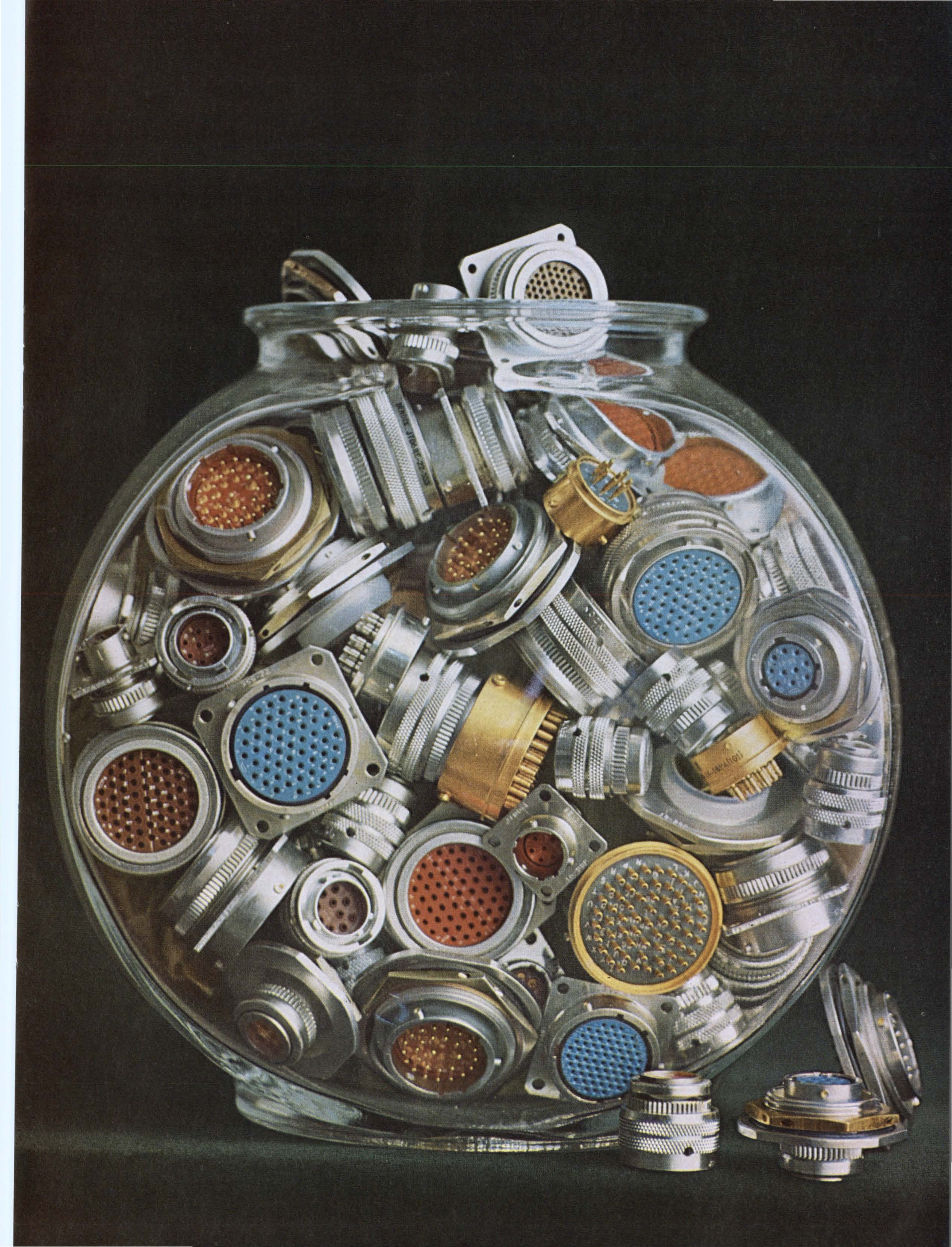
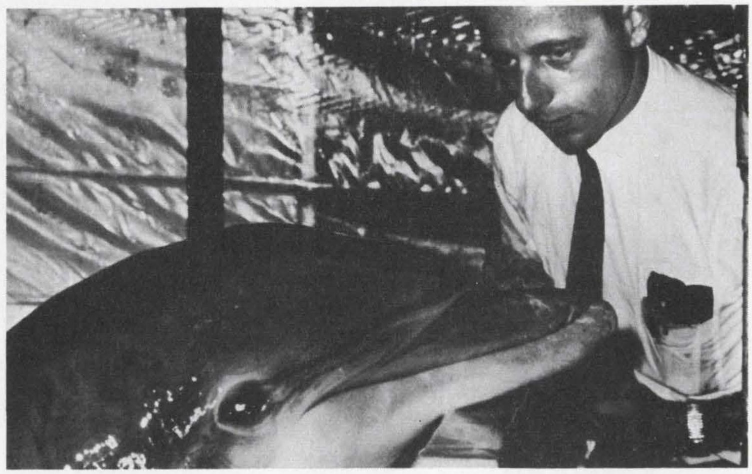
ON READER-SERVICE CARD CIRCLE 39



Dolphins receive top billing



Einhorn and Pequod size each other up.

With a dozen years' experience in technical publishing before he joined our editorial staff this year, News Editor Richard Einhorn found his latest major project both intriguing and exasperating. Dolphins, he discovered, are not only friendly but also very mischievous. He recalls how one named Pequod once seized his notebook and practically blotted out an interview with researcher Dr. John Lilly. In fact, regular wettings are an occupational hazard of working with dolphins, and a pair of black shoes permanently bleached by seawater is Einhorn's enduring reminder of this fact.

Nevertheless, out of the amicable working relationship that Einhorn established both with the dolphins themselves and their investigators comes the second feature this year on electronics and the life sciences (the first was "Probing the mind's 'computer,' ED 11, May 24). It took him to Florida, California and Massachusetts, and includes some of the very last ideas on dolphin communications of a noted researcher, the late Prof. Dwight Batteau, President of Listening, Inc., of Arlington, Mass.

New column makes its bow

A new regular feature makes its first appearance in this issue. It grew out of an editorial discussion of how to answer the tremendous number of readers' questions about integrated circuits. ELECTRONIC DESIGN has launched a cooperative effort with Integrated Circuit Engineering, Inc., of Phoenix, Ariz., who give courses on microelectronics all over the world. Technical Editor Roger Field is in charge of this end of the project, which will draw on our many sources and ICE's experience to answer the most interesting questions we receive.

EDITORIAL

Engineers are no longer islands unto themselves

The United States has spent some $50 billion on space and space-related activities in the 10 years since Sputnik. The 'fallout' from these programs has spread in many directions—from Teflon-coated cooking utensils to cigarette-pack-sized transistor radios to communications satellites that make possible instant television and telephone communications around the world.

The most important result of the past decade, however, cannot be measured simply in dollars or in numbers of new products for the consumer market. What has happened is that the role of the engineer has changed. Once there were mechanical and civil engineers—jacks-of-all trades—who were called on to find practical solutions to problems in almost all engineering areas. Then came the day of the rigid engineering specialty. Now, says the National Society of Professional Engineers, we are "back to the concept that an engineer is a man of the modern world who can and will tackle any problem to which application of scientific principles offers a possible solution."

"The 10 years since Sputnik jarred the U.S. out of its scientific complacency have brought the evolution of a new kind of engineer, who must take a broad look at a whole problem, so that he can dream and dare well beyond the strictness of his training," says Paul H. Robbins, the executive director of the society.

The task of constructing and launching a space vehicle the size of Saturn/Apollo, which stands some 36 stories high and that holds vast quantities of fuel, equipment, controls and a living environment for men, requires an engineer who, according to Robbins, "can back away from his own specialty and his own field, for a better look at what his peers are doing in other areas."

He has to learn the language of other disciplines, learn more of their problems, see what is being done or what could be done elsewhere that would help him solve his design problem.

If the metallurgical engineer can develop a lighter, stronger metal, then the structural engineer can design a more advanced spacecraft; if the chemical engineer can come up with a better, tougher, lighter plastic, then the electronic designer could do a better job miniaturizing components.

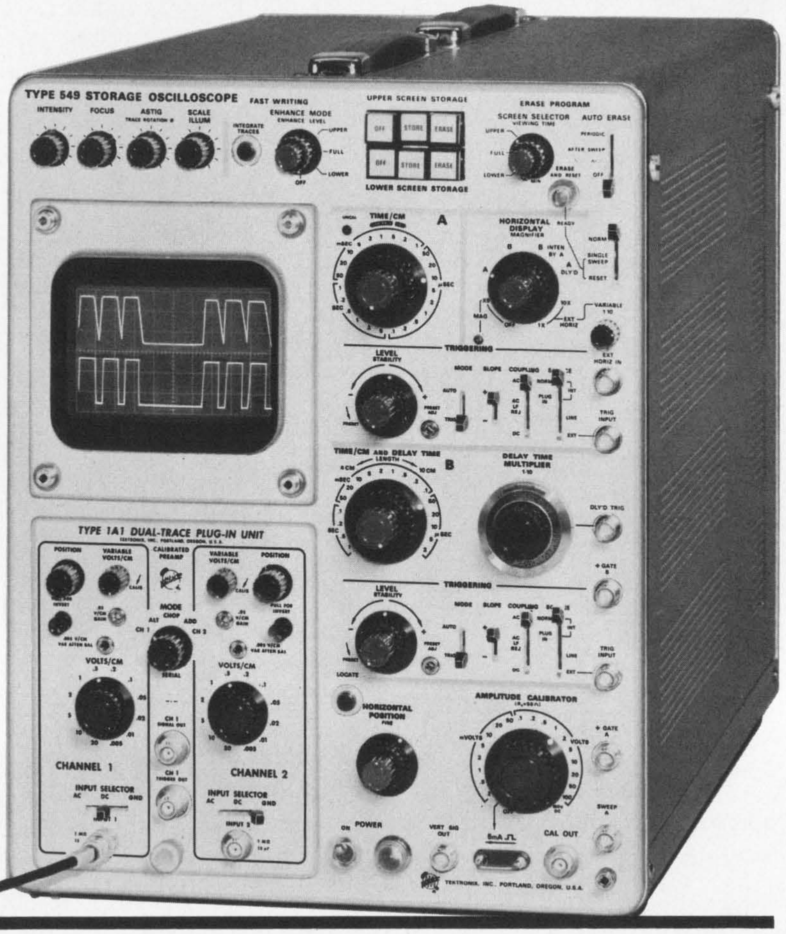
The engineer who really gets ahead today is the engineer who knows what his colleague in an allied field is doing. The two, by cooperating, may solve a problem that has stumped each alone.

RALPH DOBRINER

◄ ON READER-SERVICE CARD CIRCLE 43

variable viewing time 5 cm/μs stored writing speed

split-screen displays



all in the Tektronix Type 549 Storage Oscilloscope

Waveform display showing train of pulses. Upper screen in the stored mode shows three pulses with falltime of the pulse trailing edge showing system deficiency. Lower screen in conventional display mode shows the same pulse train with corrections applied to provide a well formed pulse shape. Pulse width shown is 8 μs with risetime of 0.1 μs. Vertical deflection factor is 0.5 volts/cm. Horizontal deflection factor is 10 μs/cm. Repetitive sweep used for both displays.

The Type 549 allows up to one hour of continuous visual storage, giving you ample time in most applications to measure and analyze stored waveforms. Stored displays can be erased in less than one-quarter of a second.

Split-screen displays

Unique with Tektronix storage oscilloscopes, split-screen displays bring you many advantages in waveform-comparison applications. You can use either half of the 6 cm by 10 cm display area for stored displays, the other half for nonstored displays, with independent control of each half. You can also use the entire screen for either type of display.

Variable viewing time

Variable viewing time — an outstanding feature of the Type 549 — allows you to automatically store displays, view them for a selected time, then automatically erase them on either or both halves of the screen. Two modes of operation are possible. In the After-Sweep Automatic Erase Mode, the selectable viewing time of 0.5 s to 5 s begins at the end of each complete sweep. After the viewing time, the display is automatically erased and the cycle begins again when the next sweep is triggered by a signal.

In the Periodic Automatic Erase Mode, the sequence of storing, viewing time and erasure is continuous and independent of the sweep or signal. In this mode, the viewing time can also be varied from 0.5 s to 5 s.

There is no degradation of stored traces during the selected viewing time, in either mode, and you can retain or erase displays manually whenever desired.

Bistable storage advantages

With bistable storage oscilloscopes, such as the Type 564 and Type 549, the contrast ratio and brightness of stored displays are constant and independent of the viewing time, writing and sweep speeds, or signal repetition rates. This also simplifies waveform photography. Once initial camera settings are made for photographs of one stored display, no further adjustments are needed for photographs of subsequent stored displays.

Tektronix bistable storage cathode ray tubes are not inherently susceptible to burn-damage and require only the ordinary precautions taken in operating conventional oscilloscopes.

Plug-in unit adaptability

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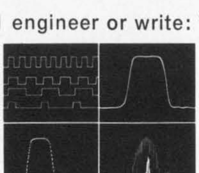
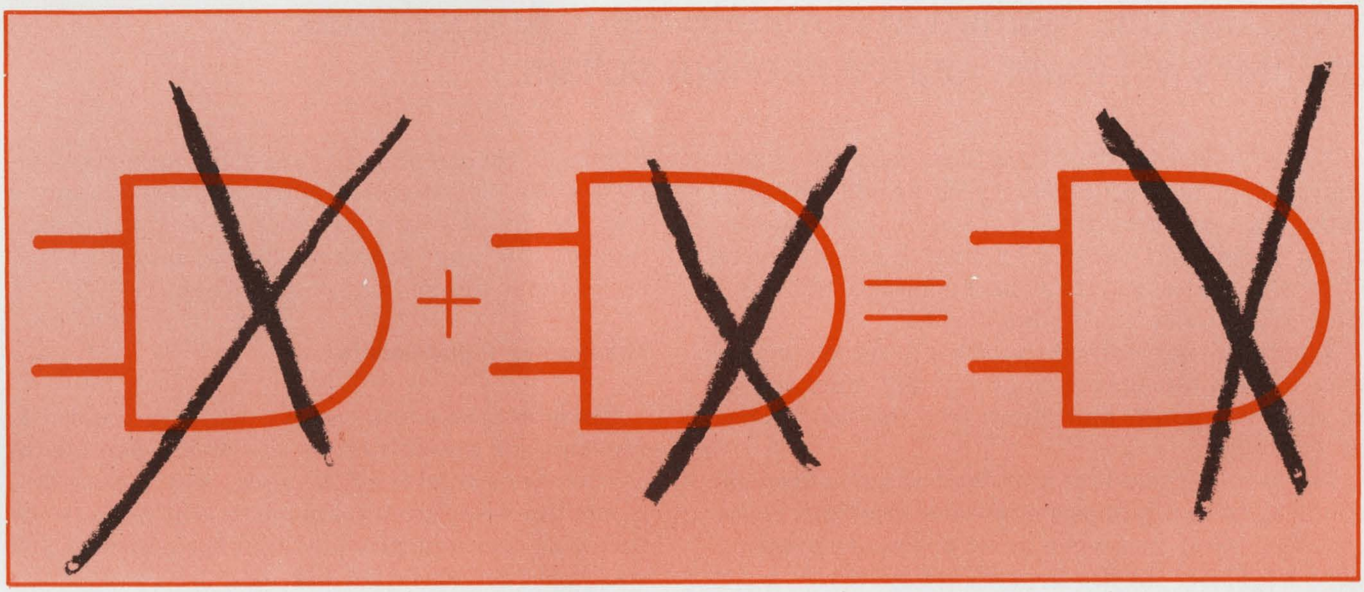


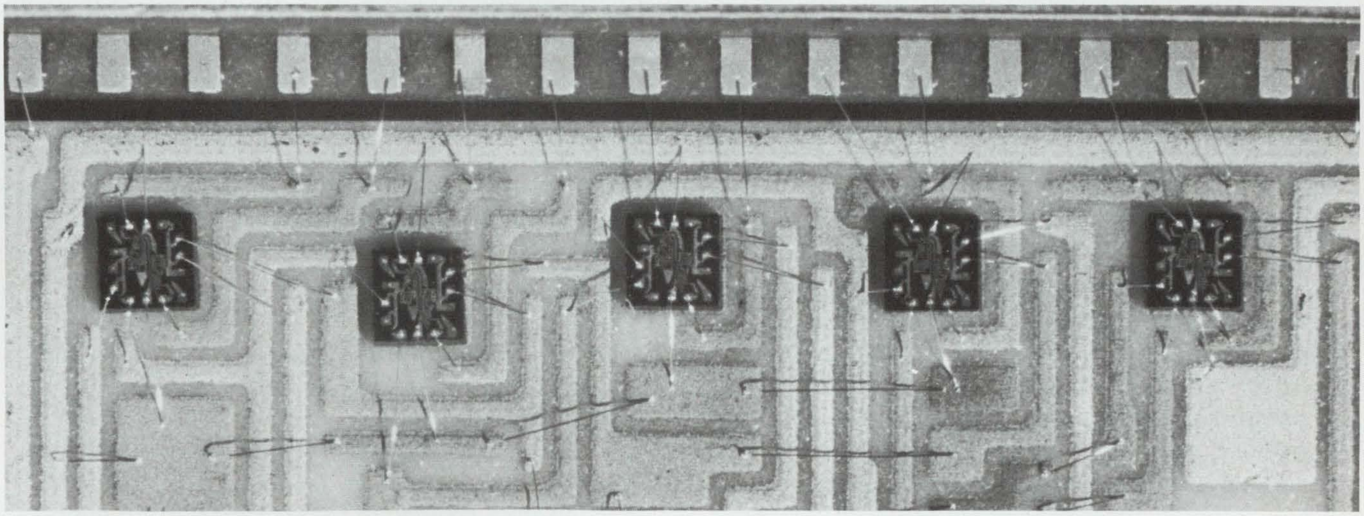
. . . in all Tektronix 530-540-550-series plug-in oscilloscopes

ON READER-SERVICE CARD CIRCLE 46

Technology



Counters can be designed without gates or a central clock. The use of only J-K flip-flops with an asynchronous counting system cuts component costs and design time. Page 82



Are you abreast of latest developments in microelectronics? "Test your IC IQ," a new regular feature, answers your questions. It makes its first appearance on page 100.

Also in this section:

Counter designs swing without gates

if you use this method to eliminate them. And gateless counters will lower your component dollars.

Nearly every computing system uses frequency counters. Binary counters, which provide division ratios that are powers of two, are the least complicated to design. Counting by anything but powers of two, however, can consume a good deal of design time and require many components.

The following method enables a designer to produce a counter that counts by any number. It requires no gates, and eliminates the need for a central clock.

In essence, then, it is a method of asynchronous counting with flip-flops alone—J-K flip-flops. These counters count only when input pulses are present; between pulses the flip-flops do not switch.

The output of these counting circuits is simply the input divided by the integer that the circuit is designed to count by. For example, in counting by seven the counter would produce an output pulse for every seventh pulse on its input.

The method uses an extra flip-flop or two to eliminate two gate networks per stage; each network usually consists of two to five gates. In other words, a given counter may well have "counters" within it.

The method differs from simple synchronous counting in that its counters do not always count in a simple, uninterrupted binary sequence. And, unlike simple counters, the input flip-flop is not always prepared to take another input pulse immediately after the preceding pulse switches it. For some counter transitions, certain input pulses have to be timed no more closely than a length of time determined by the particular counter's maximum recovery factor. That is, several flip-flops may have to flip in sequence owing to the various feedback loops. Thus the input pulses must be spaced at intervals greater than the propagation delay of one stage multiplied by the greatest number of stages that may have to flip in sequence. That is:

$$t_{MAX} = F_{R(MAX)}\, t_d,$$

where t_d is the propagation delay of the flip-flop, and $F_{R(MAX)}$ is the largest recovery factor between counts as the counter is pulsed through its complete cycle. (If the maximum recovery factor is one, the counter is equivalent to a synchronous counter and input pulses can be fed into it as fast as its input flip-flop can handle them.)

Peter S. Duryee, Senior Engineer, Motorola Government Electronics Div., Scottsdale, Ariz.

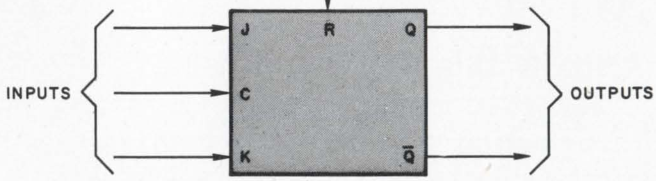
The flip-flop requirements

There are, of course, many ways to build J-K flip-flops and a wide variety of J-K flip-flop microcircuits are available off the shelf. Any J-K circuit, monolithic or discrete component, will work in the following counters, provided that it performs these standard functions (see Fig. 1):

- With logic zeros on both J and K inputs, a pulse to *C* input causes no change at the output.
- With a zero on *K* and one on *J*, a pulse to *C* forces the flip-flop to a *SET* state regardless of its previous state.
- With a one on *K* and zero on *J*, a pulse to *C* forces a *RESET* state.
- With ones on both *J* and *K*, each pulse to *C* causes the flip-flop to change state.
- An *R* input *RESETS* the flip-flop and has priority over all other inputs.

Find the elusive clock

In some logic families there is no clock, *C*, input. An input marked trigger, *T* may sometimes be used to perform this function. Where there is neither clock input nor trigger input, there are inevitably two (or more) *J* and two (or more) *K* inputs. In these units a trigger is formed merely by connecting one of the *J* inputs to one of the *K*s. (Motorola's



1. **The sole part that counts** is this J-K flip-flop. The clock input, C, is often called the trigger input, T. R overrides all other inputs and resets the flip-flop. Unused inputs must be terminated according to the manufacturer's recommendations.

high-speed emitter-coupled logic, for example, has just such an arrangement. In addition, its inputs are inverted. In this special case, then, the designer should use the same wiring diagrams but be sure to interchange Q and $\overline{Q}$ and wire J and K input to logic zero wherever the diagrams call for connection to the logic one bus voltage.)

Regardless of the logic used, be sure to follow the manufacturer's recommendations for the disposal of unused inputs. Some manufacturers require their connection to supply voltage; some to the return line; some to a logic bus; some to a similar, but operating, input. Some logic families may not operate properly if unused inputs are left dangling, or if they are improperly connected.

Table 1 does the legwork

Table 1 tabulates all the information needed to design quickly a gateless counter that counts by any number from two to 100. Schematics, and alternative schematics were applicable, give the designs for the most commonly used integers, namely one through 20.

The first column (on the left) indicates the counting unit (the input-output frequency ratio).

The second column shows the number of J-K flip-flops required for gateless counting by that integer.

Column three indicates the minimum number of flip-flops required even if the designer uses gates. Notice that gateless counting never requires more than two flip-flops more than gated counting, except for the case of counting by 59s, where three additional flip-flops are needed for gateless counting. In many cases, gateless design requires no additional flip-flops.

The fourth column gives the arithmetic in the form of a number group, which can be easily translated into a logic design. (An example is given below.) Schematics are included for the common counting integers, two to 20.

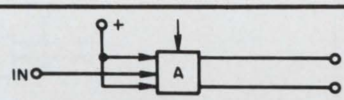
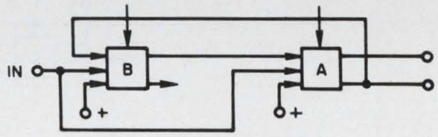
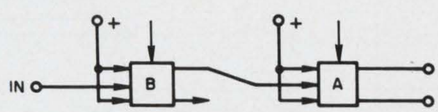
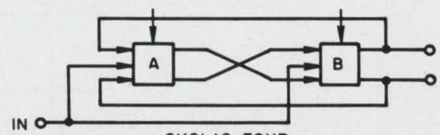
Column five pinpoints the type of feedback used by the logic circuit. The numbers refer to feedback loops that appear in Table 2.

How to derive a number group

The number groups are extremely easy to derive.

(text continued on p. 88)

Table I. Schematics for gateless counting

Input / Output	No. F-F Gateless counters	No. F-F Gated counters	Form for wiring		Type of counters
2	1	1	2	 STRAIGHT TWO MAXIMUM RECOVERY FACTOR = I	
3	2	2	(2 + 1)	 STRAIGHT THREE M R F = I	I
4	2	2	4	 STRAIGHT FOUR M R F = 2  CYCLIC FOUR M R F = I	

(continued on next page)

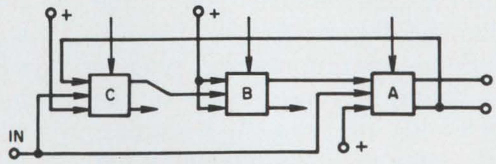
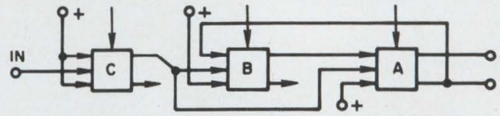
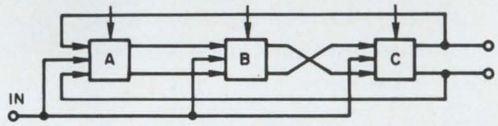
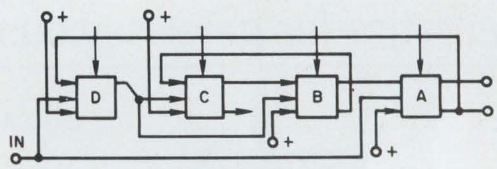
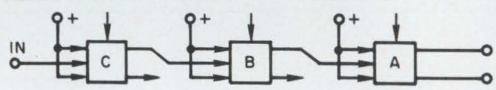
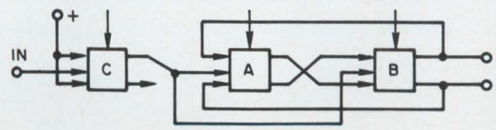
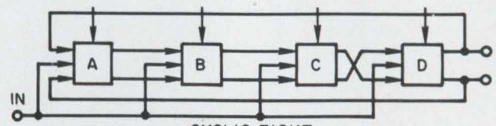
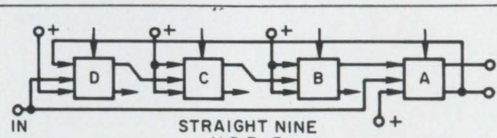
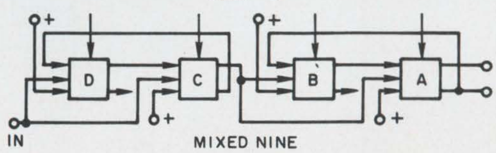
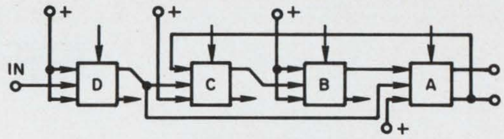
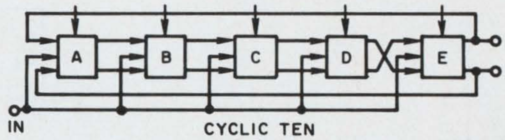
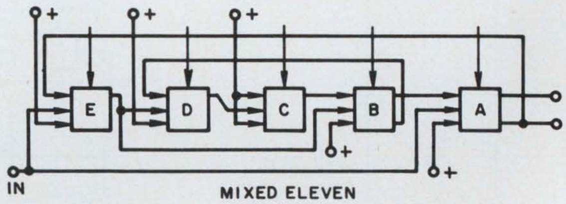
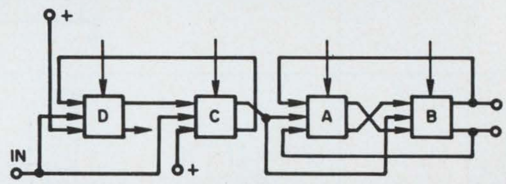
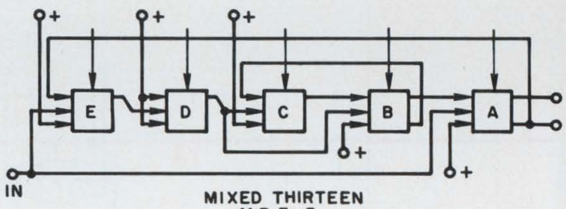
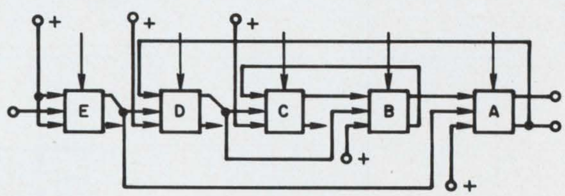
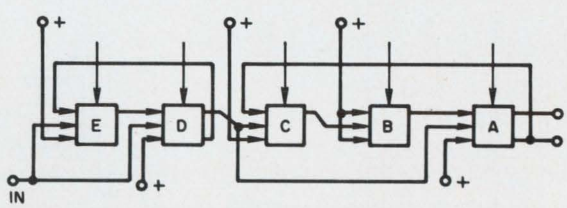
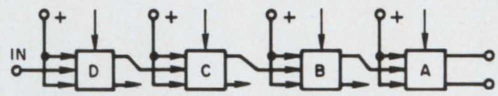
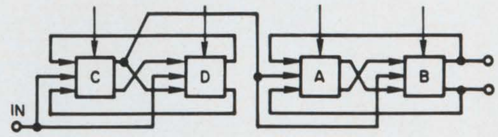
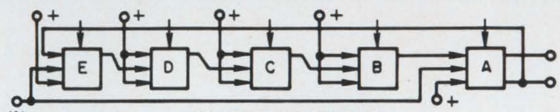
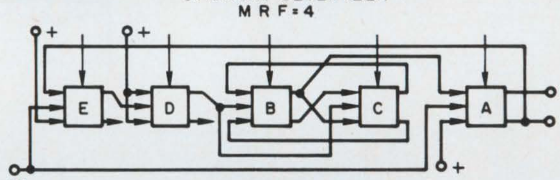
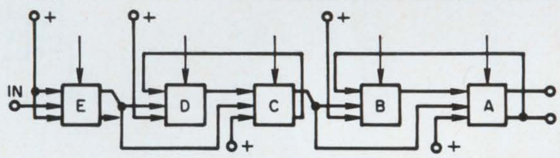
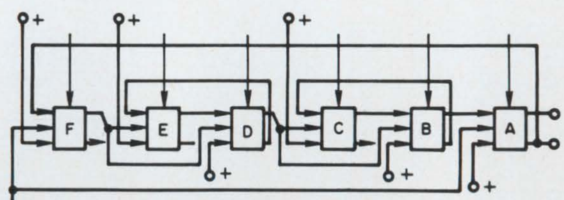
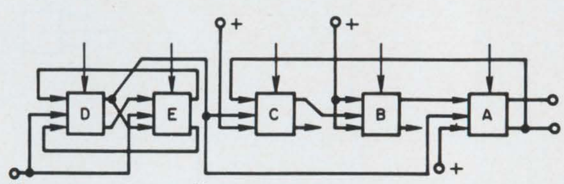
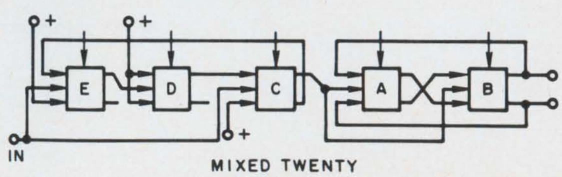
Input/Output	No. F-F Gateless counters	No. F-F Gated counters	Form for wiring		Type of counters
5	3	3	(4 + 1)	 STRAIGHT FIVE MAXIMUM RECOVERY FACTOR = 2	I
6	3	3	2(2 + 1)	 STRAIGHT SIX M R F = 2  CYCLIC SIX M R F = 1	I
7	4	3	2(2 + 1) + 1	 MIXED SEVEN M R F = 2	II
8	3	3	8	 STRAIGHT EIGHT M R F = 3  SEMICYCLIC EIGHT M R F = 2  CYCLIC EIGHT M R F = 1	I
9	4	4	(8 + 1) OR (2 + 1) (2 + 1)	 STRAIGHT NINE M R F = 3  MIXED NINE M R F = 2	

Table I. continued

Input/Output	No. F-F Gateless counters	No. F-F Gated counters	Form for wiring		Type of counters
10	4	4	2(4 + 1)	 STRAIGHT TEN MRF=3  CYCLIC TEN MRF=1	I
11	5	4	2(4 + 1) + 1	 MIXED ELEVEN MRF=3	II
12	4	4	4(2 + 1)	 MIXED TWELVE MRF=2	I
13	5	4	4(2 + 1) + 1	 MIXED THIRTEEN MRF=3	II
14	5	4	2[2(2 + 1) + 1]	 MIXED FOURTEEN MRF=3	II
15	5	4	(2 + 1) (4 + 1)	 MIXED FIFTEEN MRF=3	I

(continued on next page)

Table I. continued

Input/Output	No. F-F Gateless counters	No. F-F Gated counters	Form for wiring		Type of counters
16	4	4	16	 STRAIGHT SIXTEEN MAXIMUM RECOVERY FACTOR = 4  SEMICYCLIC SIXTEEN M R F = 2	
17	5	5	(16 + 1)	 STRAIGHT SEVENTEEN M R F = 4  MIXED SEVENTEEN M R F = 3	I
18	5	5	2(8 + 1) OR 2(2 + 1) (2 + 1)	 MIXED EIGHTEEN M R F = 3	I
19	6	5	2(8 + 1) + 1 OR 2(2 + 1) (2 + 1) + 1	 MIXED NINETEEN M R F = 3	II
20	5	5	4(4 + 1)	 MIXED TWENTY M R F = 3  MIXED TWENTY M R F = 2	I

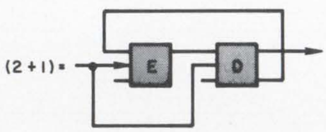
Input/Output	No. F-F Gateless counters	No. F-F Gated counters	Form for wiring	Type of counters
21	6	5	(2 + 1) [2 (2 + 1) + 1] OR 4 (4 + 1) + 1	II
22	6	5	2 [2 (4 + 1) + 1]	II
23	7	5	2 [2 (4 + 1) + 1] + 1	II
24	5	5	8 (2 + 1)	I
25	6	5	8 (2 + 1) + 1 OR (4 + 1) (4 + 1)	II or I
26	7	5	2 [4 (2 + 1) + 1] + 1	II
27	6	5	(2 + 1) (2 + 1) (2 + 1) OR (8 + 1) (2 + 1)	I
28	6	5	4 [2 (2 + 1) + 1]	II
29	7	5	4 [2 (2 + 1) + 1] + 1	II
30	6	5	2 (2 + 1) (4 + 1)	I
31	7	5	2 (2 + 1) (4 + 1) + 1	II
32	5	5	32	
33	6	6	(32 + 1)	I
34	6	6	2 (16 + 1)	I
35	7	6	(4 + 1) [2 (2 + 1) + 1]	II
36	6	6	4 (2 + 1) (2 + 1) OR 4 (8 + 1)	I
37	7	6	4 (2 + 1) (2 + 1) + 1 OR 4 (8 + 1) + 1	II
38	7	6	2 [2 (8 + 1) + 1]	II
39	8	6	2 [2 (8 + 1) + 1] + 1	II
40	6	6	8 (4 + 1)	I
41	7	6	8 (4 + 1) + 1	II
42	7	6	2 (2 + 1) [2 (2 + 1) + 1]	II
43	8	6	2 (2 + 1) [2 (2 + 1) + 1] + 1	II
44	7	6	4 [2 (4 + 1) + 1]	II
45	7	6	(2 + 1) (2 + 1) (4 + 1) OR (8 + 1) (4 + 1)	I
46	8	6	2 {2 [2 (4 + 1) + 1] + 1}	II
47	8	6	[2 (2) + 1] (2 + 1) (2 + 1) + 2	
48	6	6	16 (2 + 1)	I
49	7	6	16 (2 + 1) + 1	II
50	7	6	2 (4 + 1) (4 + 1)	I
51	8	6	2 (4 + 1) (4 + 1) + 1	II
52	7	6	4 [4 (2 + 1) + 1]	II
53	8	6	4 [4 (2 + 1) + 1] + 1	II
54	7	6	2 (8 + 1) (2 + 1)	I
55	8	6	(4 + 1) [2 (4 + 1) + 1] OR 2 (8 + 1) (2 + 1) + 1	II
56	7	6	8 [2 (2 + 1) + 1]	II
57	8	6	8 [2 (2 + 1) + 1] + 1	II
58	8	6	2 {4 [2 (2 + 1) + 1] + 1}	II
59	9	6	2 {4 [2 (2 + 1) + 1] + 1} + 1	II
60	7	6	4 (2 + 1) (4 + 1)	I

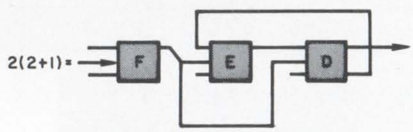
Suppose, for example, counting is to be done by a number that does not appear in Table 1, say, 117. The goal is to reduce 117 to numbers that are either unity or powers of two:

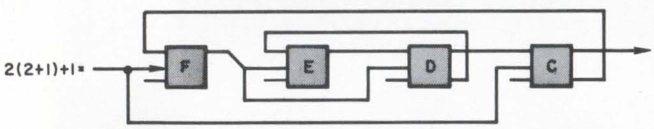
$$\begin{aligned}117 &= 116 + 1\\ &= 2(58) + 1\\ &= 4(29) + 1\\ &= 4(28 + 1) + 1\\ &= 4[4(7) + 1] + 1\\ &= 4[4(6 + 1) + 1] + 1\\ &= 4\{4[2(3) + 1] + 1\} + 1\\ &= 4\{4[2\ (2 + 1) + 1] + 1\} + 1 \quad \text{(This is the number group)}\end{aligned}$$

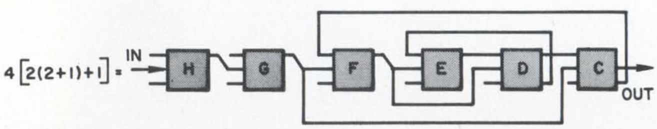
$$2 + 2 + 1 + 1 + 1 + 1 + 1 + 1 = 10 \quad \text{(Number of flip-flops)}$$

One and twos in the number group can each be implemented with one flip-flop. Higher powers of two can be implemented with a number of flip-flops equal to the power itself. For instance, a four requires two flip-flops; an eight requires three. It is fairly easy to translate the number group into a pin-to-pin schematic. Take a number group such as 59, for instance. Table 1 suggests $2\{4\ [2(2+1) + 1] + 1\} + 1 = 59$. Start from the center:

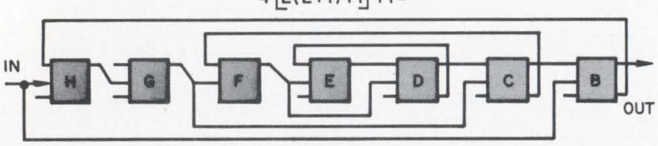


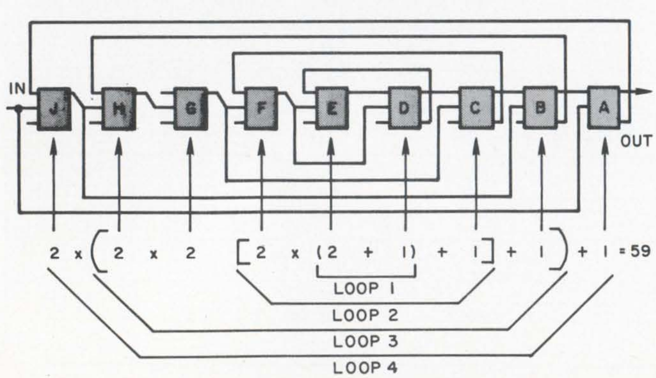




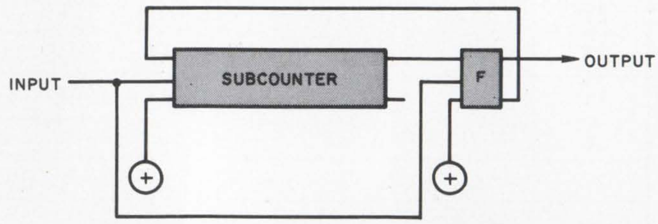


4[2(2+1)+1]+1=

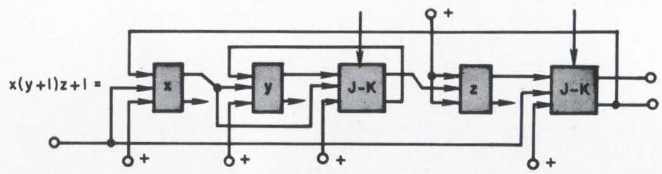




Straight binary counting is accomplished by cascading the flip-flops, so that the Q output is connected to the C input of the following stage. (For examples, see the straight two, straight four and straight eight counters in Table 1.) To perform other than straight binary counting with few components, various feedback forms are used. For example, to add one to a subcount, the following feedback (called type I) is useful:



To add one to a subcount, y, to which one has already been added and the sum multiplied by any two integers, x and z, use a type II enclosed loop feedback:



Unlike types I and II, the more complex feedback schemes cannot implement all integers, but occasionally they offer a slight reduction in the number of flip-flops. For example, type I or type II implementations of 47 and 94 each require nine and ten flip-flops, respectively. A more complex feedback mented by this same feedback. And often the more exotic feedbacks increase the maximum recovery factor. ■ ■

Test your retention

Here are questions based on the main points of this article. They are to help you see if you have overlooked any important ideas. You'll find the answers in the article.

1. Does a counter with a high maximum recovery factor count slower than one with a recovery factor of unity?

2. How many extra flip-flops will usually be needed to rid a counter design of all gates?

3. What is the maximum recovery factor that a synchronous (clocked) counter can possess?

4. What are the necessary and sufficient properties of the flip-flops in these gateless counter designs?

5. To what terms must the counting number be reduced to determine the flip-flop configuration?

The RCA-TA2628 solid-state laser with threshold current of less than 15A at room temperature needs only a simple solid-state circuit and a small battery for a typical power output of ...3 crazy watts!

Approx. ½ actual size

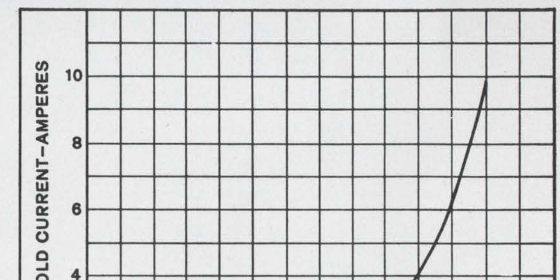
There's nothing crazy or complicated about putting RCA's new GaAs injection laser to work in your circuits today! This tiny, highly efficient unit is one of the more practical laser diodes around.

It operates at room temperature and all you need to drive it is a low cost transistor or SCR, a couple of resistors and capacitors, and a triggering diode. No expensive or cumbersome cryogenic hardware or high-current power supplies.

The peak emission wavelength of the TA2628 is 9050 ± 50 Å and you can get a typical output of 3 watts if you drive it with a pulse current of 30A. It is backed by life test data in excess of 1000 hours and its range of applications is limited only by your imagination.

We have just published a brand new Application Note (AN-3439) on this unit, which we would like to send you. At the same time we will forward you data sheets on RCA's other solid-state optical devices—the TA2930, a 50-watt laser, and the TA7008, IR emitting diode. Write: RCA Commercial Engineering, Section SG 12-1, Harrison, N. J. 07029.

Also available through your RCA Distributor



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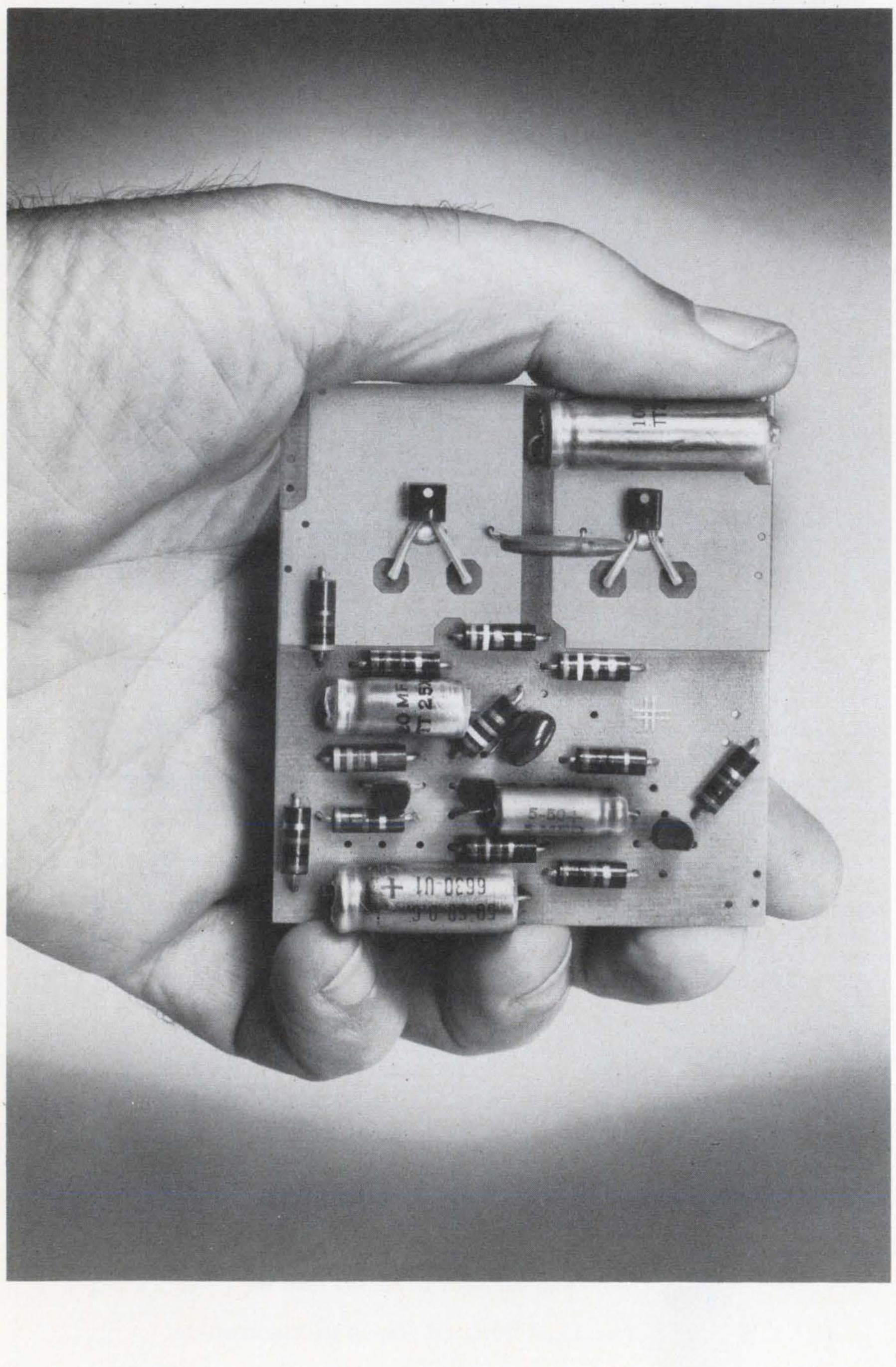
ON READER-SERVICE CARD CIRCLE 44

Reduce circuit costs with 16 new plastic-package transistors from TI



Texas Instruments announces 16 new transistors to improve performance, simplify circuitry and reduce your product costs. Included are silicon amplifiers, oscillators and switches. An economy version of the 2N4416 FET is available, too.

All the new transistors are offered in TI's exclusive SILECT™ economy plastic package. Lead configurations include: in-line, TO-18, and high-frequency. The new HF arrangement provides improved isolation and lower feedback capacitance for VHF and UHF devices.

TI's SILECT package, backed by 30,000,000 hours of testing, is fully capable of meeting military specifications. Reliability has been found to be equivalent to metal-can devices tested under the same conditions.

High-dissipation SILECT package eliminates heat sinks

Here are the first economy small-signal transistors to feature power dissipation of 1.6 watts at 25°C case temperature – nearly twice that of devices with comparable packages. Specially processed, high-thermal conductivity leads achieve this added dissipation. Designated as NPN types TIS90 and TIS92, and PNP types TIS91 and TIS93, these complementary devices are also available in matched pairs (TIS90M/TIS91M and TIS92M/TIS93M).

The new, high-dissipation packaging allows plastic transistors to be used in applications formerly restricted to metal-case, medium power devices or to the use of elaborate and expensive heat sinks.

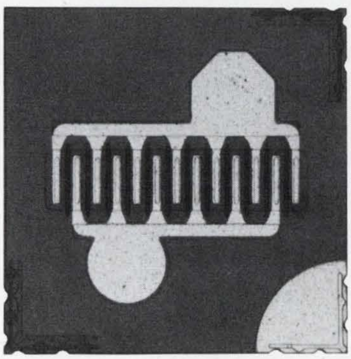
An effective heat sink can be obtained *at no extra cost* by leaving an area of copper on the face of the etched circuit board and connecting the high-conductivity collector lead to it (as shown at left).

The complementary pairs are designed for low-cost audio driver and output circuits up to two watts for phonograph applications.

Electrical characteristics are similar to the 2N2222 NPN and 2N2907 PNP families.

Circle 213 for data sheet.

New high-frequency FET doubles previous frequency capability



The new TIS88 silicon FET—plastic-encapsulated equivalent of the 2N4416 also offered by TI—features a frequency capability twice that of similar devices previously available in low-cost plastic packages. The high-performance FET operates up to 400 MHz with 10 dB minimum power gain. High transconductance and low feedback capacitance make this new device especially useful for consumer, industrial and military applications, including FM RF amplifiers, cascode-connected VHF amplifiers and sonobouy input amplifiers. Performance characteristics include a low noise figure (4 dB maximum at 400 MHz) and low leakage (I_{GSS} = 1nA maximum).

Circle 214 for data sheet.

New low-cost NPN devices for TV and audio applications

TIS83. Designed for use in UHF tuners, the new TIS83 transistor features a high injection current (I_{osc} = 2.5 mA minimum at 930 MHz). Transconductance is high (Y_{fs} = 70 mmhos at 200 MHz), permitting use with Schottky-barrier or AFC diodes.

Circle 215 for data sheet.

TIS84-85. New TIS84-85 transistors are designed for RF amplifiers and first and second video IF applications. They feature low noise figures (3.3 dB max @ 200 MHz for the TIS84), low feedback capacitance (0.4 pF maximum) and excellent forward AGC characteristics. The AGC control-voltage range is narrow, making only one device necessary for both IF sockets. The 100-mil B-E-C high frequency pin configuration isolates input and output circuitry.

Circle 216 for data sheet, which includes 10 performance curves and two application circuits.

TIS86-87. New TIS86-87 high-frequency silicon transistors are designed for such TV applications as mixers, reverse-AGC IF, and third IF. Feedback capacitance is low at 0.45 pF maximum, permitting unneutralized IF-stage design. Real and imaginary parts of y-parameters at 45 and 200 MHz simplify circuit design. Pin configurations are 100-mil, B-E-C.

Circle 217 for data sheet.

TIS94-99. This is a complete family of low-noise, low-to-medium current SILECT transistors for use in hi-fi audio amplifiers and general purpose low-frequency applications. They feature excellent Beta linearity to 100 mA, high current gain, low noise figures and high breakdown voltage (65 V min $V_{(BR)\ CEO}$ for the TIS96 and TIS99).

Circle 218 for data sheet.

Benefits of SILECT construction

Moisture resistance—SILECT transistors meet MIL STD 202C, Method 106B.

Stability—Transfer molding gives maximum stability...with no detrimental effect on the wafer.

Solderability—The plastic withstands all normal soldering temperatures without deformation.

Ruggedness—Solid package protects against vibration and shock.

Indexability—The flat surface may be used to index leads for automatic insertion.

Two lead configurations...both TO-18 pin-circle and TO-92 in-line are available for all standard devices.

See your TI sales representative or authorized distributor for more information, including price and delivery quotations.

TEXAS INSTRUMENTS
INCORPORATED

Use tunnel diodes in threshold logic

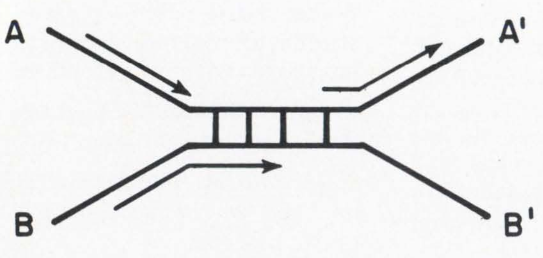
An actron—a discrete component gate—can be built to realize a variety of functions.

Recent promising practical[1,2,3,4] and theoretical[5,6,7] developments in threshold logic indicate that its application will lead to significant simplifications and cost savings in the design and construction of logic circuits. While many believe that the ultimate success of threshold logic systems will hinge on the development of integrated-circuit threshold gates[8], many useful threshold logic circuits can be built with discrete-component gates.

In particular, gates built with tunnel diodes have been found extremely practical. This article, then, will describe operation, design and applications of such a two-diode gate. Since this gate has no counterpart in the familiar Boolean class of gates (it is simultaneously an AND, OR, and EXCLUSIVE OR), it will be called an Actron. Its versatility will be demonstrated by showing how to use it in several typical logic circuits.

The actron — what is it?

An actron is a threshold logic element built with two tunnel diodes the state of which (high or low) is determined by the input current amplitudes. It bears a strong similarity to Crane's neuristor[9,10] hypothesis which describes a structure called a T-S junction (see sketch below).



It functions in such a way as to inhibit the flow of information on a line by the passage of a pulse on an adjacent line. As is shown in the sketch, a pulse traveling along line *A* triggers the junction producing an output at *A′*. The action of *A* excites *B* in such a manner as to obliterate any pulse occurring on line *B* during the time of excitation on line *A* or until line *B* has recovered. The same is also true of the relationship between *B* and *A*.

In a sense, then, the actron is a modified tunnel-diode EXCLUSIVE OR circuit. The neuristor-like action is achieved by arranging the diodes so that turning on one of them automatically disables the other, by operating the actron in a monostable mode, and by using a relatively large propagation period. Specifically, the propagation period is selected to be approximately one-half the on time of the monostable mode for proper switching.

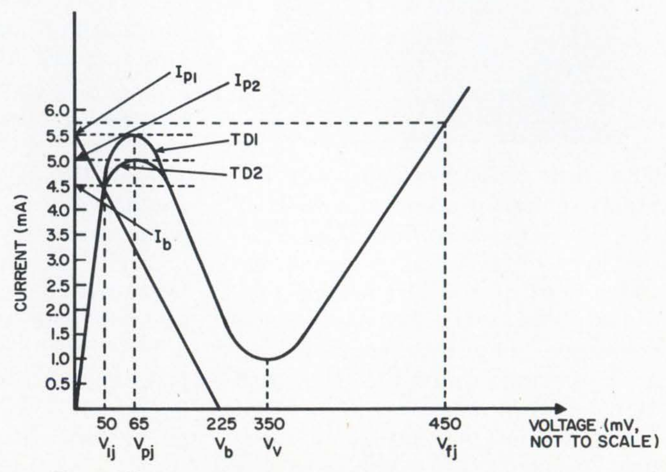
Analyze actron's operation

To describe the actron's electrical characteristics, it is necessary to define certain circuit parameter symbols, which are listed in the box.

Figure 1 illustrates the composite characteristic curves of the two tunnel diodes, *TD1* and *TD2*. The only difference between the two curves is that the peak current, I_{p1}, of *TD1* is greater than that of *TD2*, I_{p2}—an essential factor for operating the actron.

To simplify the operating explanation of the actron (Fig. 2), backward diodes* *CR1* through *CR4* have been added to ensure unidirectional

*Backward diodes: GE trade name for tunnel rectifiers. They exhibit minimum voltage drop in the reverse direction and maximum drop in the forward direction—typically 90 and 550 mV, respectively.



1. **The difference between peak currents,** I_{p1} and I_{p2}, of the two tunnel diodes, TD1 and TD2, is the necessary condition for the successful operation of the actron. Other symbols are defined in the box.

Carl A. Budde, President, Diginetics, Glendale, Calif.

current flow, but the voltage drop they introduce will not be taken into consideration. Inductances in the input wires are there to provide necessary delays.

I_{p1} is chosen to be greater than I_{p2} (Fig. 1) and I_b to fall below I_{p2} as determined by *R5* (Fig. 2). Before application of the input voltage both tunnel diodes are in their low state, as determined by the bias current I_b. A voltage, e_2, applied to either A' or B' will produce an input current to *TD2* of I_{2a} or I_{2b} which, when added to I_b, will result in a total current flowing through both *TD1* and *TD2*, the magnitude of which is insufficient to switch either *TD1* or *TD2*. If, however, e_2 is applied to A' and B' simultaneously, a current, $I_{2t} = I_{2a} + I_{2b}$, will flow and be added to I_b. This current $(I_{2t} + I_b)$ is greater than I_{p2}, but less than I_{p1}. Therefore, *TD2* will switch to the high state, V_{f2}, producing an output at *D*. No output will be present at *C* at this time. It has been shown, then, that:

$$\left.\begin{array}{l} I_{p2} > I_b + I_{2a} \\ I_{p2} > I_b + I_{2b} \end{array}\right\} \text{ no output (logic 0) ;}$$

$$I_{p2} < I_b + I_{2a} + I_{2b} = I_b + I_{2t},$$

so there is an output at *D* (logic 1), which satisfies a simple AND function. In Boolean notation, $A'B' = D$, which means that there is an output when a signal is applied to both A' and B'.

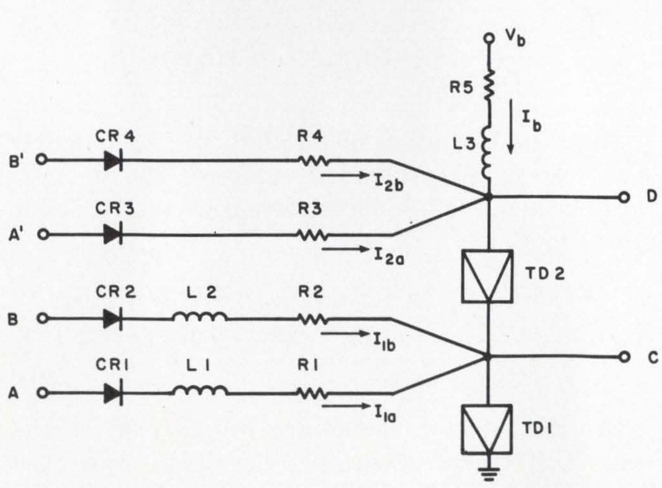
Consider *TD1* next. If a voltage, e_1, is applied to either *A* or *B*, then a current, $I_{1t} = I_{1a} = I_{1b}$, will be added to I_b and flow into *TD1*. This resultant current is greater than I_{p1} and so will cause *TD1* to switch to the high state, V_{f1}. With *TD1* in the high state, an output will be present at *C* for an OR function. So:

$$I_{1t} + I_b > I_{p1}.$$

Using Boolean notation for OR, this can be written:

$$A \dot{+} B = C,$$

where a dotted plus sign means OR.



2. **EXCLUSIVE OR** is obtained from the actron when A′ and B′ are connected to A and B, respectively. Backward diodes CR1 through CR4 assure unidirectional signal flow. See text for the explanation.

Now examine the actron when *A* and *B* are connected to A' and B', respectively, and the output is taken at *C* (Fig. 3). With an input at either *A* or *B*, output *C* will be high, V_{f1}. When both *A* and *B* receive inputs simultaneously, *C* will remain low because *L1* (Fig. 2) is in series with *R1* and *L2* in series with *R2*. These provide delay in the current build-up (I_{1a} and I_{1b}) to *TD1*. This guarantees that *TD2* will switch first when *A* and *B* both have inputs. Thus:

$$C = A\bar{B} \dot{+} \bar{A}B,$$

where the bar over a symbol means NOT.

Don't forget the diode interaction

This basic actron configuration is capable of performing AND, OR and EXCLUSIVE OR functions. One factor must, however, be taken into consideration at all times if both *C* and *D* outputs are used. Owing to the nature of the tunnel diode, a nonisolation feature is always present: whenever an output is present at *C*, so will it be at *D*. In other words, during the OR operation both *C* and *D* will appear in the high state. In some cases, depending on the over-all function of the system using actrons, this may be a problem—a problem, however, that is not insoluble.

Normally, when the actron is used as a solid-state realization of a neuron or the hypothesized neuristor, false outputs are not a problem, since the actron performs in the EXCLUSIVE OR mode with the output taken at *C* only.

Before the actron is defined mathematically, two more important factors need clarification. Firstly, the actron performs in the monopulse mode, that is, there is one output pulse for each input pulse. The monopulse mode is secured by selecting V_b to be below $\sum_{j=1}^{2} V_i + V_v$, that is, the tunnel diode

Circuit parameters

I_b Bias current
I_{pj} Peak current of tunnel diode
I_{vj} Valley current
V_{1j} Quiescent voltage across tunnel diode
V_{pj} Peak voltage
V_{fj} Forward voltage (during switching)
V_{tr} Voltage drop across backward diode
V_{vj} Valley voltage
I_{ja}, I_{jb} Input currents to tunnel diodes
V_b Bias voltage

In the above, the subscript *j* denotes either 1 or 2, depending on which tunnel diode is under discussion.

will always switch back to its low state on removal of the input current. Secondly, backward diodes are used where current steering and unidirectional information flow are need. Regardless of the function, however, they must be in series with the "primed inputs" (see Fig. 2). This is to block nondelayed current from flowing back to any input stages.

Building a practical actron

For analysis of the actron, two hypothetical tunnel diodes with the following characteristics are assumed:

$$I_{p1} = 5.5\text{ mA},$$
$$I_{p2} = 5.0\text{ mA},$$
$$V_{vj} = 350\text{ mV},$$
$$V_{1j} = 50\text{ mV},$$
$$V_{fj} = 450\text{ mV},$$
$$V_{pj} = 65\text{ mV}.$$

The only difference between *TD1* and *TD2* is that *TD1* has a 10% higher I_p, making it equal to 5.5 mA. In experiments a pair of matched General Electric TDP-3 tunnel diodes were used. *TD1* was shunted by a resistor to raise the effective peak-to-valley ratio, but this did not seem to affect the over-all performance. The TDP-3 has an I_p spread of from 4.2 to 5.2 mA. For simplicity, the tunnel diodes were all assumed to have either 5.0- or 5.5-mA I_p.

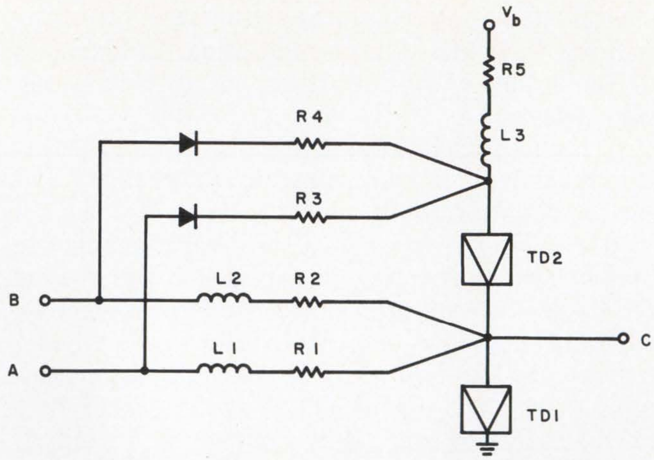
The biasing point, which must be set below I_p of *TD2*, depends on a number of factors such as peak current distributions, variations anticipated in ambient temperature, and component tolerance. Since the distribution of tunnel diodes supplied by GE was within ±2% of 4.7 mA, it was possible to bias at 10% below I_{p2} for a greater safety margin and assume all components good to within ±2.5%. Environment? Strictly room temperature, 25°C, although tunnel diodes, in general, can be used in extreme temperature conditions. While the characteristic shifts with respect to its axis, and the high-voltage region shifts with respect to the low-voltage region, the general nature of the characteristic will remain the same. The bias voltage, current and resistor *R5* are calculated as follows:

$$V_b = \left[\sum_{j=1}^{2} V_{1j} + V_v\right]/2 = 225\text{ mV}. \qquad (1)$$

$$I_b = I_{p2} - (10\%\text{ of } I_{p2}) = 4.5\text{ mA}. \qquad (2)$$

$$R5 = \left[V_b - \sum_{j=1}^{2} V_{1j}\right]/I_b = 25.5\,\Omega. \qquad (3)$$

Five years' experience has shown that it is generally quite satisfactory to use simple equations to determine such time constants as the on time of a monopulse oscillator. An on period, τ_ω, of approximately 400 ns is arbitrarily chosen and *L3* is determined from $L3 = \tau_\omega R5 \approx 10\,\mu$H.



3. **TD2 switches before TD1** when an input is applied to either A or B because of the slight delay due to L1 and L2.

In determining values for the input resistors, *R1* through *R4*, the input voltage, e_a, applied to either *A* or *B* is assumed to come from another actron, and is taken as V_{fj} or 450 mV. Starting from the top, $R3 = R4$ is solved for first. A 5% overage on input current to either *TD1* or *TD2* is assumed, to ensure switching. Then:

$$I_{2a} = I_{2b} = (I_{p2} + 0.05\, I_{p2})/2 = 0.375\text{ mA}; \qquad (4)$$

hence:

$$\sum_{n=a}^{b} I_{2n} + I_b = 5.25\text{ mA}, \qquad (5)$$

which is greater than I_{p2} (5 mA) but less than I_{p1} (5.5 mA).

Now, with only one input, say *A*, the current flowing through *TD1* will be:

$$I_b + I_{2a} + I_{1a},$$

and should exceed I_{p1} by 5% for switching, or:

$$I_{p1} + 0.05\, I_{p1} \approx 5.75\text{ mA}. \qquad (6)$$

Therefore:

$$I_{1a} = I_{1b} = (I_{p1} + 0.05 I_{p1}) - I_b - I_{2a} \qquad (7)$$
$$= 5.75\text{ mA} - 4.5\text{ mA} - 0.375\text{ mA}$$
$$= 0.875\text{ mA}.$$

Since the resistance of either *L1* or *L2* is small with respect to anticipated values of *R1* and *R2*, it can be neglected. The resistors can then be calculated as follows:

$$R1 = R2 = (ea - V_{11})/I_{1n} = 465 \approx 470\,\Omega, \qquad (8)$$

$$R3 = R4 = [ea - V_{tr} - (V_{11} + V_{12})]/I_{2n}$$
$$= 695 \approx 680\,\Omega, \qquad (9)$$

where the resistor values are rounded off to the nearest standard value; V_{tr}, the drop across the backward diode due to I_{2n}, is taken to be 90 mV, and the subscript *n* denotes either *a* or *b*.

For a value of *L*, the delay or propagation period, τ_0, was taken as one-half the on period of the actron, or 200 ns. It is given by:

$$L1 = L2 = \tau_0 R1 = (200 \times 10^{-9})\ (470) = 94\mu\text{H}. \tag{10}$$

To summarize the actron's operation, look at Fig. 3. With the application of a step input at *A*, *TD2* and *TD1* experience an almost simultaneous rise in current. This current increase is due to the action of *R3* but is insufficient to rise above the peak current of either *TD1* or *TD2*. At the moment the input is applied, the current flowing in *L1* and *R1* is equal to zero. It starts rising exponentially toward a maximum value of I_{1a}. When it reaches a point where, when added to I_{2a} and I_b, the total equals I_{p1}, *TD1* switches on and output *C* rises from 50 to 450 mV. If, on the other hand, inputs are applied to both *A* and *B*, the current increase down through *TD2* is sufficient to switch it to the high state, V_{f2}.

With either *TD1* or *TD2* in the high state, bias current I_b starts to collapse in *L3* toward a value of I_{vj}. When I_{vj} is reached, the on tunnel diode switches off. The current then begins to increase in *L3*, until it returns to I_b. A good rule of thumb is that this period of time, known as the recovery period or refractory period, is about 3.5 times the pulse width, or on time.

Figure 4a illustrates two actrons, with alternate inputs applied to *A*, *B* or *C*; Fig. 4b shows the anticipated waveforms referenced to zero time, t_0. The following can be observed:

- With either *A* or *B* inputs present, an output will result at *3*, provided an input at *C* did not occur one time period after the application of *A* or *B*.
- With inputs *A* and *B* appearing simultaneously, no output will be present at *1* or *3*. If *C* is present, however, an output can be generated at *3*. While it is possible for current to flow from *3* back into *1*, it will have no effect because point *2* is switching.
- If an input is provided to *C* only, an output will be present at *3* after $t_{03} + 1$ and at *1* after $t_{03} + 2$.

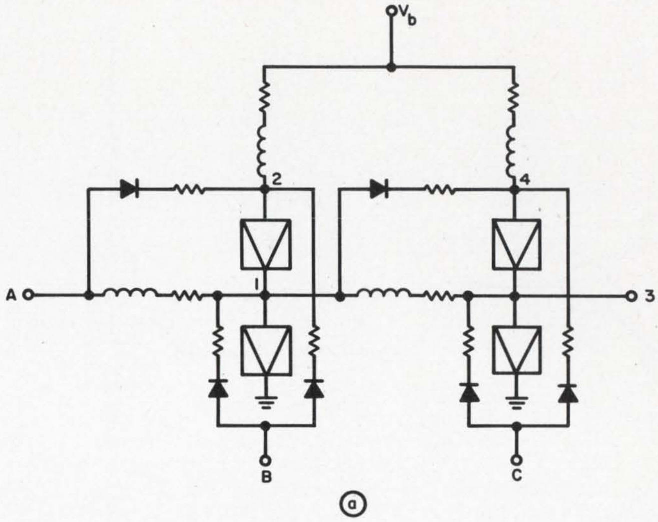
How many inputs or outputs?

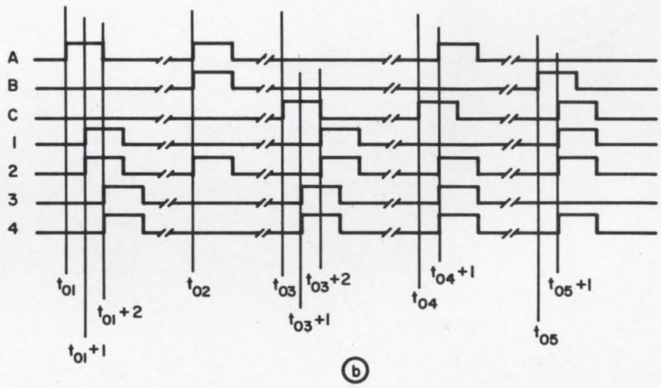
Ideally as many lines would be accommodated in and out of the actron as required. Certain practical limitations, however, prevent this. Since no backward diodes are used for the lower input tunnel diode, it is shunted by the input resistors. This raises the effective peak current while at the same time degrading the peak-to-valley current ratio. For instance, the current component I_x that flows away from tunnel diode *TD1* is:

$$I_x = V_{11}/R_i/N, \tag{11}$$

where R_i is the input resistor $= 465\ \Omega$, N is the number of input/output lines $= 3$. Therefore, $I_x = 322\ \mu\text{A}$, and the current flowing through *TD1* is actually:

$$I_b - I_x = 4.178\ \text{mA}. \tag{12}$$





4. **Practical considerations** limit the number of input and output lines entering an actron to about four (a). The action of this double-actron circuit (b) is described in text. Component values are omitted because they are the same as in the basic actron (Fig. 2).

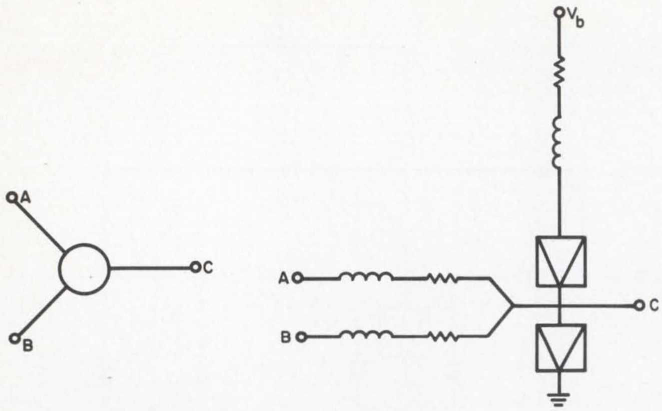
This, of course, is only at bias point V_{1j} and will change as I_{pi} is approached. The change is quite tolerable in view of the many variables and their accompanying distributions. At V_{pj}, which was set at 65 mV, the dynamic resistance of the tunnel diode with a 5-mA I_p is equal to 13 ohms. Therefore to raise the effective peak current 10 per cent, a shunt, R_{sh}, of 130 ohms is required. Since input resistance R_i is equal to 465 ohms, the maximum number of input and output lines that may be accommodated is:

$$R_i/R_{sh} = 3.57. \tag{13}$$

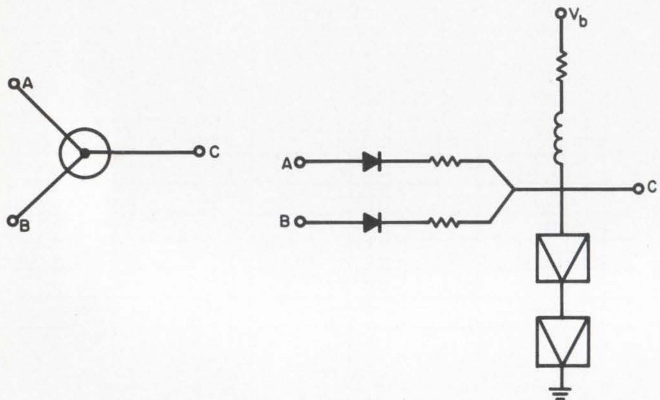
so the maximum number of lines that can be conveniently tolerated is three. In actual practice, it is possible with a little care to accommodate up to four lines. It might be added at this point that the goal is to develop a structure that would theoretically accommodate an infinite number of lines.

New logic symbols are needed

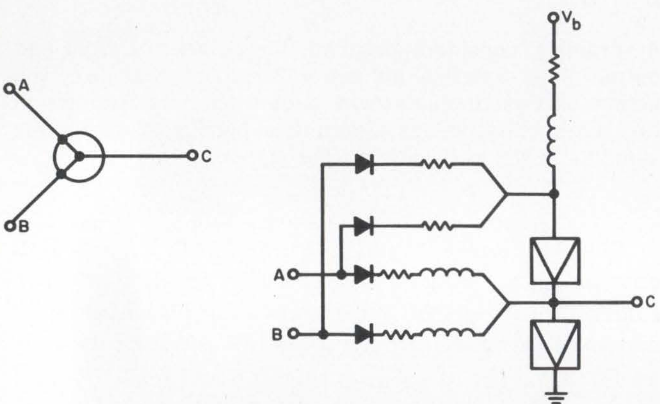
Although for the most part the actron would be used in the EXCLUSIVE OR configuration with-



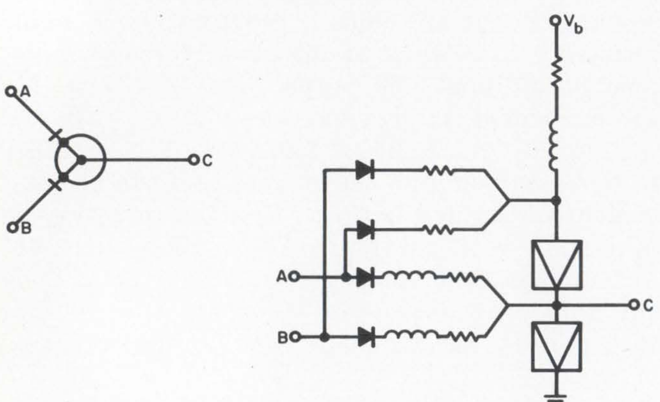
(a) OR



(b) AND



(c) NONDIRECTIONAL EXCLUSIVE OR



(d) EXCLUSIVE OR WITH STEERING

5. **Actron's versatility** in realizing a variety of logic functions is demonstrated with the new logic symbols and corresponding circuit schematics. Once again, component values are those of Fig. 2.

out benefit of steering diodes, other cases will arise from time to time where simple logic decisions such as AND and OR will be required. For this reason a set of logic symbols has been devised.

The symbols (Fig. 5) provide all the basic circuit configurations. The central circle may be considered the top tunnel diode, *TD2*, with the actron viewed from the top. An OR junction (Fig. 5a) is formed beneath *TD2*, and an AND junction (Fig. 5b) is formed above *TD2*. For the nondirectional EXCLUSIVE OR, the top lines are led to the bottom by dots at the crossing of the lines and the edge of the circle (Fig. 5c). Steering diodes are shown as a short bar crossing an information line (Fig. 5d). If a line is brought out of the circle, it is taken to be the top of *TD2*, etc.

Some circuit configurations using these logic symbols will give a better understanding of the actron.

Build a half-adder with carry

In Fig. 6, owing to the nonisolating nature of the tunnel diode, there will be an output from *TD2*, actron *1*, only when *A* and *B* are both present. This output acts as a single input to actron *2*, which in turn produces an output (carry). The carry will occur at $t_0 + 1$.

. . . and a binary counter

In Fig. 7b four pulses should have been applied to the input *A*. However, a pulse was deliberately dropped (illustrated by dashed lines) from the series. This was done to show the actron's insensitivity to errors in the input data and to test the logic. With the outputs taken, say, at *3* and *6* (Fig. 7a), both are present for a total binary count of three. The output at *3* is missing after the arrival of the second pulse to line *A*, but the output at *6* is present, giving a binary two.

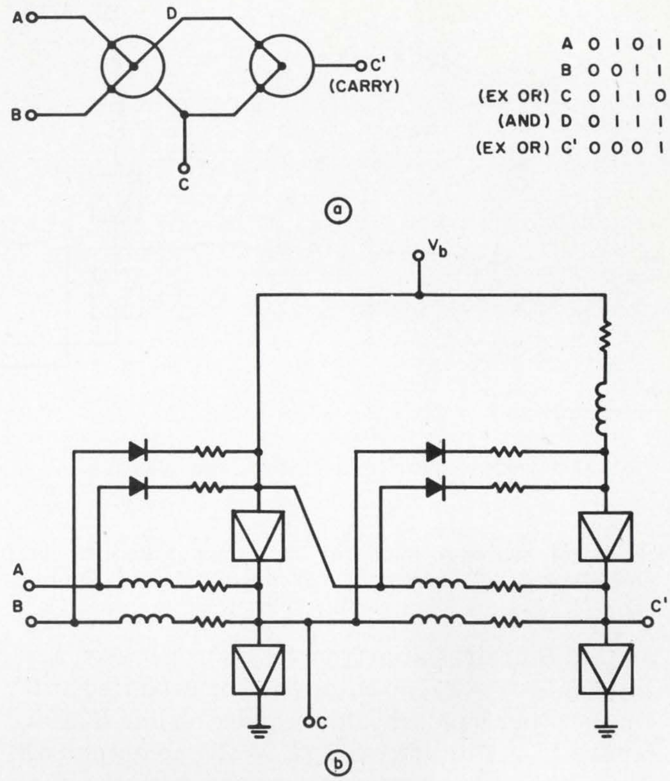
It can be added here that, unlike conventional flip-flops, in actron counters outputs can be taken from a number of points.

In the line coupling *1* to *3* and *4* to *6* in Fig. 7a, the wiggle is an additional delay period introduced to prevent the output of *3* from obliteration when it arrives at *1* while *1* is still in the refractory stage.

Just what happens? With a pulse present at *A*, actron *1* fires in the OR mode, producing two outputs. These two outputs are coupled to actron *7* which appears as an EXCLUSIVE OR and no output is generated. The output of actron *1* is also coupled to actron *2* (in the OR mode), which is in turn coupled to actron *3*, also in the OR mode. The output taken from actron *3* is delayed so that it reaches actron *1* after the latter has had time to recover. If no additional input is present at *A* when an input arrives at actron *1* from actron *3*, the cycle will be repeated as above. If, however, a pulse does exist at A, actron *1* will assume the EXCLUSIVE OR configuration and no output will be available for coupling to actron *2*. On the other hand, only one input will now be provided for actron *7* by actron *1*. This causes actron *7* to behave as an OR function, producing an output on line B. This output on line B is coupled to actron *4* in the same manner as A was coupled to actron *1*, and the same procedure is followed as above. Figure 7c is a schematic representation of the logic circuit of Fig. 7a.

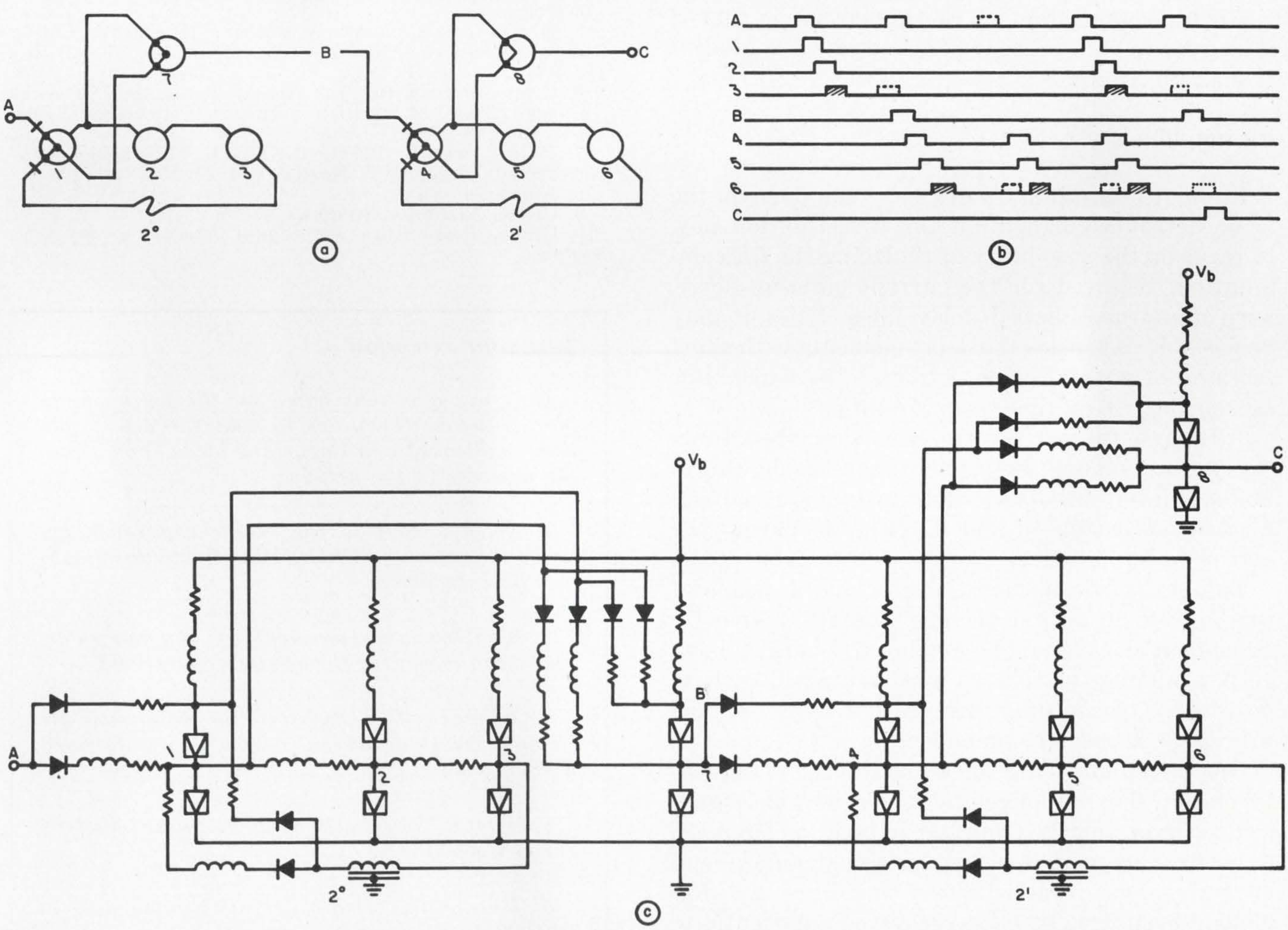
What about neuristor hypothesis?

The realization of Crane's neuristor hypothesis by the actron is accomplished by the connection given in Figs. 8b and 8c. The logic model of the neuristor is shown in Fig. 8a. A pulse applied to A at t_0 fires actron *1* at $t_0 + 1$. Two outputs are present from actron *1* at $t_0 + 1$; they propagate to actrons *2* and *3*, producing simultaneous outputs from them at $t_0 + 2$. Outputs from actron *3* are produced on line A' and also on the line to actron *4*. No output is generated by actron *4* since pulses from actrons *2* and *3* arrive together and actron *4* performs in the EXCLUSIVE OR mode. If a pulse

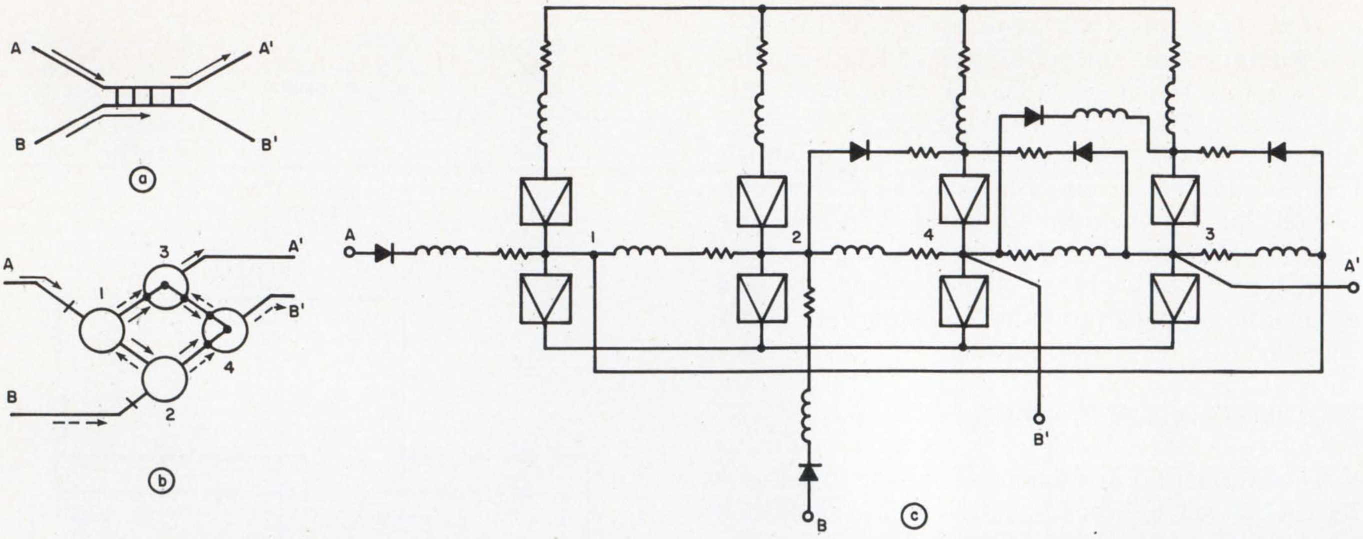


A	0	1	0	1
B	0	0	1	1
(EX OR) C	0	1	1	0
(AND) D	0	1	1	1
(EX OR) C'	0	0	0	1

6. **Half-adder with carry** can be built with only two actrons. The truth table describes the operation.



7. **Binary counter** (a) uses eight actrons. See text for the step-by-step explanation of the action (b), shown in (c).



8. **Actron-neuristor similarity** is demonstrated by first considering T-S junction[5,6] (a) operation: the information flow on a line, say, A, is inhibited by the passage of a pulse on an adjacent line. Actron equivalent is in (b), (c).

on line B arrives at actron *2*'s input between $t_0 +$ 1 and 3.5 $(t_0 + 2)$, no output will be produced at B'. On the other hand, should the pulse on line B arrive before $t_0 + 1$ or after 3.5 $(t_0 + 2)$, no output will be produced by actron *3*, but an output will be present at B' because of the action of actron *4*.

Exactly the same is true of the effect of B on A' when a pulse on line B arrives at t_0.

An interesting feature of this circuit is that if A and B are both present at t_0, outputs are present from both A' and B' at $t_0 + 2$.

It's not 'blue-sky'

Enough preliminary work has been done on the basic actron configuration for investigation now to focus on the possibility of replacing the LR combination, required for the current build-up delay, with miniature lumped delay lines. Later it may be possible to replace the delay elements with short sections of coaxial cable, while at the same time decreasing the on time to around 5 ns.

Although the actron has been described functioning in a monopulse asynchronous mode, this is not absolutely necessary. For instance, removing $L3$ and increasing V_b and R_5 (Fig. 2) permit the actron to be biased to operate in a bistable mode.

To obtain information transfer and a means of turning off an actron after a transfer, a two- or three-beat clock would be employed. There is, however, a number of serious disadvantages, such as no reverse or multiple information paths, so this procedure is not recommended.

One difficulty facing the actron's user is that information flow no longer takes place in an organized fashion, that is, from left to right or from top to bottom. Instead, it is free to flow along any and all active lines, that is, those that have not previously been fired or have recovered sufficiently to support another discharge. ■ ■

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7. P. M. Lewis II, "Practical Guide to Threshold Logic," ELECTRONIC DESIGN, XV, No. 22 (Oct. 25, 1967), 65-88.
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9. Crane, *Neuristor Studies.*
10. Crane, *Possibilities for Signal Processing in Axon Systems.*

Test your retention

Here are questions based on the main points of this article. They are to help you see if you have overlooked any important ideas. You'll find the answers in the article.

1. Briefly, what is the major difference between the actron EXCLUSIVE OR and an equivalent Boolean gate?

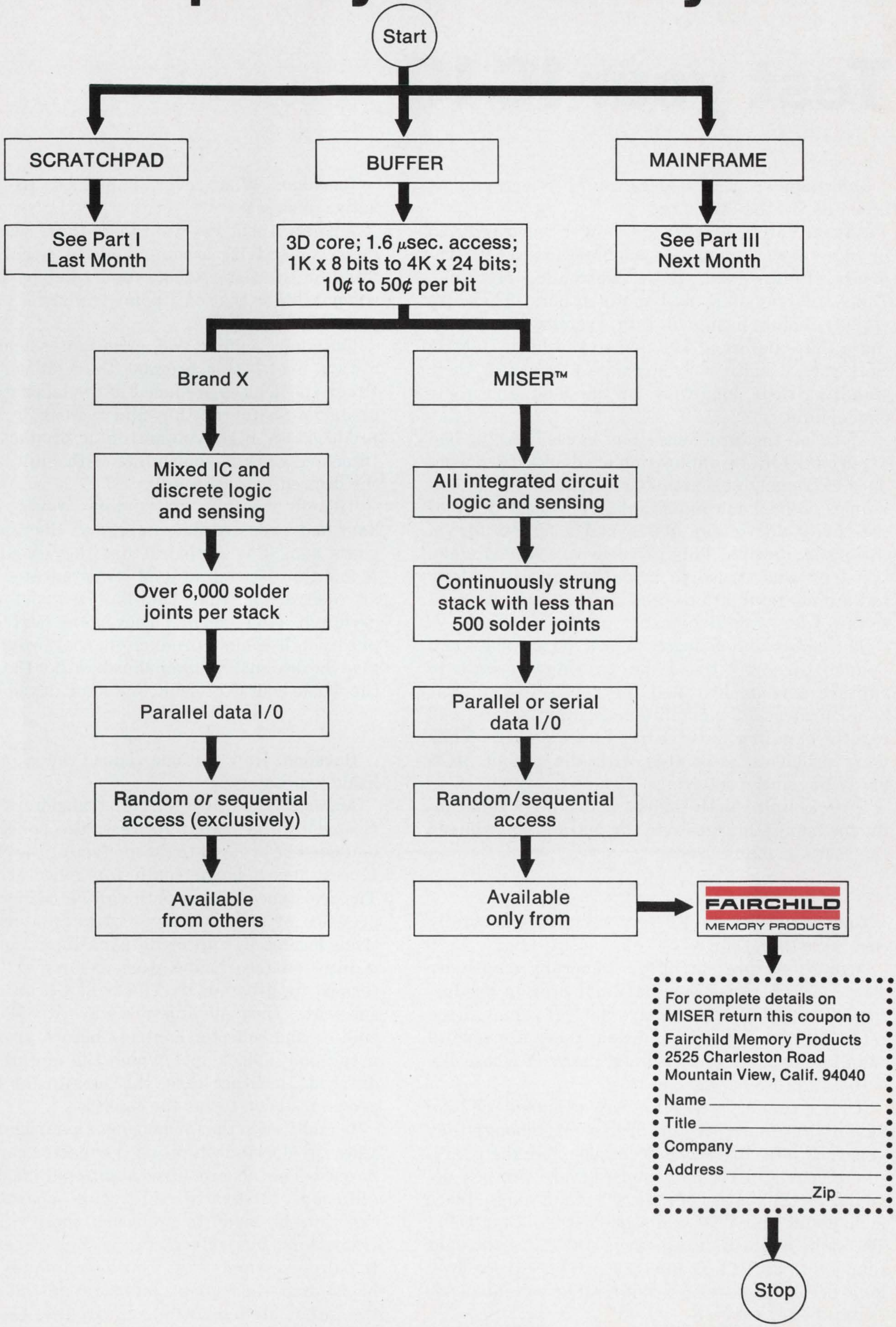
2. What basic requirement for the tunnel diodes must be met for the actron's operation?

3. What is the most striking difference between a two-stage actron counter and a standard flip-flop counter?

4. What is the purpose of the backward diodes? Series inductances?

5. Why is an actron's operation analogous to that of a neuristor T-S junction?

How to improve your memory: Part II



ON READER-SERVICE CARD CIRCLE 45

Test your IC IQ

Question: To what degree are MOS arrays now accepted by the industry?

Answer: MOS arrays are now being produced by many large companies, such as General Instruments, Philco-Ford, RCA, Fairchild, Motorola, Texas Instruments, and many others. They are rapidly being designed into systems, especially those that operate at low power and below 1-MHz clock rate, despite early stigmata attached to their stability, their longevity in the field and their producibility.

Most of the problems that caused early, bad experiences in the application of MOS arrays were once extremely serious. Oxide instability, for example, seemed unconquerable. It caused drift of the threshold voltage which had a magnitude on the order of volts. This problem was solved when the drift was traced to oxide impurities—chiefly sodium contamination—and drift is now reduced to the order of millivolts.

The gates are delicate: a few dozen volts can "punch through" the oxide, causing the gate to rupture permanently and the device to fail. But Zener protection, built into most input stages, and careful handling have reduced such failure. Thus most problems associated with the use of MOS array have been solved.

This, coupled with the entry of major semiconductor manufacturers into the market, has allayed the fears of many users.

Question: Why do TTL microcircuits generally cost more than DTL?

Answer: At present, TTLs generally cost more than DTLs because they have not been in production as long and so they have not yet achieved the DTLs' high volume. In addition, there are several suppliers producing DTL lines, many of whose circuits are interchangeable.

TTL circuits, however, were designed to take advantage of microcircuit processing. Though they generally offer higher performance than their DTL counterparts, TTL puts more severe process demands on the control of inverse beta. Even so, there is no doubt that TTL will soon cost less than DTL. The slope of the demand curve for TTL is steeper than DTL, so TTL should reach DTL's price level long before it develops comparable volume. (See facing page, above.)

Question: What ever happened to thin-film active devices?

Answer: About two years ago there was a great flurry of activity accompanied by predictions of thin-film transistors that would offer performance comparable to that of bipolar transistors at a considerably lower price.

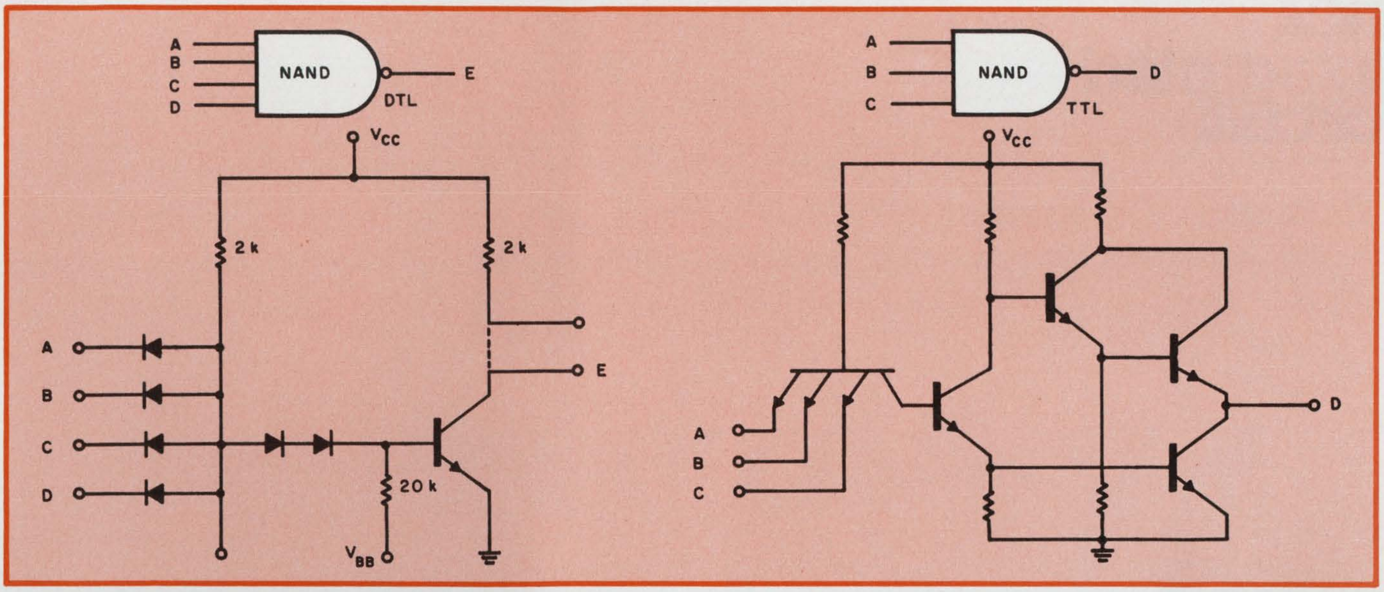
Cadmium sulfide and cadmium selenide have always held better promise than silicon dioxide. Prototype devices produced in the laboratory were unstable. So far no thin-film transistor has been produced in high volume on a production line. Intensive work is continuing with high hopes for the desired breakthrough.

Though thin-film transistors would probably have had a considerable impact on the market two years ago, it is doubtful that they would today. Monolithic bipolar and MOS integrated circuits are delivering what thin-film transistor arrays promised. Now, even if they were perfected and put in high-volume production, they would simply give the designer another choice rather than change the whole course of semiconductor development.

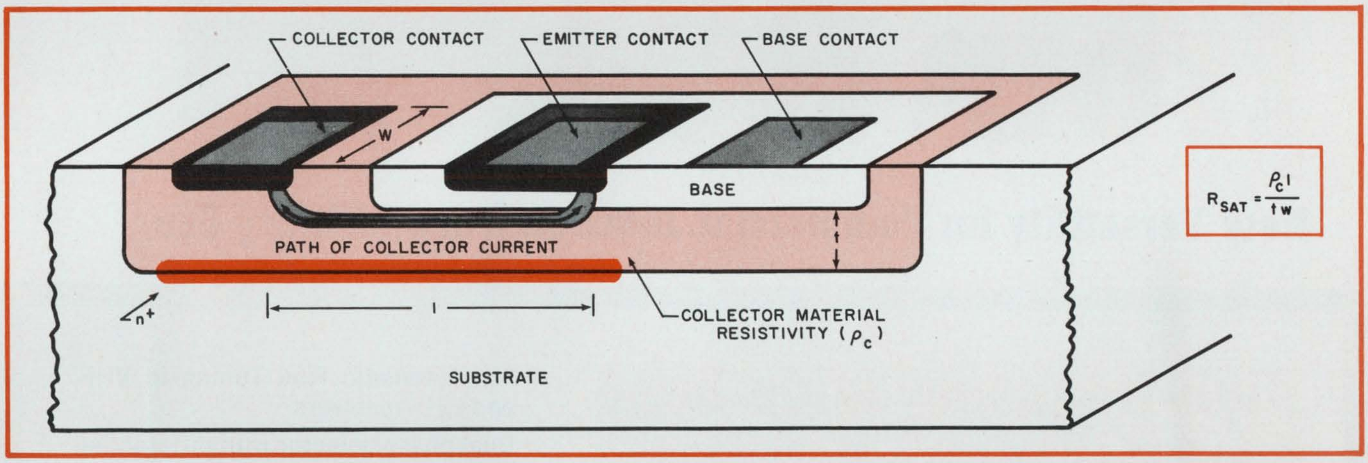
Question: How can one reduce the r_{sat} of monolithic transistors?

Answer: When microcircuit transistors are fabricated by the planar process, the collector contact must be brought to the surface of the chip. This necessitates a longer path for collector current. The resistance of this path can be reduced by the presence of a buried layer of n^+ material selectively located by appropriate masking and a heavy n diffusion (see facing page, below) or it can be formed by growing n^+ epitaxial silicon on the p substrate, then etching it away except between emitter and collector contacts before growing the n epitaxial silicon into which the circuit is to be diffused. In either case, the subsequent epitaxial grown n silicon forms the collector.

In addition to the formation of a buried n^+ layer, a heavily-doped deep-diffused collector contact can be used. This also requires additional masking and diffusion. Integrated saturation characteristics can thus be made to approach those of discrete transistors, but only at the cost of several additional processing steps. These techniques are now being used throughout industry particularly for the faster, high-performance circuits. ■■



A typical DTL NAND gate (left) contains many more diodes and far fewer transistors than a typical TTL NAND gate (right). Ultimately, when TTL production reaches present DTL production, it should cost less for the same functions. This is true in spite of the fact that TTL requires closer control of inverse beta.



The microcircuit transistor's longer collector-current path usually produces a higher saturation resistance than its discrete counterpart. In the standard process, a buried layer of n+ silicon produces a low-resistance path for this current. Its saturation resistance can thus be made almost as low as that of a discrete transistor.

A new forum for the discussion of ICs

Today the questions that engineers most frequently ask the editors of ELECTRONIC DESIGN relate to the design, production and marketing of integrated circuits.

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To keep its readers abreast of this rapidly evolving technology, ELECTRONIC DESIGN presents, in addition to its normal reports, this new regular column.

The column is the result of collaboration between ICE (Integrated Circuit Engineering Co., Phoenix, Ariz.) and the editors of ELECTRONIC DESIGN. ICE is an institution that is well equipped to handle such questions—it runs week-long seminars on integrated circuitry all over the world.

Readers are invited to send questions to Integrated Circuits, ELECTRONIC DESIGN, 850 Third Ave., New York, N.Y. 10022. Those who submit questions chosen for publication will receive a complimentary copy of *Microelectronic Design*. (Earliest postmark wins in event of identical questions.)

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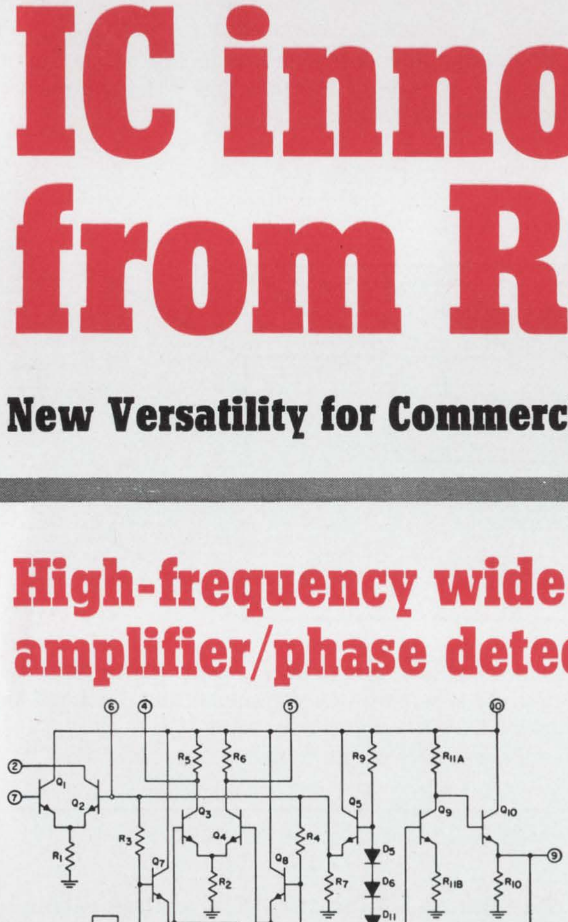

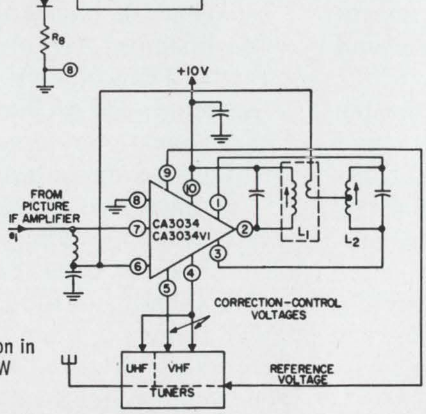

Block diagram of typical AFC application in color TV receiver. Also suitable for B&W and FM receivers.

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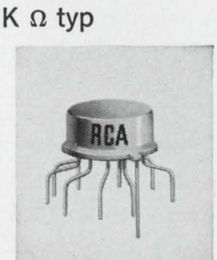

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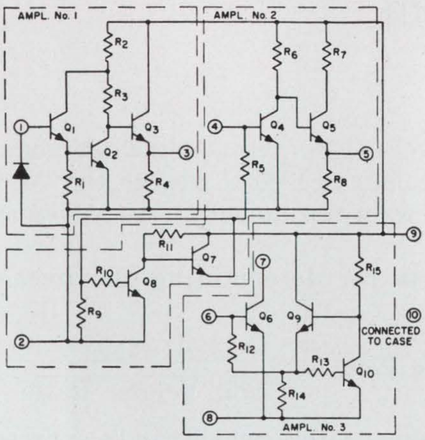

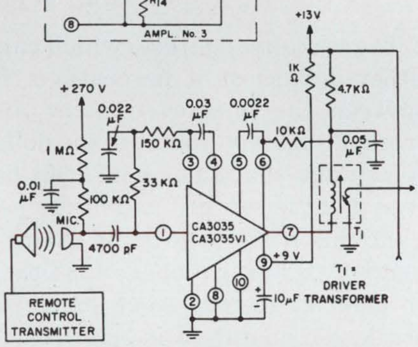

Low noise performance and outstanding wide-band response make this three-in-one unit general purpose amplifier array ideal for TV remote control.

- Three separate amplifiers; gain and bandwidth for each adjustable by external circuitry
- Can operate as individual units—or in cascade for 132 dB gain (typ) @ 40 KHz
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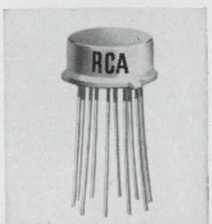
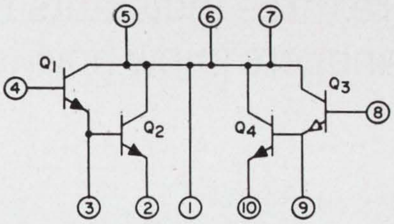
  Ampl. #2 46dB typ
  Ampl. #3 42dB typ
- Bandwidth @ −3 dB point—Ampl. #1 500 KHz
  Ampl. #2 2.5 MHz
  Ampl. #3 2.5 MHz
- Operating temperature range −55°C to +125°C
- All three amplifiers single-ended, only one power supply needed
- Typical applications: TV remote control; IF systems; instrumentation amplifiers; chopper amplifiers

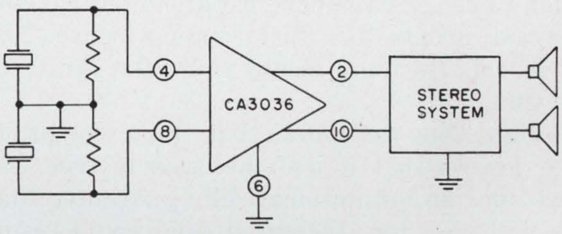


RCA CA3035 wide-band high-gain ampl. in TO-5 package. Price $1.50 (1,000+)

RCA CA3035V1 with pre-formed leads. Price $1.50 (1,000+)

Dual Darlington amplifier array





Block diagram of application as stereo phono pre-amp. Cartridges designed around the CA3036 can provide enhanced fidelity, low hum pick-up without shielding. Response flat to 1MHz @ $R_L = 1K\Omega$

- Voltage gain for either pair 26 dB (typ)
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- Gain-bandwidth product for either pair 200 MHz
- h_{FE} for either pair 4540 typ. @ $I_{C1} + I_{C2} = 1mA$
- Operating temperature range −55°C to +125°C
- $V_{CEO} = 15V$ max.
- $V_{CBO} = 30V$ max.
- $V_{EBO} = 5V$ max.
- I_C (each transistor) = 50 mA max.
- Emitter-follower output
- Typical applications: stereo phono amplifiers; differential ampls; op amp driver; mixer

RCA CA3036 Dual Darlington Array in 10-lead TO-5 package. Price 98¢ (1,000+)

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Listen to an inexperienced businessman:

"I don't need any financial expert to tell me how to increase profits. It's just common sense. The more you sell, the more money you make. Any fool knows that."

He's right. Any *fool* knows that. But a wise profit planner knows that it isn't necessarily true. Increased sales do not automatically guarantee that profits will rise, too. Increased sales could result in decreased profits, or even a loss.

Wise businessmen—including smart engineer managers—use three barometers to plan profits. They are the profit/volume ratio, the breakeven point and the margin of safety.

[This article on how costs and sales volume are interrelated to effect a company's profit or loss is the third of a three-part series on cost analysis, budgeting and profit/volume analysis. The first ("Profit by learning cost analysis," ED 23, November 8, 1967, pp. 96-101) reviewed the need to analyze, identify and formulate the various types of costs. The second ("Good budgeting can boost profits," ED 24, Nov. 22, 1967, pp. 88-93) showed how this cost information is used in setting up effective budgets.]

The *profit/volume ratio* tells you how much of each sales dollar is available after direct or variable costs are paid to help absorb overhead—the fixed costs. Once the overhead is absorbed, the balance of the sales dollar contributes to profits. Ideally, you want the P/V ratio to be as high as possible, thus absorbing overhead costs as quickly as possible.

One formula* for determining the P/V ratio is this one:

$$\text{P/V ratio} = \frac{\text{Profit} + \text{Fixed Costs}}{\text{Sales}}.$$

*Another method of determining the P/V ratio is:

$$\text{P/V Ratio} = \frac{\text{Sales Income} - \text{Variable Costs}}{\text{Sales Income}}$$

In this article, however, all calculations will follow the formula cited in the text.

Lawrence M. Matthews, Vice President, Stevenson, Jordan & Harrison Management Consultants, Inc., New York.

The *breakeven point* tells you the minimum sales volume (income) needed to absorb the overhead. Ideally, you want this amount to be as low as possible.

A formula for determining the breakeven point is:

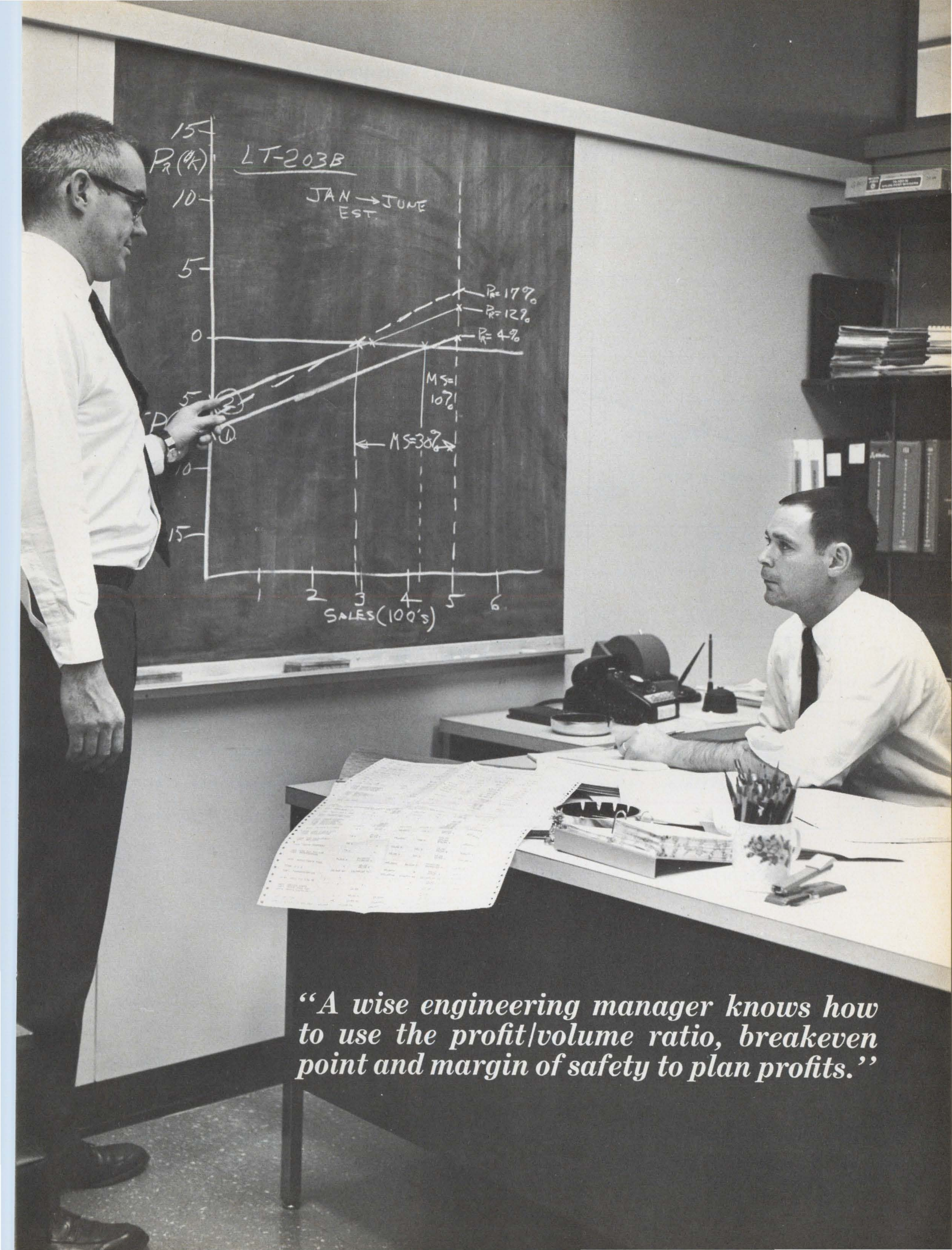
$$\text{Breakeven Point} = \frac{\text{Fixed Costs}}{\text{Profit/Volume Ratio}}.$$

The *margin of safety,* which can be expressed in either dollars or a percentage, is the difference between the breakeven point and your present average sales volume. It is the dollar amount or the percentage that sales can drop before the breakeven point is reached and losses begin. Ideally, you want this margin to be as great as possible. If a company is losing money, it is the amount of dollars or percentage that sales must increase before a breakeven operation is achieved.

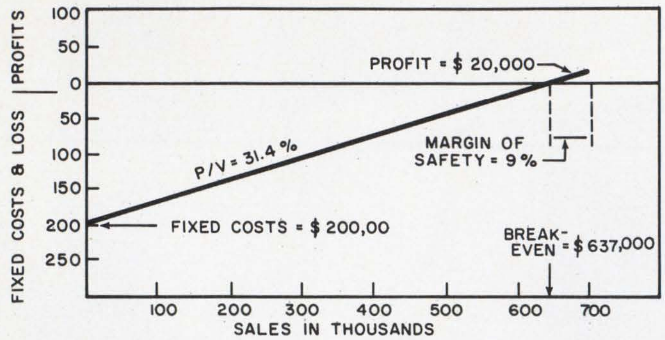
Table 1. Monthly profit and loss statement

Sales				
70,000 units @ $10 apiece				$700,000
Expenses	Fixed	Variable	Total	
Material		$200,000	$200,000	
Direct labor		230,000	230,000	
Indirect labor	$ 20,000		20,000	
Instruments	25,000	25,000	50,000	
Operating supplies	15,000	15,000	30,000	
Depreciation, taxes, insurances, etc.	60,000		60,000	
Selling expenses	40,000	10,000	50,000	
Administrative expenses	40,000		40,000	
	$200,000	$480,000	$680,000	
Total expenses				680,000
Profit				$ 20,000

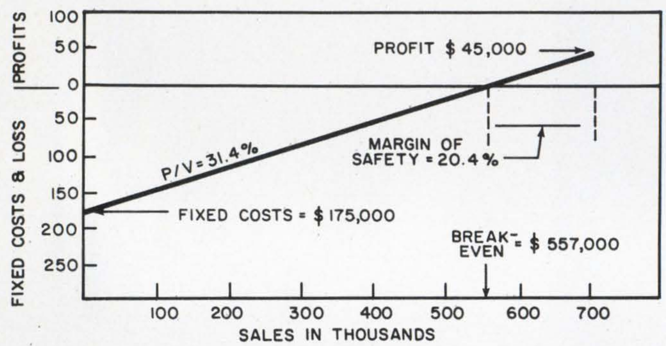
John O'Brien (right), manager, special products, Semiconductor Department, EG&G, Bedford, Mass., discusses his department's profit/volume chart with William Dolan (left), the department controller.



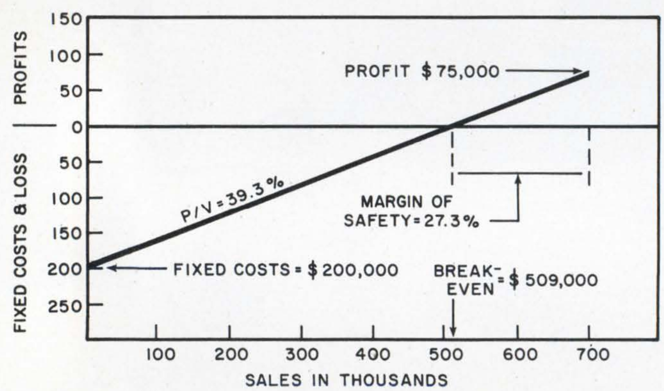
"A wise engineering manager knows how to use the profit/volume ratio, breakeven point and margin of safety to plan profits."



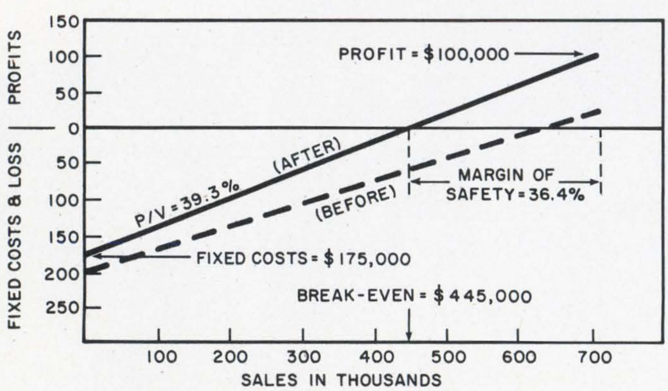
1. The monthly profit/volume chart of DEF Electronics Co., before reducing any costs.



2. The P/V chart of DEF Electronics after fixed costs have been reduced.



3. The P/V chart of DEF Electronics after restoring fixed costs and reducing variable costs.



4. The P/V chart, as it looked initially (broken diagonal line) and after cost reductions were made.

Table 2. Monthly profit and loss statement

A. Action taken:

(a) Applied ratio-delay study findings and reduced crew by 2 men.
(b) Started small instrument requisition system, improved test set-up design, obtained certain purchase price reductions.
(c) Installed monthly flexible budget, installed a supply requisition system.
(d) Reviewed insurance coverage and costs, reduced monthly expenses.
(e) Tightened up on entertainment and travel costs, combined two territories.
(f) Through a secretary-typist pool, saved one girl, reduced certain miscellaneous expenses.

B. Results of the action:

Income – sales				$700,000
Expenses	Fixed	Variable	Total	
Material		$200,000	$200,000	
Direct labor		230,000	230,000	
Indirect labor	$ 11,000(a)		11,000	
Instruments	22,500(b)	25,000	47,500	
Supplies	13,500(c)	15,000	28,500	
Deprec., insur., taxes, etc.	56,000(d)		56,000	
Selling expense	37,000(e)	10,000	47,000	
Administrative expense	35,000(f)		35,000	
	$175,000	$480,000	$655,000	
Total expenses				655,000
Pre-tax profit				$ 45,000

Table 3. Monthly profit and loss statement

A. Action taken:

(a) Purchasing action and value-analysis studies reduced material cost by 10%.
(b) Overtime reduction drive, work measurement and budgets reduced labor by 11%.
(c) Instrument requisition system, purchasing action and better design reduced test equipment costs.
(d) Monthly budgets and supply requisition system reduced supply costs.

B. Results of the action:

Income – sales				$700,000
Expenses	Fixed	Variable	Total	
Material		$180,000(a)	$180,000	
Labor		205,000(b)	205,000	
Indirect labor	$ 20,000		20,000	
Instruments	25,000	20,000(c)	45,000	
Supplies	15,000	12,000(d)	27,000	
Deprec., insur., taxes, etc.	60,000		60,000	
Selling expenses	40,000	8,000(e)	48,000	
Administrative expenses	40,000		40,000	
	$200,000	$425,000	$625,000	
Total expenses				625,000
Pre-tax profit				$ 75,000

The formulas for determining the margin of safety dollars and percentage are:

$$\text{Margin of Safety \$} = \text{Sales} - \text{Breakeven Point}$$

$$\text{Margin of Safety \%} = \frac{\text{Sales} - \text{Breakeven Point}}{\text{Sales}}$$

Let's calculate the P/V ratio, breakeven point and margin of safety for a hypothetical company called DEF Electronics and interpret our findings.

Table 1 shows its monthly profit and loss statement.

This company makes one product selling at $10 a unit. With 70,000 units sold in the average month, sales income is $700,000. Analyzing its costs, we determine that at that sales volume, its variable costs are $480,000 and its fixed costs $200,000 more. Subtracting $680,000 in costs from $700,000 of income, we have a $20,000 profit.

From these three knowns—monthly sales volume, monthly fixed costs and monthly profit—we can develop the P/V ratio, breakeven point and margin of safety.

The profit/volume chart (Fig. 1) shows sales income scaled along the x axis. The y axis, however, is bisected with a zero intercept. Above this intercept on the y axis are scaled dollars of profit. Below the zero intercept are scaled both dollars of loss and dollars of fixed costs.

We know the company has $20,000 profit at the current monthly sales income of $700,000. Therefore above the $700,000 sales point on the x ordinate, we go past the zero intercept to $20,000 on the profit scale of the y axis. Thus we have one point.

From our analysis, we determine that fixed costs total $200,000 a month. Therefore at zero sales income we go below the zero intercept to $200,000 on the fixed cost scale of the y axis. We now have a second point.

We can now draw a straight line connecting the fixed cost point on the y axis that is below the zero intercept with the point of profit above both the zero intercept line and the average monthly sales income. This is our *profit/volume line*. Where this line crosses the zero intercept is our breakeven point. The linear distance along the x axis between the breakeven point and the average monthly volume is our margin of safety.

Though you can read these three items off the chart, you obtain more precise answers by doing the actual calculation.

First, get the P/V ratio

You start the calculation by determining the P/V ratio. Using the previously mentioned formula:

$$\text{P/V Ratio} = \frac{\text{Profit} + \text{Fixed Costs}}{\text{Sales}}$$

and using the data for DEF Electronics, we calculate:

$$\text{P/V Ratio} = \frac{\$20{,}000 + \$200{,}000}{\$700{,}000} = 31.4\%.$$

Thus $31.40 of every $100 of sales is available for the absorption of overhead and, once overhead is absorbed, for additions to profit.

Next, find breakeven point

Knowing the P/V ratio, we can calculate the breakeven point, which is reached when the overhead or fixed costs are totally absorbed. With the formula:

$$\text{Breakeven Point} = \frac{\text{Fixed Costs}}{\text{Profit/Volume Ratio}},$$

we calculate:

$$\text{Breakeven Point} = \frac{\$200{,}000}{0.314} = \$637{,}000.$$

Finally, determine margin of safety

With the breakeven point, it is a simple deduction to obtain the margin of safety for DEF Electronics:

$$\begin{aligned}\text{Margin of Safety \$} &= \text{Sales} - \text{Breakeven Point}\\ &= \$700{,}00 - \$637{,}000\\ &= \$63{,}000\end{aligned}$$

$$\begin{aligned}\text{Margin of Safety \%} &= \frac{\text{Sales} - \text{Breakeven Point}}{\text{Sales}}\\ &= \frac{\$700{,}000 - \$637{,}000}{\$700{,}000}\\ &= 9\%.\end{aligned}$$

Planning improvements

Obviously DEF Electronics is not doing too well. In a month when sales are 9% below the monthly average, a loss is likely. Its margin of safety is dangerously thin. Also, DEF is making only $20,000 on $700,000 sales volume, a profit margin of slightly less than 3% before taxes.

So we institute a course of action that will improve this situation. We will first take action to reduce fixed costs and see what effect these reductions have on the P/V ratio, breakeven point and margin of safety. Note that we will do nothing to increase or decrease sales; the only change will be in reducing fixed costs.

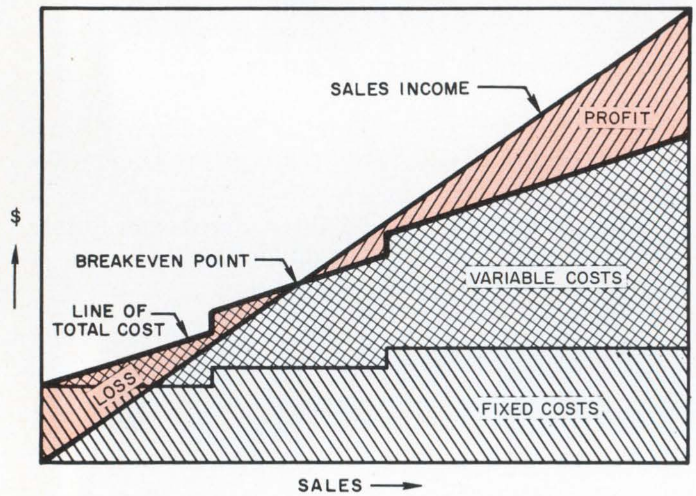
Table 2 shows the revised profit and loss statement after making cost improvements.

Comparing this with the first profit and loss statement, we see that costs have been reduced from $200,000 to $175,000. As a result, our profits increase from $20,000 to $45,000.

We now revise the P/V chart (Fig. 2).

Table 4. Monthly profit and loss statement

Income – sales				$700,000
Expenses	Fixed	Variable	Total	
Material		$180,000	$180,000	
Labor		205,000	205,000	
Indirect labor	$ 11,000		11,000	
Instruments	22,500	20,000	42,500	
Supplies	13,500	12,000	25,500	
Deprec., insur., taxes, etc.	56,000		56,000	
Selling expense	37,000	8,000	45,000	
Administrative expense	35,000		35,000	
	$175,000	$425,000	$600,000	
Total expenses				600,000
Pre-tax profit				$100,000



5. A standard breakeven chart. Note that the fixed costs are not fixed ad infinitum, while the variable cost line is both linear and step.

The new P/V ratio calculation is:

$$\text{P/V Ratio} = \frac{\$45{,}000 + \$175{,}000}{\$700{,}000} = 31.4\%.$$

Thus reductions in fixed costs have no effect on the P/V ratio. They did, however, affect both the breakeven point and the margin of safety:

$$\text{Breakeven Point} = \frac{\$175{,}000}{0.314} = \$557{,}000.$$

$$\text{Margin of Safety \$} = \$700{,}000 - \$557{,}000 = \$143{,}000.$$

$$\text{Margin of Safety \%} = \frac{\$700{,}000 - \$557{,}000}{\$700{,}000} = 20.4\%.$$

Thus the breakeven point has been improved — lowered by $80,000. The margin-of-safety dollar figure has been increased from $63,000 to $143,000, while the margin of safety percentage jumped from 9 to 20.4%.

Reducing variable costs

Suppose we return the fixed costs to their pre-reduction level of $200,000 and initiate a series of actions to reduce variable costs. What effect will this have on the P/V ratio, breakeven point and margin of safety? Again, we neither increase nor decrease sales; the only change is the reduction in variable costs.

Table 3 shows the revised profit and loss statement after reducing the variable costs and returning the fixed costs to their original levels.

At the same $700,000 monthly sales volume, we have reduced variable costs by $55,000 to $425,000. As a result, our profits rose from $20,000 to $75,000. Thus we have a revised P/V chart for DEF Electronics (Fig. 3).

The P/V ratio calculation now is:

$$\text{P/V Ratio} = \frac{\$75{,}000 + \$200{,}000}{\$700{,}000} = 39.3\%.$$

Reductions in variable costs have increased the P/V ratio, which means that the contribution to overhead absorption and to profits has been increased. In this instance, we now have $39.30 instead of $31.40 of every $100 of sales available to cover overhead and eventually to add to profit, once all overhead is covered.

These reductions in variable costs also improve the breakeven point and the margin of safety:

$$\text{Breakeven Point} = \frac{\$200{,}000}{0.393} = \$509{,}000.$$

$$\text{Margin of Safety \$} = \$700{,}000 - \$509{,}000 = \$191{,}000.$$

$$\text{Margin of Safety \%} = \frac{\$700{,}000 - \$509{,}000}{\$700{,}000} = 27.3\%.$$

The breakeven point has been reduced by $128,000. The margin of safety dollars and percentage go up threefold.

Combining all reductions

Now, we shall combine the reductions in both fixed and variable costs.

Table 4 shows the new profit and loss statement for DEF Electronics.

For the same average monthly sales volume of $700,000, we have increased profits to $100,000—a rise of $80,000—by reducing costs by $80,000.

The "before" and "after" P/V chart is shown in Fig. 4.

And here are our new calculations:

$$\text{P/V Ratio} = \frac{\$100{,}000 + \$175{,}000}{\$700{,}000} = 39.3\%.$$

$$\text{Breakeven Point} = \frac{\$175{,}000}{0.393} = \$445{,}000.$$

$$\text{Margin of Safety \$} = \$700{,}000 - \$445{,}000 = \$255{,}000.$$

$$\text{Margin of Safety \%} = \frac{\$700{,}000 - \$445{,}000}{\$700{,}000} = 36.4\%.$$

By reducing the fixed and variable costs of DEF Electronics, we have effected these improvements:

- The P/V ratio has increased from 31.4% to 39.3%.
- The breakeven point has been reduced from $637,000 to $445,000.
- The margin of safety dollars has risen from $63,000 to $255,000.
- The margin of safety percentage has increased from 9 to 36.4%.

By effectively controlling costs, we have greatly improved the company's profit picture.

From this experience we can draw some rules.

When fixed costs are reduced:

1. Profits are increased.
2. The breakeven point is reduced.
3. The margin of safety is increased.
4. The profit/volume ratio is unaffected.

When variable costs are reduced:

1. Profits are increased.
2. The breakeven point is reduced.
3. The margin of safety is increased.
4. The profit/volume ratio is increased.

Using the P/V ratio

The P/V ratio is a measure and control that has a great many applications for management. It may, for example, be used to evaluate the following:

- The relative effectiveness of two plants making similar products.
- The relative performance of divisions within a corporation.
- The company's performance versus the competition's.
- Current operating performance compared with past periods.
- The effect of cost changes. If, for instance, a new labor contract has been negotiated, P/V analysis can show the effect of the increases upon the company.
- What sales volume increase, what cost improvement action or what combination of the two will be needed to maintain the past company profit position in the face of increased costs.
- The net effect of proposed capital-investment projects that will increase fixed costs but reduce variable costs.
- The net effect of proposed marketing actions, such as:

1. Price reductions that will reduce income per unit but yield a greater unit sale. ("How many more units must we sell if we reduce prices 10%?")
2. Advertising and sales campaigns calculated to increase volume. ("What increase in sales will we need to cover an advertising campaign costing $100,000 or to pay for four additional salesmen?")

- The relative contributions to overhead absorption and profit of products, territories and/or customers.

Applying breakeven knowledge

A company may feel itself comfortably past the breakeven point. "Of what importance is it to know the breakeven point?" the neophyte may ask.

The reply: Every management should know the effects of its decisions and actions upon the corporate breakeven point. Management should establish its own desired margin of safety and then make a concerted effort to assure that the company maintains that margin.

More than one engineering manager has been caught unawares when the company's breakeven point and margin of safety deteriorated. Disaster often resulted. ■ ■

Test your retention

Here is a problem based on the main points of this article. You'll find the solution on page 178.

The Sensor and Control Co. had the following operating results for a 12-month period:

Month	Sales	Profit or (Loss)
Jan.	$375,000	($ 25,000)
Feb.	350,000	(10,000)
Mar.	275,000	(75,000)
Apr.	325,000	(50,000)
May	400,000	15,000
June	500,000	75,000
July	525,000	50,000
Aug.	750,000	200,000
Sept.	800,000	175,000
Oct.	700,000	125,000
Nov.	575,000	135,000
Dec.	425,000	(15,000)
	$6,000,000	$600,000

Estimate the monthly fixed costs. Then calculate the company's profit/volume ratio, breakeven point and margin of safety in both dollars and percentage.

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Prime Experience	Secondary Experience

Desired Salary	**Availability Date**

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City, State			
Dates	to	to	to
Title			
Specialty			

Education – indicate major if degree is not self-explanatory

Degree			
College			
City, State			
Dates	to	to	to

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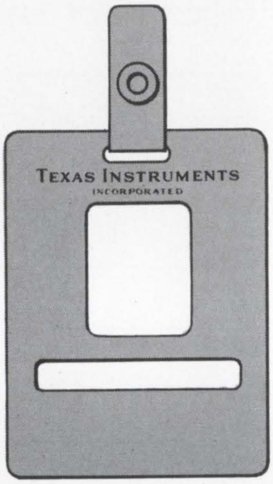

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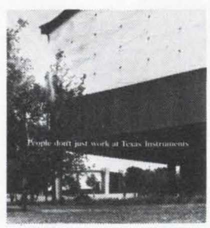

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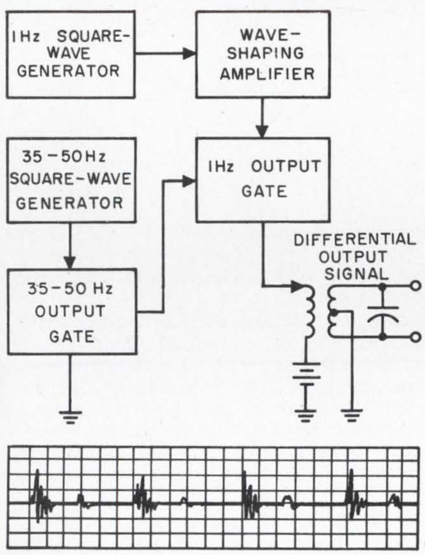
Circuit duplicates sound of heart

Problem: Design an instrument that can duplicate the sounds of the human heart. Its output, a phonocardiogram, has become a very important tool in physiological monitoring of astronauts in flight and during flight simulation. To calibrate and check such a device, it is necessary to simulate, with accurate control, the timing and amplitude of heart activity.

Solution: Build a phonocardiogram simulator with the circuitry in the accompanying diagram. It produces a pattern of electrical signals that duplicate exactly in time and amplitude, the sounds of the human heart. The waveforms are adjustable to simulate all known ranges of human heart activity.



The 1-Hz square-wave multivibrator generates the basic repetition rate of the signal complex. The 35-to-50-Hz multivibrator generates the frequency within each "heart sound" pulse. Circuit resistances are used to control pulse amplitude, and a potentiometer is used to regulate output voltage level.

This innovation can be used to check telemetry systems and instrumentation systems for phonocardiogram monitoring in hospitals and for training personnel to use such systems.

Inquiries about this invention can be made to: Technology Utilization Officer, Kennedy Space Center, Kennedy Space Center, Florida 32899. Reference: B67-10239.

Small computers analyze circuits

Problem: Design a set of linear circuit analysis programs to be used on a small computer system such as the IBM 1620/20K version with a 1311 disk storage drive.

Solution: CIRCS is a modification of the original IBSNAP circuit analysis program. Only the basic dc, transient analysis, and input language formats have been retained.

CIRCS can solve a linear network containing a maximum of 15 nodes (excluding ground) and 45 branches. Transistors and diodes can be included in the network as linear models and a special data card allows the user to describe the base, collector, and β or g_m characteristics of the transistor.

The analysis portion of the ac and dc programs (ACNOD1 and DCNODE) have been so radically changed that only a similarity remains between CIRCS and IBSNAP. A Mandex worst-case analysis was added to the dc program in preference to the original dc worst case. The card processing program links (AC, DC, TR) were written for use on the IBM 1620/1311 data-processing system.

By modifying the necessary input parameter information with the partials as criteria, one can establish a true worst-case solution. The sensitivities computation in CIRCS gives the user an idea of the percentage effect that a particular input parameter has on a particular node voltage with respect to the remaining input parameters.

Linear approximations are

substituted for the differentials and integrals in the transient program, so reducing the system of differential equations to a system of algebraic equations. The trapezoidal rule is used in approximating the integrals. In order to model diodes, ramp functions, sawtooth functions, etc., switching is built into the program. The programing language is Fortran II.

Complete details of this program are available from: COSMIC Computer Center, University of Georgia, Athens, Ga. 30601. Reference: B67-10173.

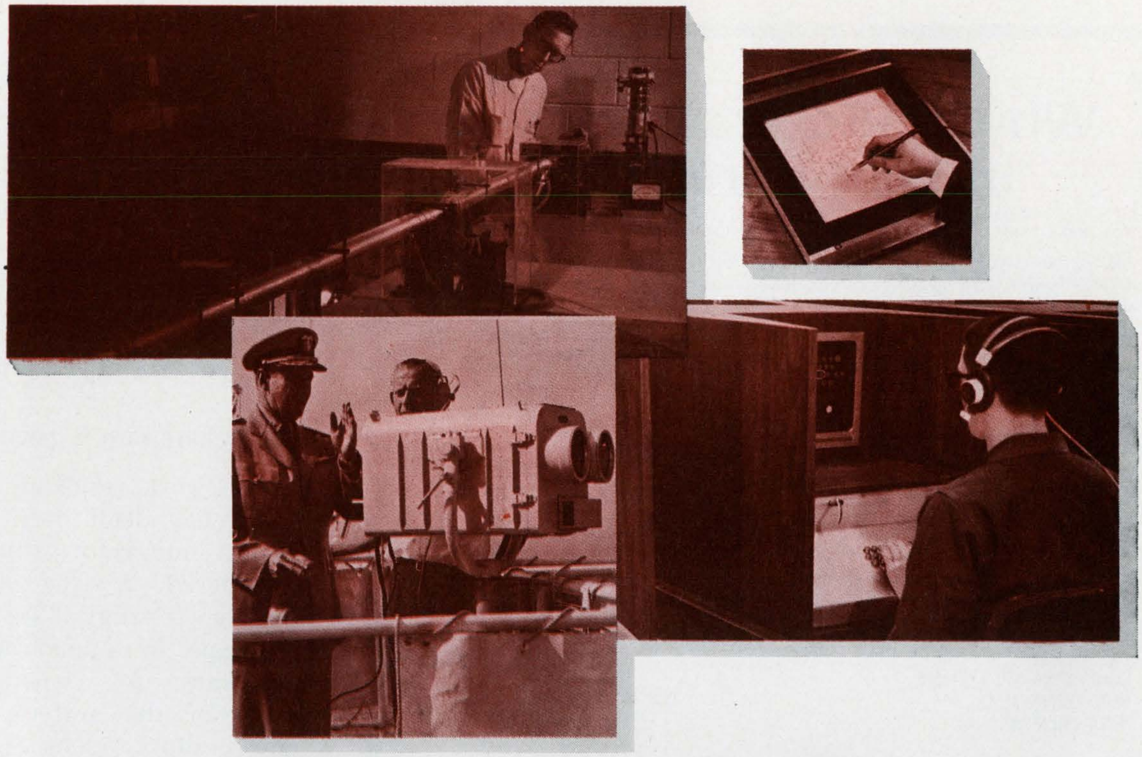
Fluid digital systems are found practical

Long life and environmental tolerance make the use of fluid amplifiers highly desirable in digital computation systems, a study prepared for NASA has found.

The fluid amplifier's tolerance to both nuclear and electromagnetic radiation and to extreme temperature ranges appears limited only by the fabrication material. Shock and vibration tolerances also appear excellent; fluid amplifiers have withstood vibration levels as high as 50g at 5000 cycles per second. Moreover the production costs of fluid-amplifier components may be low, because of the lack of close-fitting moving parts and bearing surfaces.

The digital integrator is the basic building block in digital differential analyzer systems, just as the operational amplifier is in analog computational systems. For that reason, the digital integrator was chosen as the most appropriate target to investigate.

The study found that digital computation systems with fluid amplifiers are practical. Their response speed is adequate for many space applications. Their



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potential for reliability in adverse environments, such as nuclear radiation, heat and vibration, is superior to electronic circuitry. Applications that have been considered as a result of these findings include a satellite control and a guidance computer for an escape "lifeboat" for manned orbital stations.

Better hardware is needed

The work resulting from the study has dealt only with the digital integrator, since it was considered a key feasibility problem for digital systems. For any specific application, it is necessary to consider other parts of the system, such as power supply, sensors, displays and digital-analog converters.

So far as the digital integrator itself is concerned, the following represent areas where additional study is recommended:

- Miniaturization.
- Speed.
- Power consumption.
- Packaging design and fabrication techniques.
- Instrumentation.

The work in these areas is closely interrelated. Miniaturization is required to improve speed and to reduce power consumption, for example. The degree of miniaturization will also affect the instrumentation requirements for monitoring and testing, and it will dictate certain fabrication methods. The package design must permit very close coupling of elements to achieve high operating speeds.

Complete details of the study are contained in: NASA Contractor Report, Fluid Amplifier Digital Integrator, prepared by General Electric, NASA, CR-61092, September 1965. Copies of the report are available from: Technology Utilization Officer, Marshall Space Flight Center, Huntsville, Ala., 35812. Reference: B67-10181.

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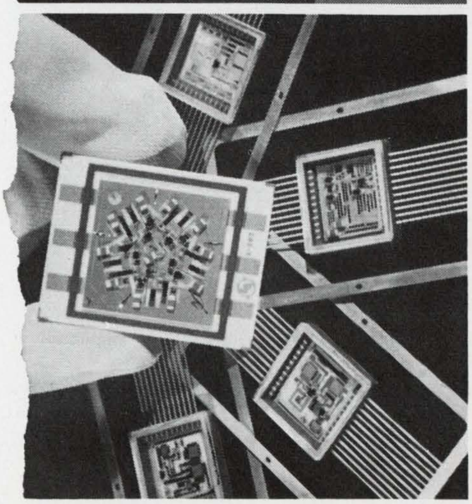

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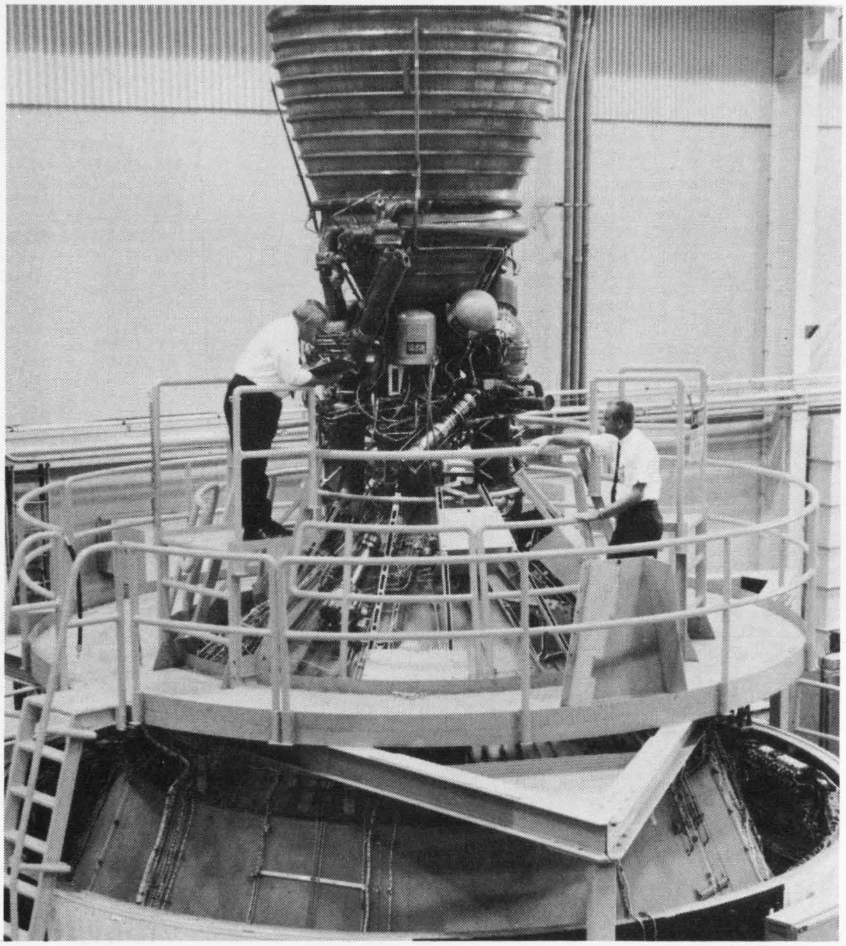

Electronic-mechanical simulator of the Kennedy Space Center's Saturn V launch control center. It is used by Boeing-Huntsville engineers and technicians to check out all components of Apollo/Saturn V vehicle.

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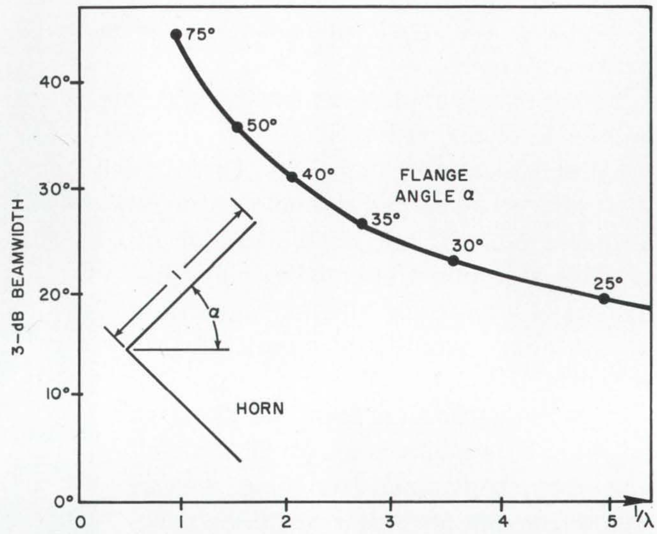
Curve gives minimum-weight design for waveguide-fed horns

The antenna designer frequently faces the problem of reducing the weight of antennas. Many waveguide-fed antennas use horns to shape a beam. The commonest application is an H-plane sectorial horn used to form the vertical-plane beam of a linear- or slotted-waveguide marine radar antenna. The horn of such an antenna often supports the rest of the structure as well as shapes the vertical beam. Minimizing horn weight will cut antenna weight, which is a design goal for rotating, scanning, or transportable antennas.

The 3-dB beam width of a horn is a function of both the horn flare angle and its total length. To achieve a particular 3-dB beam width, a range of combinations of horn flare angle and length may be used. Many of these combinations are wasteful because they require more material than is necessary for the required beam width. The combination that takes the least horn material is usually found by cut-and-try methods. The curve given here eliminates this cut-and-try process; horns can be designed from the start to use a minimum of material.

For example, a minimum-material H-plane sectorial horn giving a 25° 3-dB beam width should have a flare angle of 32.5° and a side length of 3 wavelengths. A smaller flare angle would require a greater side length to achieve the required 25° beam width, while a shorter side length would result in a greater beam width. The combination of a 32.5° horn flare angle and a 3-wavelength side length is then the minimum weight design.



Curve for minimum weight in an H-plane waveguide-fed sectorial horn. The 3-dB beam width is measured in the plane containing the horn flare. The curve can also be used for the H-plane diagram of pyramidal and biconical horns.

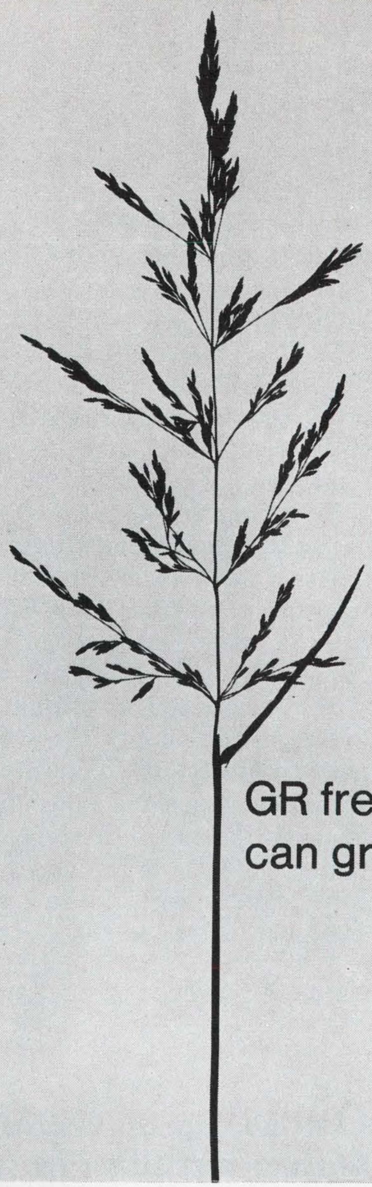
M. Michael Brady, Research Engineer, NERA A/S, Oslo, Norway.

VOTE FOR 110

Reliable one-shot has high repetition rate

Conventional monostable multivibrators suffer because their repetition rate is limited by their recovery time. After a one-shot is triggered, the circuit must return to its quiescent state before it will trigger again. A method of ensuring reliable triggering is shown in the accompanying figure.

A command pulse is coupled to an AND gate, the other input of which is enabled when *M2* is off. This produces a positive trigger that triggers *M1*. This one-shot produces a delay, T_1; the trailing edge of this pulse triggers *M2* through the inverter. *M2* now produces a pulse, also of duration T_1, during which the AND gate is inhibited, so that it cannot receive or respond to an improper trigger. By the time *M2* has produced its pulse, *M1* will have recovered and so can be triggered again. The duration of *M1*'s output pulse is such that *M2* will be



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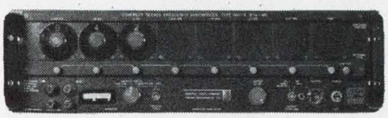

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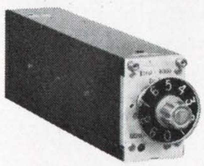
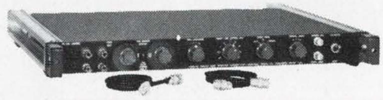
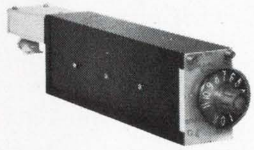


add additional digits ($455 each) as you need them for up to 7-digit resolution and . . .

at any time add a continuously adjustable decade ($550) for 2 extra figures of resolution or for continuous, manual control of frequency . . . sweep it electrically with your own external sweep signal or . . .

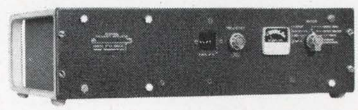


get the sweep, and frequency markers too, by adding our new sweep and marker generator ($495).

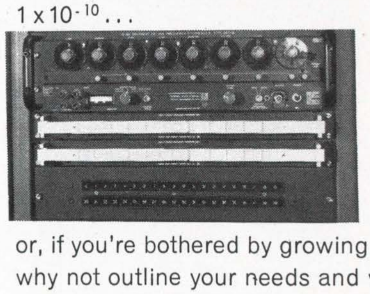


Want to go programmable? . . . use programmable decades ($545-$575) . . . new units now provide stepped programming up to 12 MHz . . . programming can be controlled by simple switch closures . . .

or, if you'd rather not flip switches, add our new preset-frequency programmer (20 channels for $1000; 40 channels for $1825) with a storage capability of up to 40 preset 7-digit frequencies per tray. Actual storage capability is unlimited if you don't mind switching trays . . .



and, if you need exceptional long-term stability, add an external frequency standard ($2050) and improve it by three orders of magnitude to better than 1×10^{-10} . . .



or, if you're bothered by growing pains, why not outline your needs and we'll recommend the right system . . . at off-the-shelf prices. Write General Radio Company, W. Concord, Massachusetts 01781; telephone (617) 369-4400; TWX (710) 347-1051.

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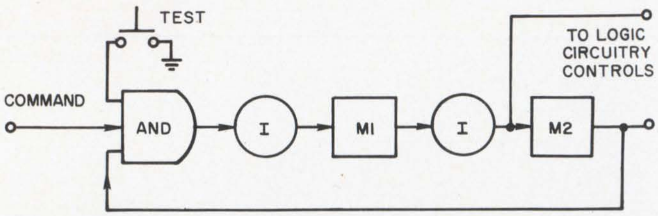


The second one-shot ensures that the first will have returned to its quiescent state before it can be triggered again.

triggered by its trailing edge. The grounding of a test lead left at the input of the AND gate also enables the gate and causes *M1* to trigger. When *M2* triggers, the trailing edge's positive transition couples through the AND gate and inverter, and again triggers *M1*.

The result is a continuous train of pulses that can be used to debug any following logic. It needs no external pulse generator or command input from another subsystem.

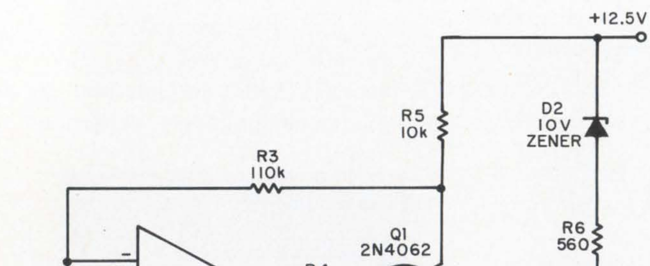
Robert Scott, Consulting Engineer, East Brunswick, N.J.

VOTE FOR 111

Voltage-to-frequency converter built with one UJT oscillator

The circuit shown is a low-cost voltage-to-frequency converter. It is appreciably simpler than conventional converters made with a blocking oscillator.

It consists of a UJT oscillator in which the rate of charge of timing capacitor *C2* is linearly dependent on the input signal voltage. The charging current is set by the voltage across resistor *R5*, which is accurately controlled by the amplifier.



Two decades of frequency range are obtained with this simple VCO (voltage-controlled oscillator).

The range of permitted charging currents is limited by the peak point and valley currents of the UJT. Provided transistor *Q1* has a gain of at least 200 over the charging-current range, linearity is limited by the leakage current of the UJT (effectively reduced by diode *D1*) and the oscillator's minimum duty cycle.

The amplifier is selected to give the required gain at the appropriate input impedance. The combination *R4C1* is used to limit the high-frequency response of the amplifier. The Zener diode is used to adjust the peak-point voltage of the UJT within the output voltage range of the amplifier.

Since the amplifier output is taken with respect to the positive supply, the over-all performance depends on the supply stability. Assuming a typical regulated transistor power supply and the components indicated, however, linearity is better than $\pm 0.5\%$ over a frequency range of two decades, for a signal range of 0 to 1 volt. The temperature coefficient is typically 0.05/°C from 10° to 40°C.

S. G. Johnson, Physicist, Regional Medical Physics Dept., Sheffield, England.

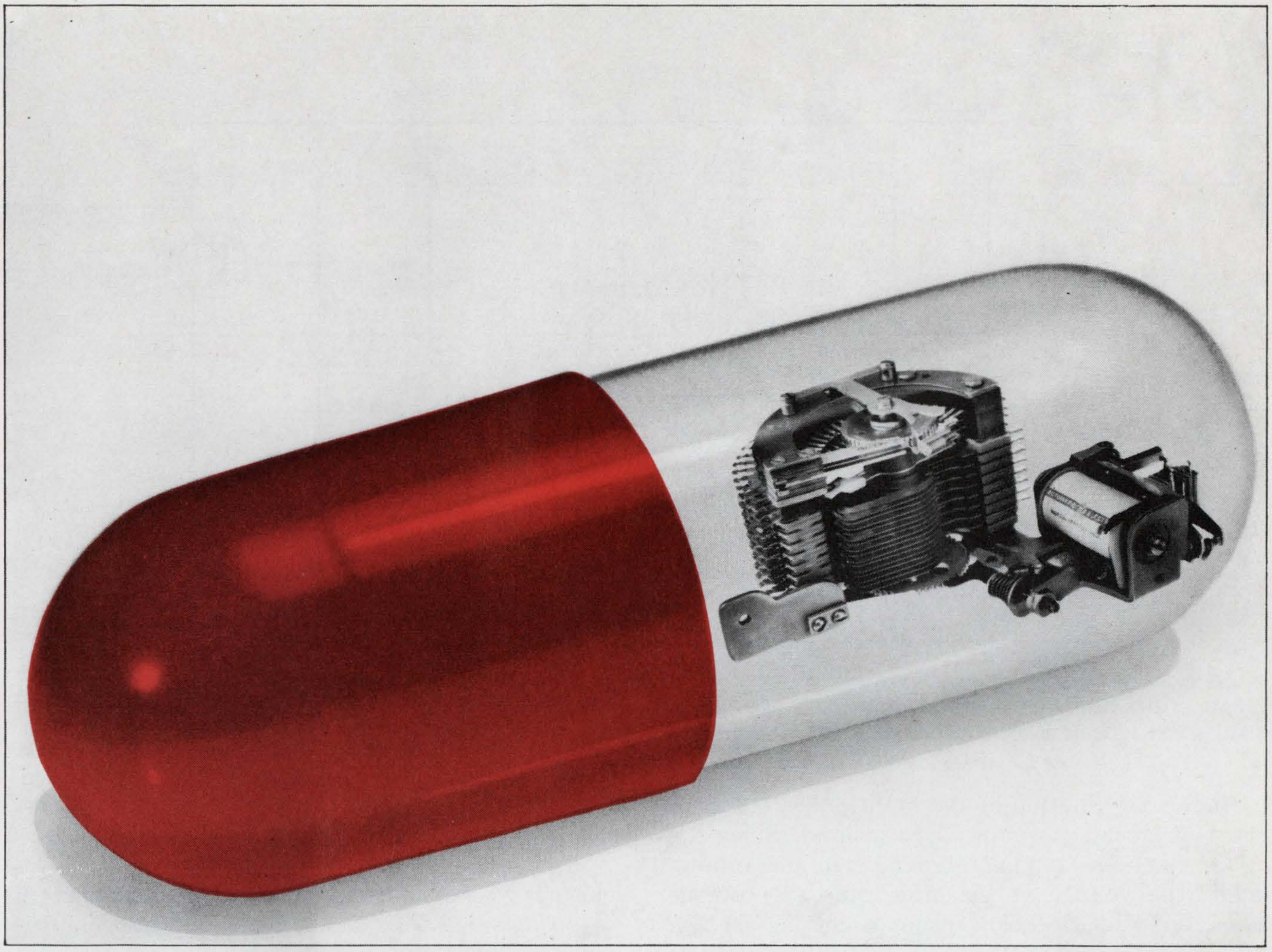
VOTE FOR 112

Compress or expand pulses with a simple circuit

The length of the output pulse is proportional to the length of the input pulse, and the output pulse is delayed for the duration of the input pulse in this circuit (see figure). The ratio of the input to output pulse widths is adjustable over a wide range.

With the length of the input pulse varying, but input-to-output-pulse-width ratio fixed, the length of the output pulse follows changes in the length of the input pulse linearity. Maximum deviation from linearity is 2% for output pulses of 50 μs to 25 ms (this range depends on the value of capacitor *C*). Ratios for input to output pulse width were kept fixed within the 0.1-to-10 range for tests.

When a pulse is applied to the input, it acts through *Q1* to switch off *Q2* and so disconnect one side of (*A*) of *C* from ground. Adjustable constant-current supply consisting of *Q3, R1, R2, R4, R5* will charge *C* for the duration of the input pulse. During this time, a second constant-current supply consisting of *Q4, R6, R7, R8* delivers sufficient current to the base of *Q5* to saturate it. *Q5* and *Q6* form a Schmitt trigger and *Q7* is used for inversion, so the output is at its low level while *Q5* is saturated.



Remedy for nightmares: AE's Type 45NC stepping switch with "shorting" levels.

Many of today's complex switching circuits look like an engineer's nightmare. Why not simplify them? You can replace whole groups of components with an AE Type 45NC "stepper."

This switch has normally closed ("shorting") levels. It's designed so that pairs of contacts *open* successively when the rotor is stepped.

The Type 45NC can solve almost any circuit-transfer or testing problem.

It's ideal for self-interrupted hunting, and you don't need auxiliary relays.

You get one or two electrical levels of either 26 or 52 point normally-closed contacts. For extra versatility, you can specify additional levels of *normally-open* contacts—on the same switch.

Contacts are gold-plated phosphor bronze. Contact resistance: a maximum of 50 to 100 milliohms, measured at 6 volts 100 milliamperes.

When you specify AE rotary stepping switches, you get the benefit of our continuous research—in design, in metals and insulating materials. All this plus *positive positioning* – a unique AE design feature that locks the rotor and makes overthrow impossible.

Find out more about AE rotary stepping switches—an economical, rugged and reliable way to simplify switching circuits. There's a lot of helpful application information in our new reference circular 1698-L. To get your copy, just ask your AE representative. Or write to the Director, Relay Control Equipment Sales, Automatic Electric, Northlake, Illinois 60164.

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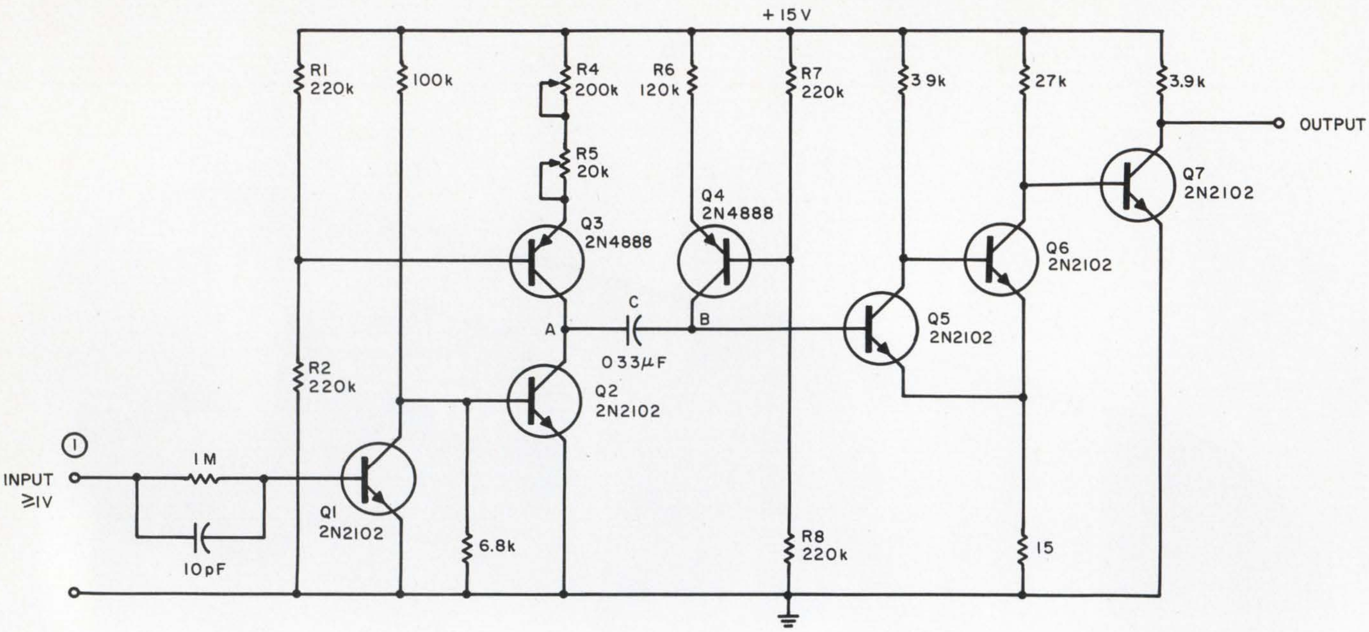
ON READER-SERVICE CARD CIRCLE 49



Length of the output pulse linearly follows changes in the input pulse length. Maximum deviation from linearity is 2% for output pulses of 50 μs to 25 ms. The speed of the circuit can be adjusted by changing C.

At the termination of the input pulse, *Q2* saturates and connects point *A* to ground. Since the voltage across *C* cannot be changed instantaneously, the voltage at the other side (*B*) of the capacitor will dip below ground, cutting off *Q5*. *Q5* and *Q7* work in phase, so the output voltage will be switched to its high level when the input pulse terminates. Constant current from the supply *Q4*, *R6*, *R7*, *R8* will begin discharging the capacitor at this instant, for current cannot flow into the base of *Q5* because this transistor is cut off. When voltage at point *B* reaches a level sufficient to turn on *Q5*, the output voltage will fall back to its low level, both ends (*A* and *B*) of *C* will be at voltages near ground level with *Q2* and *Q5* conducting; the circuit is at rest, ready to receive the next pulse.

Transistors *Q2* and *Q5* were selected for their low leakage current to improve linearity.

The ratio of input to output pulse width is adjusted with the current from constant-current supply *Q2*, *R1*, *R2*, *R4*, *R5*. When output from this supply equals the output from constant-current supply *Q4*, *R6*, *R7*, *R8*, the length of the output pulse equals the length of the input pulse. When current from *Q3* is larger than the current from *Q4*, the length of the output pulse is larger than the length of the input pulse and vice versa.

The circuit lends itself to pulse-width modulation if adjustment of current from *Q2* is made proportional to a second input signal.

Thomas Weisz, Electronics Engineer, University of Michigan, Ann Arbor, Mich.

VOTE FOR 113

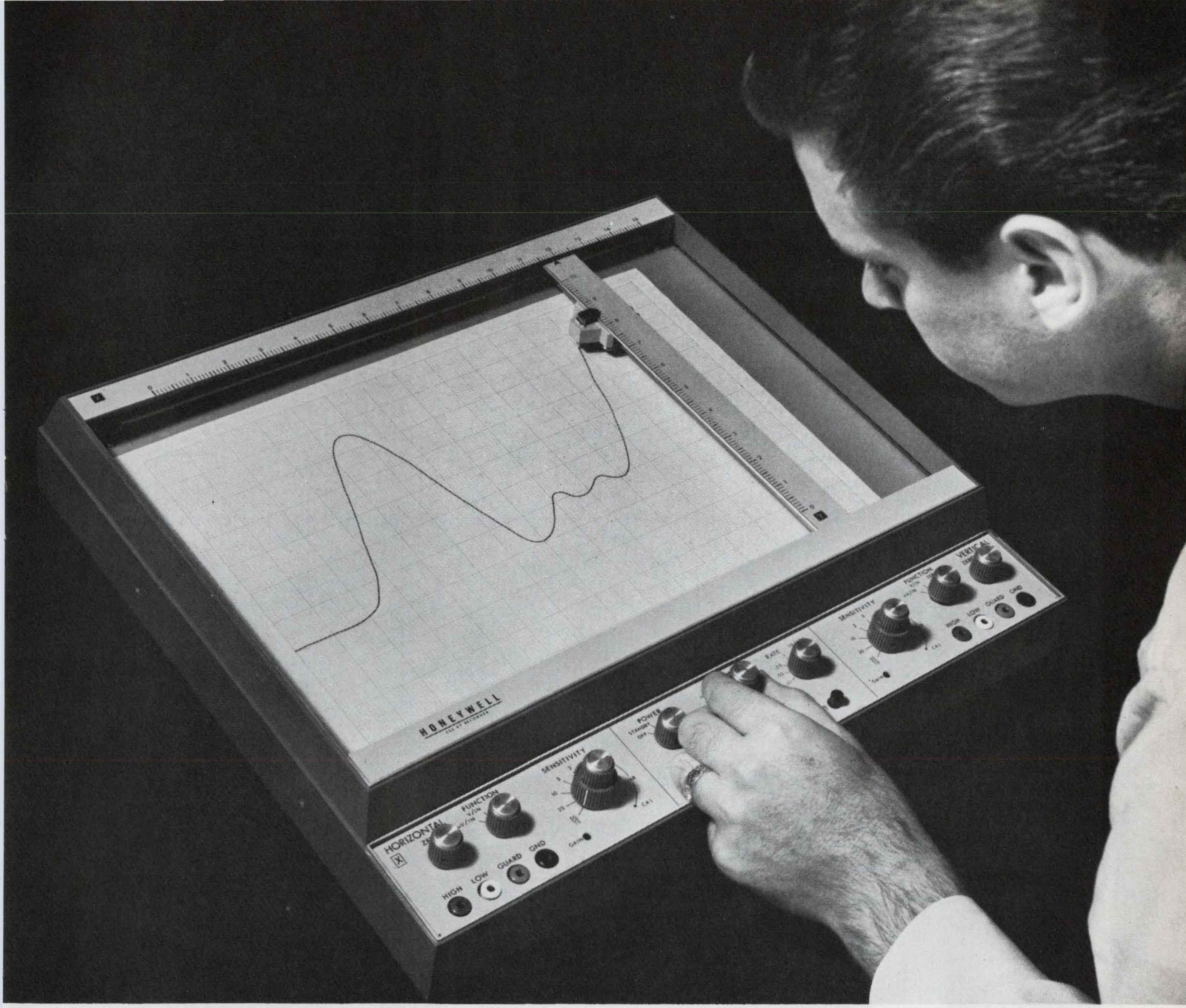
Simple circuit protects loudspeaker and audio amplifier

Fuses and circuit breakers are too slow to give reliable protection to a loudspeaker system and the amplifier that drives it. The high cost of complementary output transistors in contemporary designs makes protection against inadvertent short-circuit, undervoltage and overcurrent conditions necessary.

This is effected by diminishing the supply voltage to zero. The complete circuit appears in Fig. 1a; a simplified schematic in Fig. 1b.

Under normal conditions, point *A* is positive and transistor *Q2* is cut off. When an overcurrent or an undervoltage condition occurs, the $+E_{REG}$ voltage decreases to a value less than E_Z, diode *CR1* becomes nonconductive, and point *A* becomes negative. A negative voltage at point *A* switches transistor *Q2* on. This in turn reverse-biases transistor *Q3*, diminishing $+E_{REG}$.

Voltage divider *R3*, *R4* is selected such that the voltage at the base of *Q1* is slightly positive, to prevent spurious turn-on of *Q1*. Time constant



Self-supported at a 30° angle, the new Honeywell 550 offers convenient bench operation – converts to rack mounting easily.

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The result is the new Honeywell 550–a slim, crisply designed instrument that overcomes the mechanical problems that plague other X-Y's. Its built-in reliability is protected by a tough, molded base that seals working parts from dust and dirt, even when the 550 is rack-mounted. You get smooth, quiet operation, and you get it for a long, long time.

With true differential input, high sensitivity to 100 μv/", and accuracy of 0.15%, the dependable 550 takes a back seat to no one in the performance department. And, it's convenient to use – there's a standby position for quick, easy paper loading, a zero check position, and rear inputs and remote capability built in.

Other 550 features include: a stainless steel pen with non-clogging polished sapphire tip; sealed potentiometers for maximum field reliability; snap-on ink cartridges; a handy zero check, and a built-in event marker. There's lots more, yet the 550 is moderately priced!

If you've been bugged by your current X-Y recorder, look into the new 550. It's another example of how Honeywell's broad line, backed by local sales and service, can provide the *precise* solution to your instrumentation problems. For full details on the 550, call your local Honeywell Sales Engineer, or write: Honeywell, Test Instruments Division, 4800 East Dry Creek Road, Denver, Colorado 80217.

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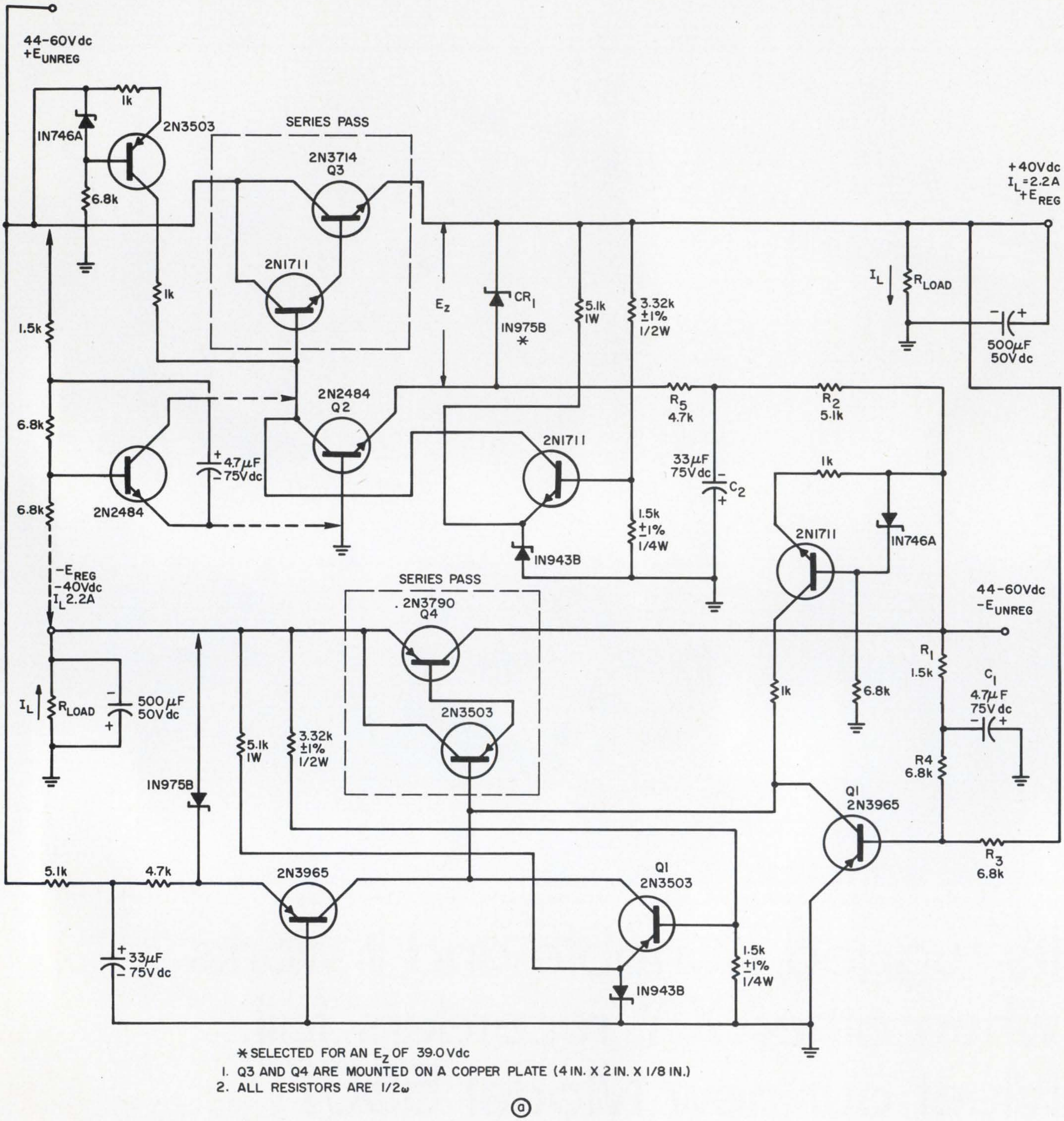


1. **Loudspeaker and audio amplifier protection** circuit operates by dropping voltage to zero.

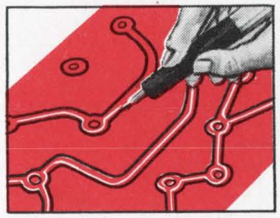
$R_1 C_1$ prevents switching transients from turning *Q1* on when power is applied.

Should $+E_{REG}$, the positive regulated supply fail, the loss kicks *Q1* on. This in turn forces *Q4*, off. With *Q4* off, the $-E_{REG}$ voltage decreases to zero.

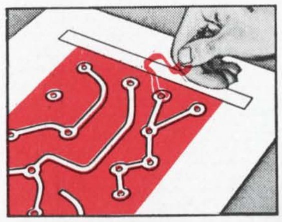
The circuit shown operates for an overload on the positive supply. Operation for the negative supply is shown by dotted lines.

Once the faulty condition has been removed, manual reset is necessary. To reset, the operator sets the power switch to off position for approximately ten seconds and then moves it to the on position.

In Making Masks for Electronic Components... ...there's no Margin for Error!



With sharp blade, outline the areas to be masked. **Do not cut through the backing sheet.** The Ulano Swivel Knife does the job quickly, easily.



Now carefully peel oft the film as outlined leaving a completed photo mask, positive or negative, that corresponds exactly to the desired pattern.

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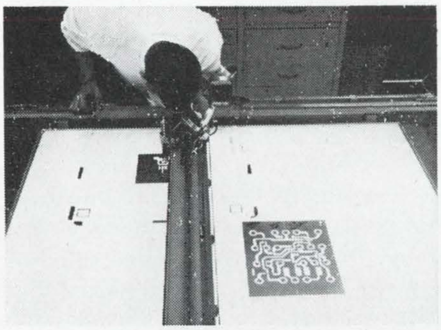

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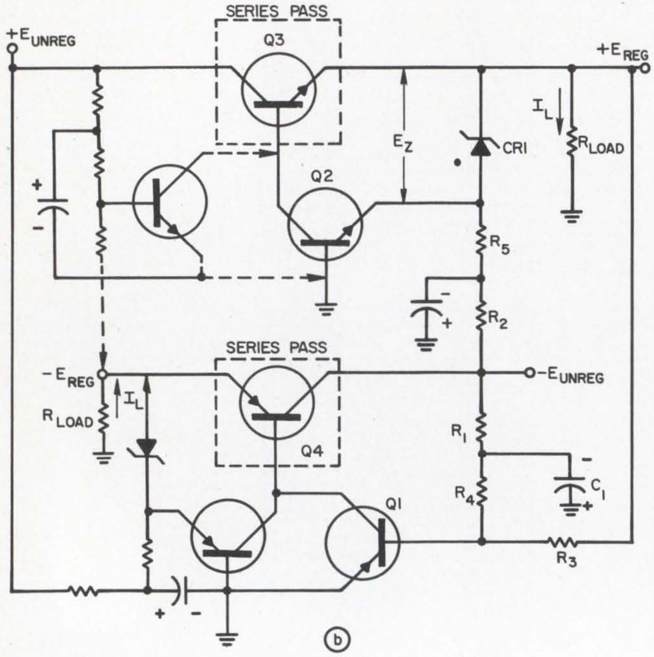
ON READER-SERVICE CARD CIRCLE 51



2. **Action** of the circuit of Fig. 1 is explained with this simplified schematic.

The design criteria for the circuit are:

$$E_Z = E_{REG} - \Delta E_{REG};$$
$$R_2 C_2 \approx 5R_1 C_1;$$
$$I_{Z(rated)} = E_{unreg}/(R_2+R_5).$$

Melvin W. Kyle, Jr., Senior Circuit Engineer, Hughes Aircraft Co., Culver City, Calif.

VOTE FOR 114

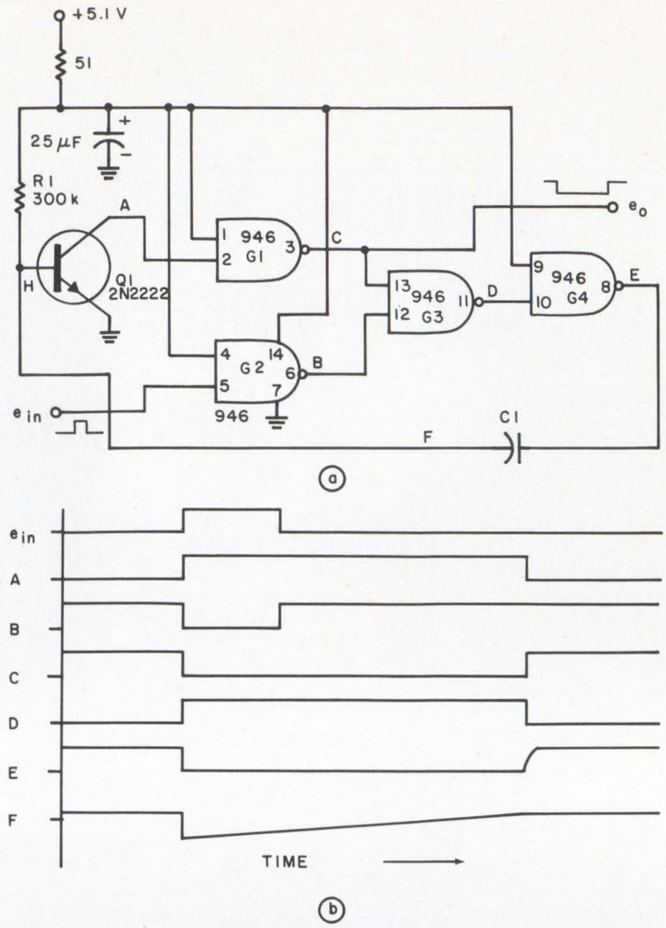
Long-duration monostable fabricated with ICs

Monolithic integrated monostables are generally limited in pulse width by the requirement for low impedance levels in the charging path. For long delays, large-value polarized capacitors are necessary, seriously affecting the temperature stability of the output. In general, monostable multivibrators built with low-level integrated logic gates suffer from the same maladies.

The low-cost circuit in Fig. 1a uses small capacitors to obtain long pulse widths. Short reset times are possible because of the large ratio between timing and reset impedances. In addition, the output pulse width is independent of input pulse width.

The circuit combines a high-beta low-leakage transistor with a DTL quad dual-input gate. In this configuration, the charge path of *R1*, *C1* and R_{sat} (saturation resistance of *G4* output transistor) controls the base of *Q1*. Circuit operation is explained in the timing diagram (Fig. 1b).

Since *Q1* is turned off very quickly by the leading edge of the negative-going waveform at point *H*, duty cycle limitations are imposed by the rest time of *C1*. *C1* resets by charging from the collector load of *G4* through the on input impedance of *Q1*. The pulse width $T_0 \approx 0.7R1C1$. Since the input impedance of *Q1* when in its saturated region is much smaller than the charging resistor *R1*, duty cycles to 94% are easily obtained.



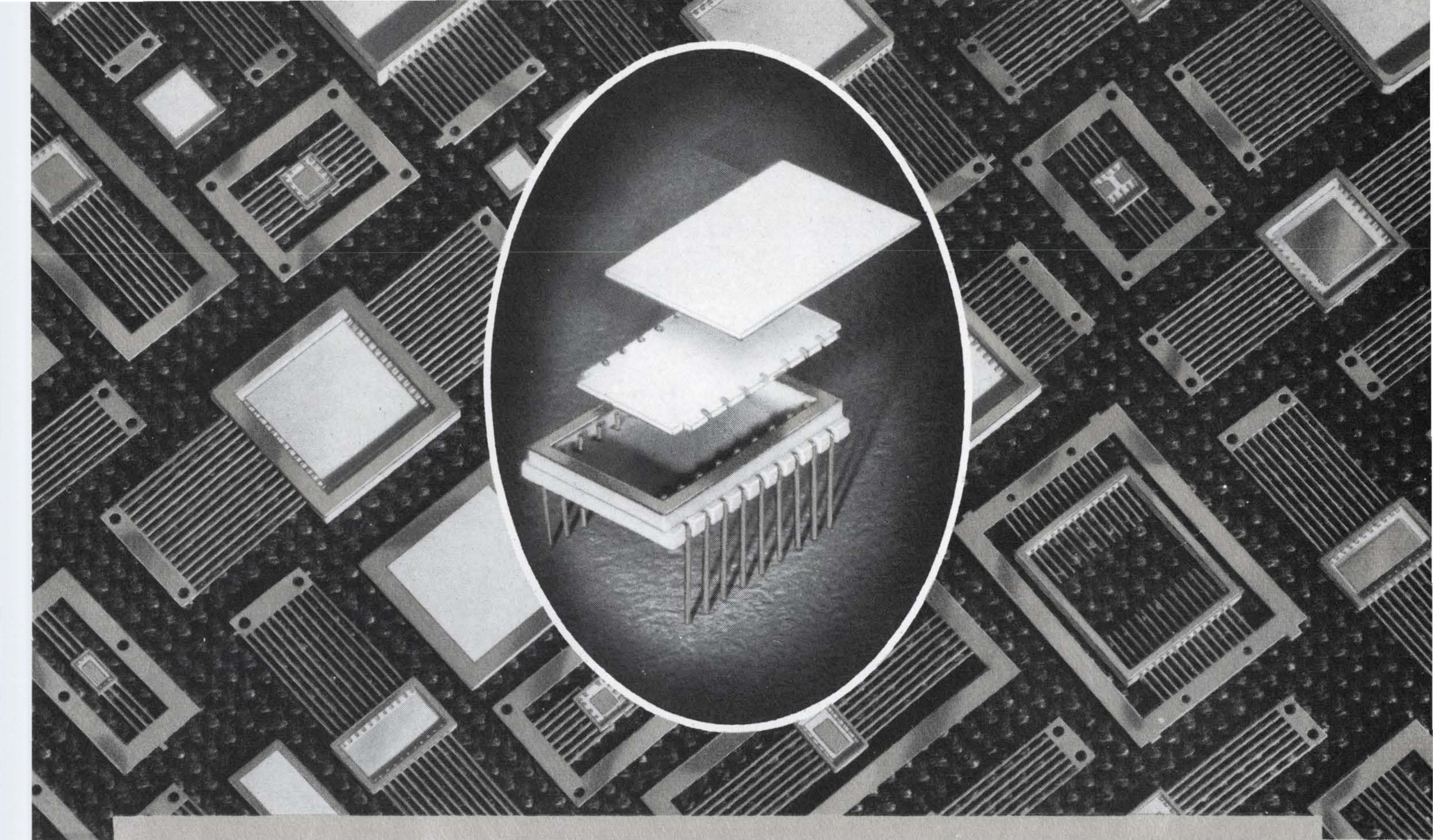
100-ms to 10-s pulse widths are obtained from this simple monostable (a) using DTL quad dual-input gate and a high-beta, low-leakage transistor. Circuit action is described in (b).

Output pulse widths from 100 ms to 10 s were obtained with this circuit by varying *C1*. No change in a given output pulse length was observed for input pulse lengths varying over a wide range of pulse widths. The price of the components in unit quantity is under $5.00.

George C. Kuipers, Senior Research Engineer, AC Electronics, Goleta, Calif.

VOTE FOR 115

IFD Winner for September 1, 1967
Allan G. Lloyd, Project Engineer, Avion Electronics, Inc., Paramus, N. J.
His Idea, "Constant-current regulator has low dissipation," has been voted the $50 Most Valuable of Issue Award.
Cast Your Vote for the Best Idea in this Issue.



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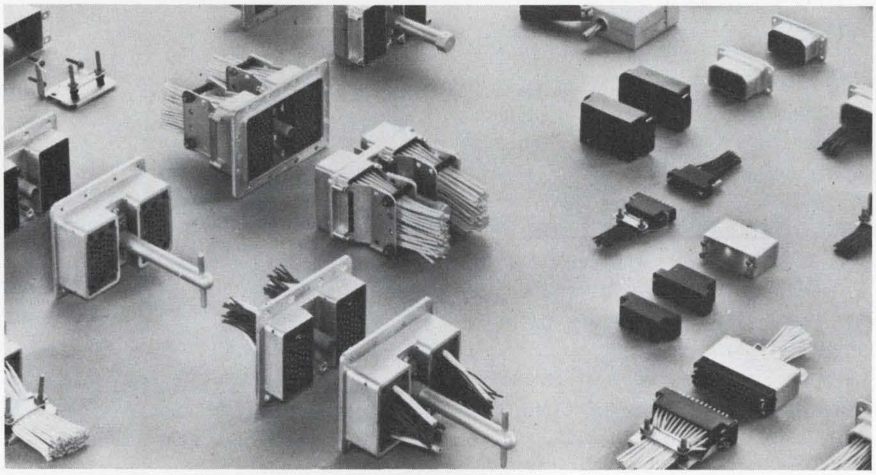
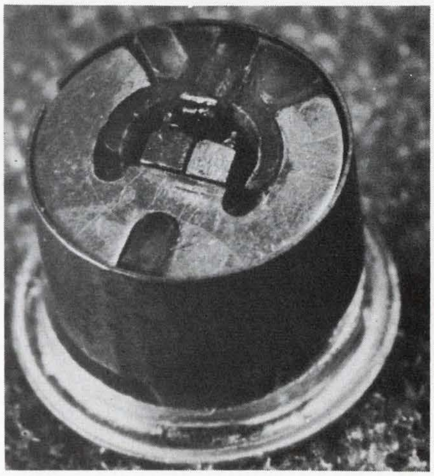
ON READER-SERVICE CARD CIRCLE 53

Products

Spectrum analyzer converter mates to all small-, large- or storage-screen oscilloscopes. The unit covers 10 MHz to 90 GHz with a 105-dBm sensitivity. Page 132

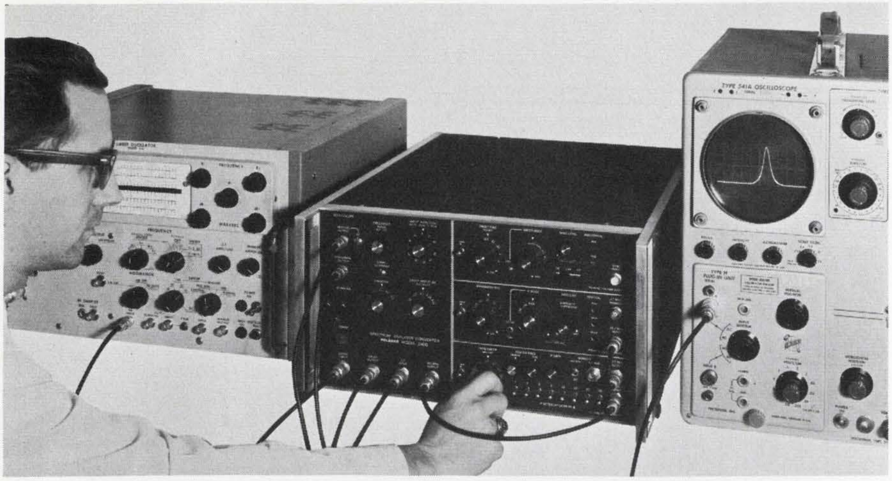


Subminiature coaxial contacts can be made in 20 seconds. The finished contacts have an OD of 0.11 in. Page 160



Relay enters TO-5 and needs no adjustment. Page 144

Also in this section:



Analyzer converter displays to 90 GHz

Polarad Co., 43-20 34th St., Long Island City, N.Y. Phone: (212) 392-4500. Price: $2990.

With a 70-dB, full-screen display and a −105-dBm sensitivity, the Polarad model 2400 calibrated Spectrum Analyzer Converter makes precise signal measurements over a frequency range of 10 MHz to 90 GHz. The unit makes it possible to mate a signal generator or oscillator to any large-, small- or storage-screen oscilloscope.

The first mixer accepts signals from 10 MHz to 14 GHz. Flat frequency response is provided to make it easier to measure signal amplitudes at different frequencies. High sensitivity comes from the low-noise mixer, followed by an i-f amplifier with a low noise figure. Any local oscillator may be linked up, so that the operator can choose his frequency. On fundamental mixing, which can be performed anywhere in the frequency range, the sensitivity is better than ±4 dB to 12.4 GHz. Second-harmonic mixing is ±9 dB over the same range. The operator can use low-fm signal generators to make measurements at narrow bandwidths.

The analyzer converter has been designed to eliminate spurious responses and to afford a range of dispersions (frequency sweeps) to 500 MHz maximum, image free. The adjustable voltage output of the sweep from 20 V to 0 V accommodates common-sweep generators.

The unit is said to combine the best features of a front-end swept analyzer with a narrowband i-f and a swept i-f for narrow dispersions. Dispersions of 3 MHz down to 10 kHz are achieved with a swept i-f. Above 3 MHz the dispersion is controlled by the sweep generator that is being used as the first local oscillator. The controls are set for a nominal maximum disperson of 500 MHz (images are 520 MHz apart). Since the sweep generator is under the operator's control, he can generate very wide dispersions. With common-sweep generators, dispersions of 4 GHz are easily generated.

Signals are easily identified in the higher bands generated by the local oscillator harmonics. The identification as to band and upper or lower mixing product is made from a front panel control by movement of the signals on the display.

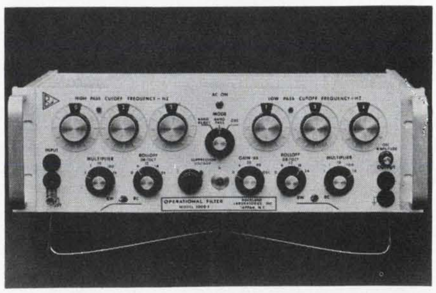
The analyzer converter is a triple superheterodyne receiver. An i-f attenuator with an 82-dB range and 1-dB steps provides for expansion of dynamic range in measuring signal amplitudes and for the precise setting of signal level points on the display. In addition, to adjust system gain for measurement about the noise level, there is a continuous amplitude control with a dynamic range of more than 40 dB.

Calibrated bandwidths from 1 kHz to 1 MHz are included to allow for resolution between adjacent signals and to make reproducible power level measurements. Bandwidths can be set from selector switches or from an AUTO position.

The display mode can be selected from three possibilities: logarithmic, linear or square law (power). The logarithmic display has a 70-dB range, accurate to ± 2 dB for a full screen display. Sweep rates are calibrated and may be internally free run, single sweep, external synchronized or line synchronized. A base line suppressor is also available for adjusting signal brightness when photographing displays. The calibrated vertical output and horizontal output are directed to the front panel for use with an oscilloscope chosen by the operator. Large screen displays, storage oscilloscopes, or just an ordinary oscilloscope may be employed. The power required is 115 or 230 V ±10%, 50 to 1000 Hz and less than 100 W.

CIRCLE NO. 298

Operational filter ranges to 11.1 kHz

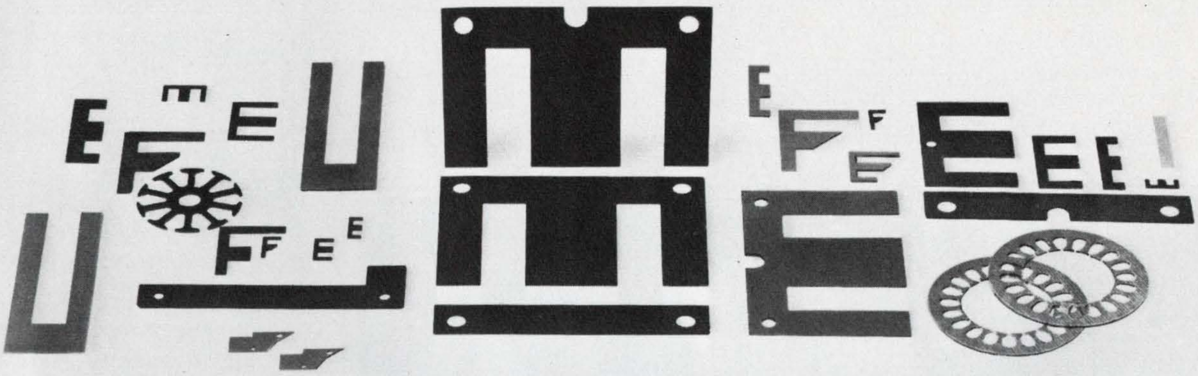


Rockland Laboratories, Inc., Box 57, Tappan, N. Y. Phone: (914) 358-7688. P & A: $1,495; 30 to 45 days.

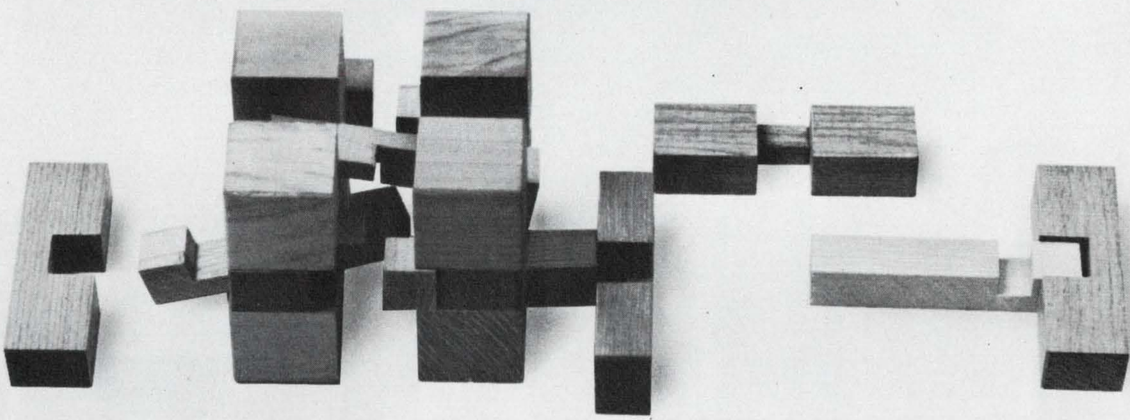
The model 1000F, operational filter functions as a variable filter and low noise amplifier, or as a sine wave oscillator over the frequency range from 0.001 Hz to 11.1 kHz. Overall gain is adjustable to 40 dB max. High pass and low pass rolloffs are adjustable to a max. of 24 dB octave. The impedance is 1 MΩ. It is available with either ac or dc operation.

CIRCLE NO. 299

you get a choice,



not a challenge



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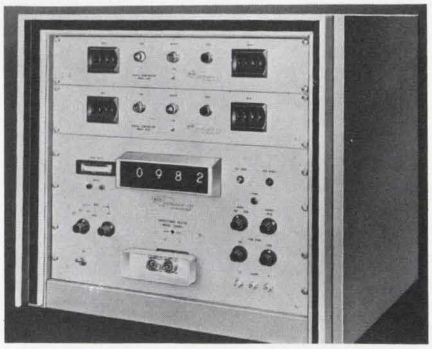
This solid-state ac power amplifier furnishes 200 VA of ac power over a frequency range of 10 to 10,000 Hz. Performance features include 0 to 130 V output, total harmonic distortion of 0.25%, line regulation of 0.02% per V, and load regulation adjustable to zero. Plug in fixed and variable frequency oscillators are furnished in a companion package of the same size. Six different oscillators are offered. One, a 3-phase oscillator can be combined with three model 2200's to produce 600 VA of power. The oscillator-amplifier combination is 3-1/2 in. high.

CIRCLE NO. 251

Capacitance tester accurate to 0.1%



Micro Instruments Co., 12901, Crenshall Blvd., Hawthorne, California. Phone: (213) 772-1275.

This capacitance test system is for sorting or grading semiconductors, voltage-variable capacitance diodes, packaged circuits, and all thin-film capacitors. Designated the model 1201-DS-2, the system includes a 1 MHz, direct reading, 4-digit, solid state capacitance tester and two 4-digit comparators. It also measures two and three terminal capacitance values, to MIL specs, up to 1,000 pF in two ranges.

CIRCLE NO. 252

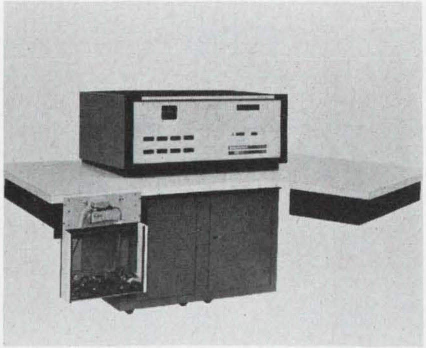
Frequency counter spans 3 Hz to 200 kHz

Anadex Instruments, Inc., 7833 Haskell Ave., Van Nuys, Calif. Phone: (213) 782-9527.

The all-silicon frequency counter is used for measuring frequency or totalizing the number of input cycles or events. Max. input sensitivity is 10 mV rms for frequencies from 3 Hz to 200 kHz, permitting operation from low-level sine-wave signals. Gate times of 0.1, 0.6, 1, 6, and 10 s are derived from 60-Hz line frequency. Variable display time is from 0.2 to 6 s and hold.

CIRCLE NO. 253

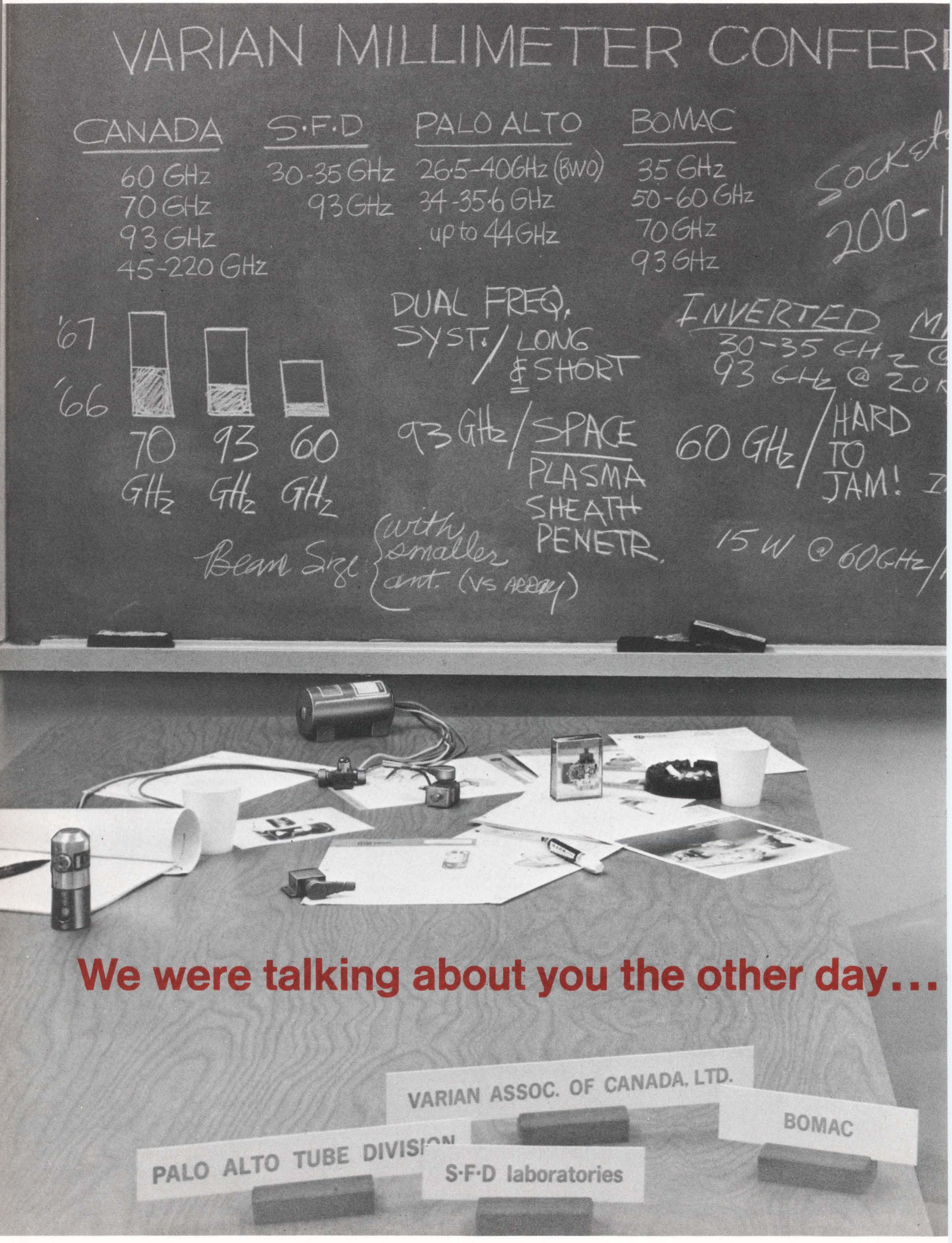
Electronics tester generates to 10 GHz



Continental Device Corp., 12515 Chedron Ave., Hawthorne, Calif. Phone: (213) 772-4551.

The SCAT 28 is a fully expandable automatic testing system. It tests anything, from diodes to ICs to large scale integration, and from modules through printed circuit cards to complete sub-assemblies. The unit uses a 20-line coaxial switch, new oscillographic techniques, high speed A-to-D converters, along with programmable power sources that sink and load. Programmable pulse generators and complete random access techniques from dc to 10 GHz are used as well to assure sources that can stay up between measurements to solve special shift-register and memory-test problems. The device measures all types, shapes and lead configurations of electronic parts. Standard features and capabilities of this tester include: dc tests, ac tests, rf tests, tape or disc-programming, dc parameters and switching time in same socket; all relays dry switched, ston-on-failure, go-no-go, random access to 20-scope probes, random access of any connection on the DUT to any stimulus supply, programmable time-base, max. number of tests unlimited programmable pulse generator, fully automatic and Kelvin connections. Options include: data output, disc program 1% reading, 0.1% reading, 0.05% reading, additional scope probes, real-time measurement capability, probe reference choppers, programmable probe attenuators, high-temperature measurements, expansion greater than 20 levels, computer control, auto transport, auto temperature control, auto segregation, auto failure analysis and auto part failure location.

CIRCLE NO. 254



VARIAN MILLIMETER CONFER
CANADA
S·F·D
PALO ALTO
BOMAC
60 GHz
70 GHz
93 GHz
45-220 GHz
30-35 GHz
93 GHz
26.5-40 GHz (BWO)
34-35.6 GHz
up to 44 GHz
35 GHz
50-60 GHz
70 GHz
93 GHz
'67
'66
70 GHz
93 GHz
60 GHz
DUAL FREQ. SYST. / LONG & SHORT
93 GHz / SPACE PLASMA SHEATH PENETR.
INVERTED
60 GHz / HARD TO JAM!
15 W @ 60 GHz
Beam Size {with smaller ant. (vs ARRAY)
We were talking about you the other day...
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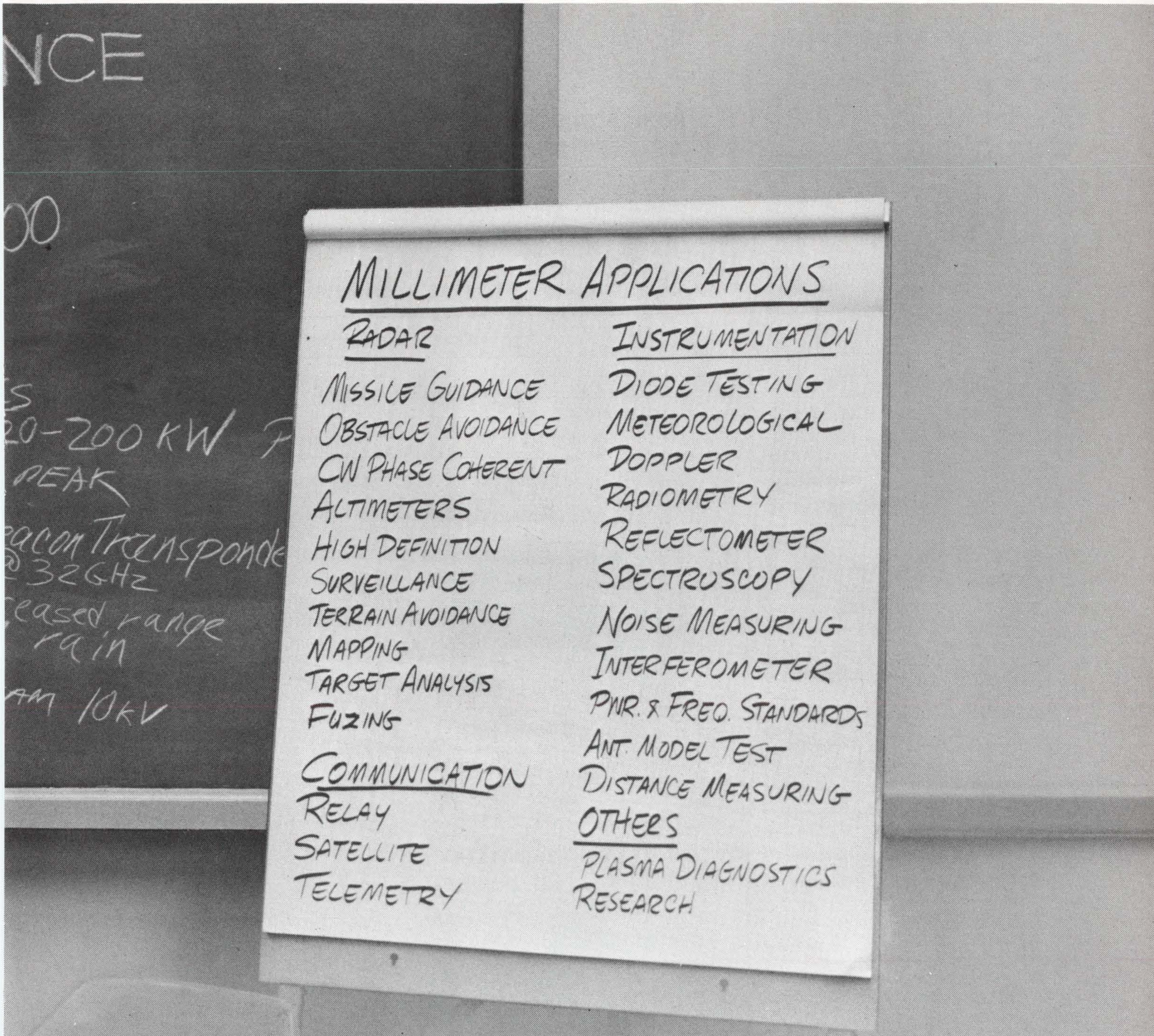
BOMAC
PALO ALTO TUBE DIVISI
S·F·D laboratories



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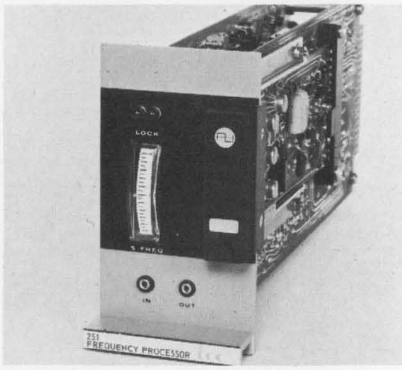
BOMAC (141) PALO ALTO TUBE DIVISION (142) S.F.D. LABORATORIES, INC. (143) VARIAN ASSOCIATES OF CANADA, LTD. (144)

Frequency processor makes a square wave



Interstate Electronics Corp., 707 E. Vermont Ave., P.O. Box 3117, Anaheim, Calif. Phone: (714) 772-2811.

The model-251 frequency processor cleans up contaminated signals, and presents it in the form of a clean high level square wave output. The unit also multiplies the signal frequency by decade and binary factors up to 128, and it demodulates wideband am/fm/pm signals. The input frequency range is 1 to 240 kHz in six plug-in steps; bandwidth range is 10 Hz.

CIRCLE NO. 255

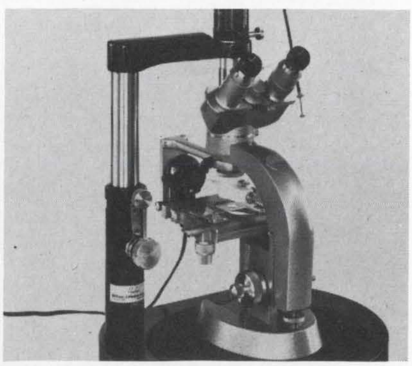
Optical tachometer reacts to 99,000 rpm

Clary Corp., Military Products Div., 320 W. Clary Ave., San Gabriel, Calif. Phone: (213) 287-6111.

The useable range of the digital optical tachometer is from 100 to 99,000 rpm with one mark used on the test wheel. Greater resolution may be achieved by using additional marks. Pulse and analog outputs are also supplied which can be fed to other electronic instruments. Measurement is made by the photoreflective probe.

CIRCLE NO. 256

Interference microscope has 100 or 200 power

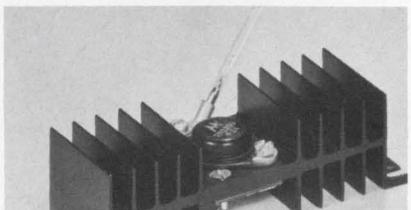


William J. Hacker & Co., Inc., P.O. Box 646, West Caldwell, N.J. Phone: (201) 226-8450.

This instrument has interference objectives of 8 and 16 mm focal length, of 20x and 10x initial magnification with resolving powers within the range of 0 to 6 microns horizontally and less than 1/10th fringe vertically. The 8 mm objective gives a 0.65 mm field of view at a magnification of 200x and a clear working distance of 0.5 mm. A sodium lamp can be supplied.

CIRCLE NO. 257

Temperature checker spots the heat



Computer Logic Corp., 1528 20th St., Santa Monica, Calif. Phone: (213) 451-9754. Price: $9.95.

A 4-in. glass mercury thermometer with a high conductivity ferrule that attaches to transistors, heat sinks, and power supplies is available. The thermometer has a range of −20 to +120°C with 5 divisions, and an accuracy of −1°.

CIRCLE NO. 258

RCA "overlay" Transistors ... for Total RF Power

New Plastic Design for SSB Communications

TA2758
(Molded Silicone Plastic)

75 Watts PEP Output (Min.)
@ 30 MHz,
IMD—30 dB (Max)

Intended for 2- to 30-MHz SSB power amplifiers operating from a 28-volt supply, this high gain transistor is encased in RCA's new plastic package with isolated pin-pad electrodes. It uses an internally mounted diode for temperature compensation.

READER-SERVICE 121

High Power Performance at 400 MHz

2N5016 (TO-60)
TA7036 (TO-60)

Both types are in the popular, time-tested TO-60 package. The RCA 2N5016 is designed for Class-B and -C rf amplifiers and offers 15 watts (min.) at 400 MHz. The TA7036 is a higher power version and provides 20 watts (min.) at the same frequency.

READER-SERVICE 122

Microwave Coaxial Package

TA7003
(Coaxial Lead Package)

1 Watt Output with 5 dB Gain
@ 2 GHz

2 Watts Output with 10 dB Gain
@ 1 GHz

Low-inductance package for UHF and microwave oscillator, frequency-multiplier, and rf-amplifier service.

READER-SERVICE 125

High Gain UHF driver or oscillator

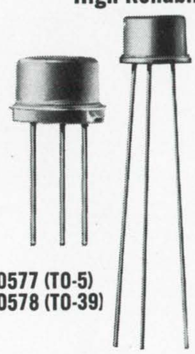
2N5108 (TO-39)

1 Watt Output (Min.)
@ 1 GHz, 5 dB Gain

High gain device for Class B or C operation in final, driver, and pre-driver amplifier stages in UHF equipment and as a fundamental frequency oscillator at 1.68 GHz. Specifically designed for L-Band pulse radar, mobile, and telemetry applications.

READER-SERVICE 126

High-Reliability types available off the shelf

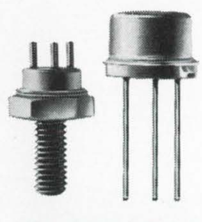


40577 (TO-5)
40578 (TO-39)

40577 is electrically similar to RCA 2N3118; 40578 has as its parent type RCA-2N3866. Both devices add to RCA's expanding high-reliability line which includes 40305, 40306, 40307 (parent types 2N3553, 2N3375 and 2N3632).

READER-SERVICE 129

JAN types with off-the-shelf availability

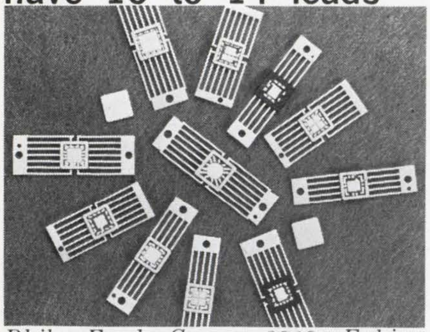


JAN—2N3553 (TO-39)
JAN—2N3375 (TO-60)

Tested to MIL-S-19500/341, these RCA "overlay" types conform to JAN specifications and are available right now in quantity.

READER-SERVICE 130

Micro flat packs have 10 to 14 leads

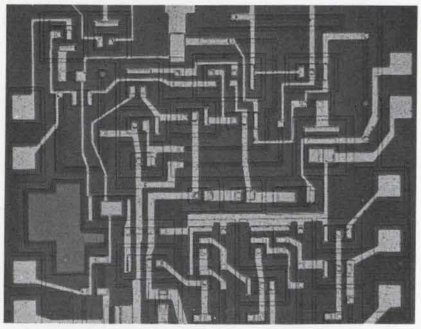


Philco-Ford Corp., 3939 Fabian Way, Palo Alto, Calif. Phone: (415) 326-4350.

Supplied in both 10- and 14-lead configurations with ceramic, metal or glass bottoms, these 1/4-in.-square flat packages are available in all material combinations and capable of any method of closure. On glass-bottom types, a grounded pad is provided for device-mounting. On ceramic-bottom types, up to four electrically isolated metalized pads are available. The package can also be obtained without metalization.

CIRCLE NO. 259

IC fm detector thresholds at 400 mV

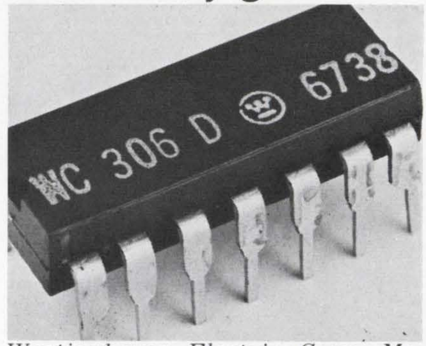


Sprague Electric Co., North Adams, Mass. Phone: (413) 664-4411.

An IC fm detector and limiter operates by a technique featuring linear gating and balanced discriminator action with an a-m rejection of 46 dB. The frequency range of the unit extends from 5 kHz to 50 MHz. It has outputs of 0.6 V with a total distortion of less than 1% with a limiting threshold voltage of 400 mV rms. A 12-V power supply is required for operation of the IC.

CIRCLE NO. 260

Op-amp ranges to 30-kHz unity gain



Westinghouse Electric Corp., Molecular Electronics Div., Box 7377, Elkridge, Md. Phone: (301) 796-3666. P&A: $9.90 (1 to 49); stock.

The WC-306 IC chip has vertical pnp as well as npn transistors. Inputs include a high impedance 300 KΩ pair. Bandwidths are available up to the 30-kHz unity gain of the 306. Using the low-input impedance terminals, you can achieve 40 dB of gain at 10 MHz. Most of the units 1100 to 4400 open loop gain can be used without exceeding 0.2% distortion.

CIRCLE NO. 261

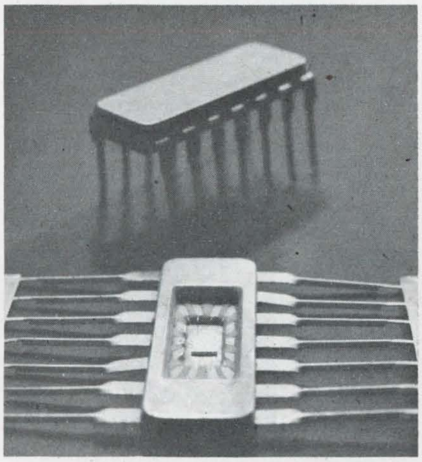
Dual 50-bit register built on single chip

National Semiconductor Corp., 2975 San Ysidro Way, Santa Clara, Calif. Phone: (408) 245-2310. Price $40 (100 lots).

The MM 402 is a dual 50-bit unit built on a single silicon chip utilizing MOS P channel enhancement mode transistors. It is designed to operate over a wide frequency spectrum and can be used in any sequential digital system that uses a two phase clocking system. The MM 402 features 1 MHz frequency operation, 0.8 mW/bit at MHz power consumption, 10 kHz at 125°C minimum operating frequency, —55 to +125°C operating temperature range and 500 Ω output impedance.

CIRCLE NO. 262

Monolithic flip-flop toggles at 25 MHz



National Semiconductor Corp., 2950 San Ysidro Way, Santa Clara, Calif. Phone: (408) 245-4320. Price: $4 to $13.10.

The DM 7501 is designed for high speed control and counting applications where multiple data inputs are not required. The unit features special clock line clamping to reduce ringing and simplify device usage. The dual binary has a toggle rate of 25 MHz, 1 V noise immunity, a guaranteed clock skew of fifteen ns, and meets all electrical and mechanical requirements of the SN5473 type dual flip-flop. It is hermetically sealed in its package.

CIRCLE NO. 263

Mini-relay in TO-5 skirts adjustment

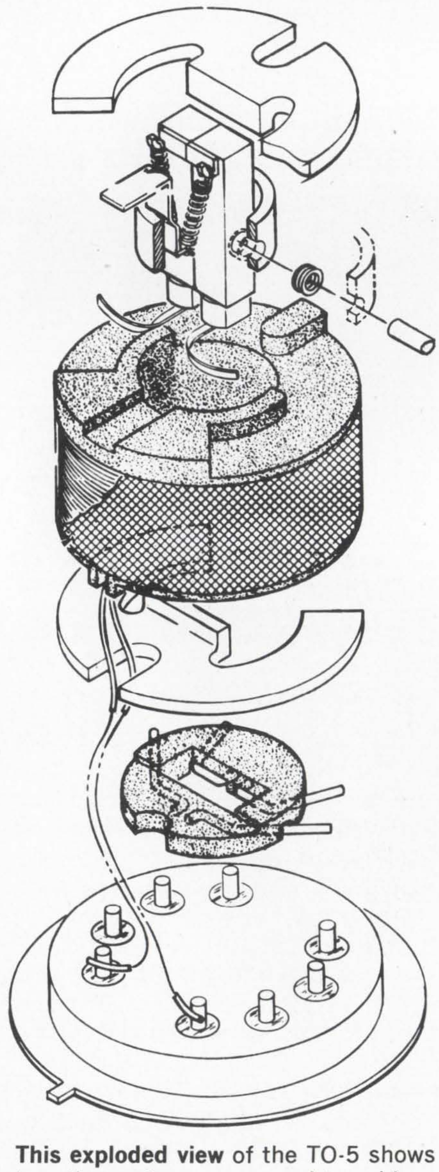
Hi-Spec Electronics Corp., 14713 Keswick Ave., Van Nuys, Calif. Phone: (213) 781-0936. Price: $50.

This microminiature relay in a TO-5 can never needs adjustment. Smaller than a dime, the device has an 0.335 in. diameter and 0.275 in. height. The 1 A, 28 V relay is designed to meet the performance requirements of MIL-R-5757. It has an operation and release time of 1.5 ms. Pilot production samples have attained 10,000,000 operations at low-level currents and 250,000 at full load.

Until now relays had to be adjusted during production by "tweaking" or bending contacts to adjust contact pressures, or applying dielectric nonmagnetic actuating materials to achieve the desired operating characteristics. With the new technique, should a relay batch not meet specifications during testing, the fix is made in the tooling, not on the individual relays.

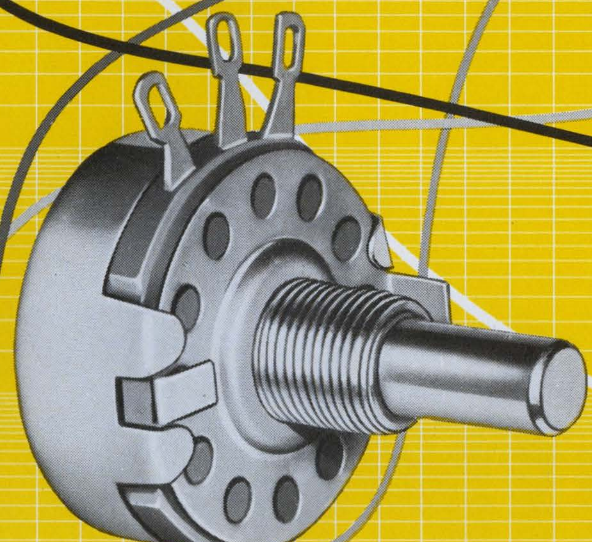
Hi-Spec's relay has its gold alloy contacts directly connected to the armature. As the armature responds to the magnetic force of the energized coil, the contacts move with it. The absence of dependent movement of parts within the relay makes it possible to establish a single datum point for the location of fixed and moving mating surfaces, with more positive contact pressures and lower contact resistance than standard relays.

CIRCLE NO. 312



This exploded view of the TO-5 shows how the parts are arranged to achieve a 1 A relay in a can.

tricky tapers...



Allen-Bradley Type J
hot molded variable resistor
shown twice actual size

Allen-Bradley Type J potentiometers offer tapers designed to your special needs!

■ When standard tapers fail to provide the control you desire, Allen-Bradley Type J potentiometers have the unique capability to provide a virtually limitless variety of curves to meet your specialized requirements. While not a precision device that is continuously taper-trimmed to very close tolerances, Allen-Bradley's control of the resistance-rotation characteristics during production assures a high degree of conformity.

Allen-Bradley Type J potentiometers have a solid hot molded resistance track made by an exclusive process which was pioneered and perfected by A-B. This solid resistance track assures smooth adjustment at all times—with none of the discrete changes in resistance that are encountered in wire-wound units. And being essentially noninductive, Type J controls can be applied in high frequency circuits where wire-wound units are useless.

Furthermore, A-B's solid molded resistance track assures low noise and long life. On accelerated tests, Type J potentiometers exceed 100,000 complete operations with less than 10% change in resistance.

For more complete details, please write: Allen-Bradley Co., 1344 S. Second St., Milwaukee, Wis. 53204. In Canada: Allen-Bradley Canada Limited. Export Office: 630 Third Ave., New York, N.Y., U.S.A. 10017.

ADDITIONAL ALLEN-BRADLEY HOT MOLDED VARIABLE RESISTORS

TYPE G CONTROLS are only ½" in diameter. Quiet, stepless operation. Rated ½ watt at 70°C. Values to 5 megohms. Type L are similar in construction but rated ½ watt at 100°C.

TYPE F TRIMMERS are for mounting directly on printed wiring boards by means of their terminals. Rated ¼ watt at 70°C. Values to 5 megohms. Type O are similar but rated 0.4 watt at 70°C.

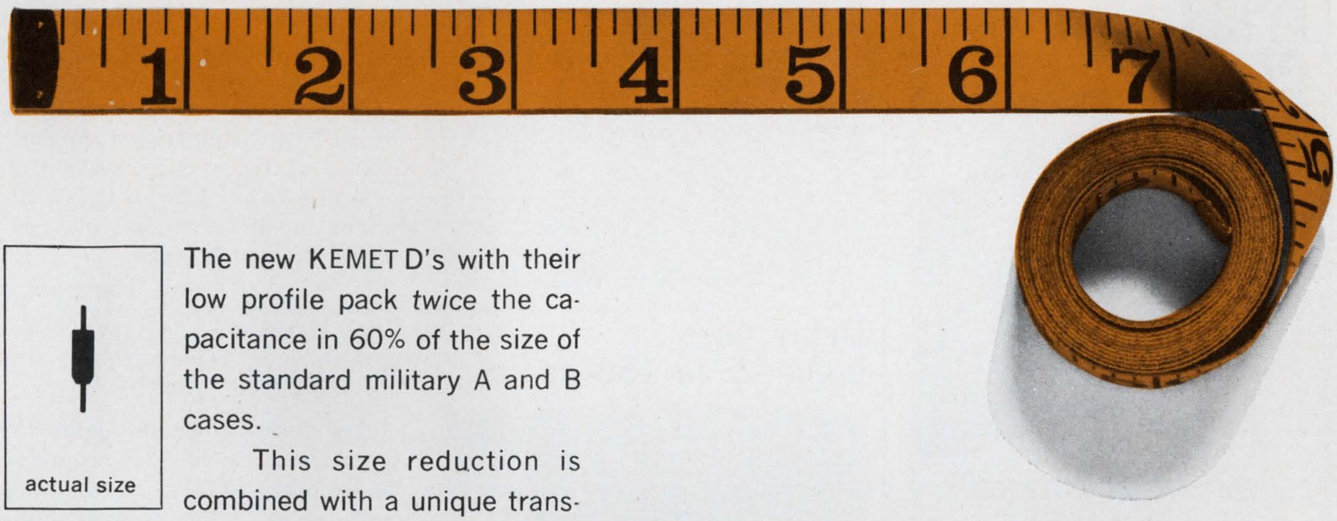
TYPE R ADJUSTABLE RESISTORS for trimming applications are built to withstand environmental extremes. Only 1¼" in length. Have stepless adjustment. Watertight and can be encapsulated. Rated ¼ watt at 70°C. Values to 2.5 megohms. Type N for less severe environments are rated ⅓ watt at 50°C.

867-3AB

ALLEN-BRADLEY
QUALITY ELECTRONIC COMPONENTS

ON READER-SERVICE CARD CIRCLE 64

They take off inches.



actual size

The new KEMET D's with their low profile pack *twice* the capacitance in 60% of the size of the standard military A and B cases.

This size reduction is combined with a unique transfer molding technique to produce a *3 case* line (A^2, A^1 and B^1) especially suited for high speed automatic insertion equipment. These new KEMET D's can be punched readily, along with resistors and diodes, onto computer cards and printed circuit boards.

Typical applications of the new KEMET D's are commercial computers and peripheral equipment, communications systems and many other areas of electronics requiring high density packaging.

With an impedance rating of *less* than 1 ohm at 10 MHz for 12 μF, the new KEMET D's are just great for computer applications with high clock rates that require low impedance at high frequencies.

Other important performance characteristics of the new KEMET D's are as follows:

Capacitance Range . . from .0047 μF to 68 μF.
Voltage Range . . . . .from 6V to 35V.
Temperature Range . . from $-55°$C to $+85°$C.
D.C. Leakage Current . . . less than 1μa at 25°C.
Temperature Cycling . . . exceeds MIL-STD-202.

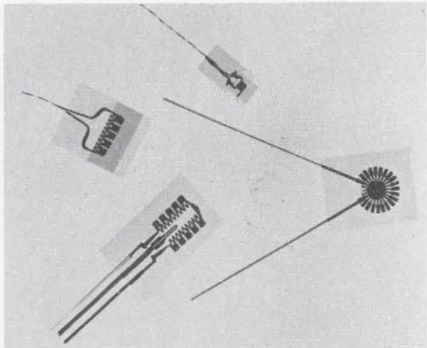
There's a new products catalog that explains the new KEMET D's in great detail. To get your copy simply contact your local Union Carbide Representative or write us direct.

The new KEMET D's, the diet capacitors, from Union Carbide, The Discovery Company.

UNION CARBIDE
ELECTRONICS

ON READER-SERVICE CARD CIRCLE 65

Heat flow sensors respond in 50 ms

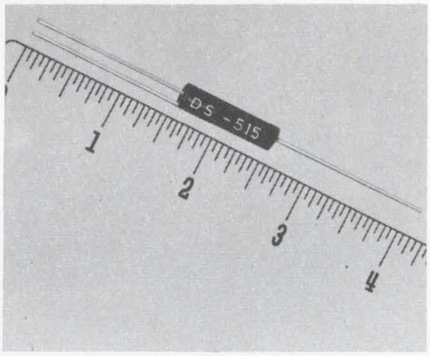


RdF Corp., 23 Elm Ave., Hudson, N.H. Phone: (603) 882-8115.

These sensors are designed for measurement of convective, conductive or radiant heat transfer with response times in the order of 50 ms. The thermal junctions of the new multi-element units have a cross-sectional thickness of 0.0002 in. and can be installed on flat or curved surfaces using conventional adhesives. They provide the capability of independent controlled heat sinks for each junction.

CIRCLE NO. 275

Delay lines span 15 to 150 ns

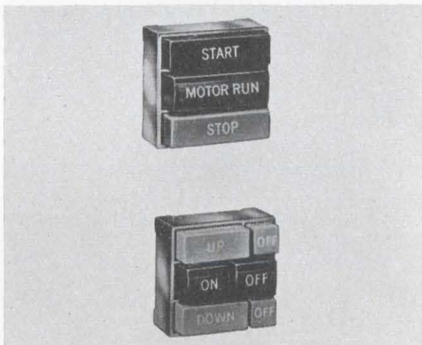


JFD Electronics Co., 15th Avenue at 62nd St., Brooklyn. Phone: (212) 331-1000. P&A: $10; 2 wks.

Distributed constant delay lines consist of 16 models ranging from delays of 15 to 50 ns in 5 ns steps. Each delay value is available in either 500Ω or 1000Ω impedances. All models in the series have a delay accuracy of ±5%. They are resin encapsulated. Typical applications are radar, computer circuits and communications equipment, up to 100 MHz.

CIRCLE NO. 276

Compact pushbuttons rated to 600 V

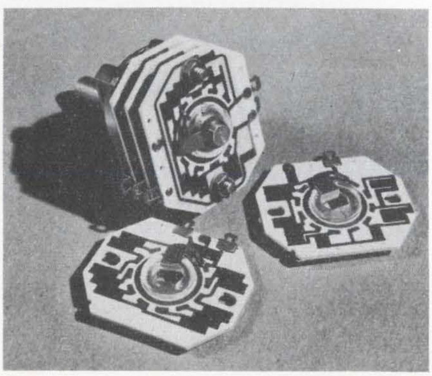


Cutler Hammer, Inc., P.O. Box 463, Milwaukee, Wisc. Phone: (414) 442-7800.

Heavy-duty oil tight compact pushbuttons permit one to six operating or indicating functions in a single case 1-7/8 in.^{2}. The pushbuttons' eighteen different contact blocks are rated at 600 V and carry full heavy duty ac ratings. The blocks are available with screw type or quick connect terminals. Snap-on buttons are offered in nine colors and eight different configurations.

CIRCLE NO. 277

Circuit deck switch combines networks



Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, Calif. Phone: (714) 871-4848.

Circuit deck series 1390 combine switch and resistor-capacitor networks in one unit. From five to ten 1/4 W resistors can be screened on each side of the wafer. Performance features include: ±5% to ±0.2% resistance tolerance; 10,000:1 ratio range; ±0.5% to ±0.1% ratio tolerance; 5 PPM/°C ratio stability over temperature range; and 0 to +65°C ambient temperature range.

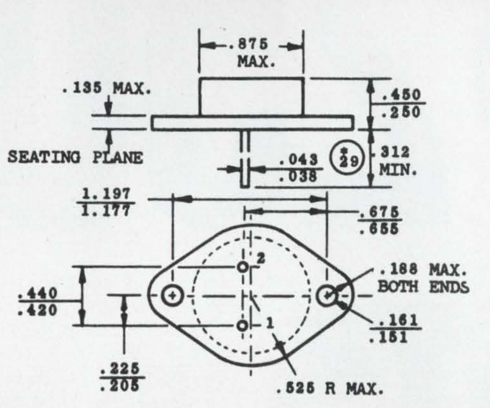
CIRCLE NO. 278

HIGH VOLTAGE HIGH POWER

PNP SILICON TRANSISTORS

	V CER	V CEO	V EBO	hf E	ICEX < .25MA @ VCEX	VCE (SAT) @ 1A, .100MA TYP	VCE (SAT) @ 1A, .100MA MAX	ft
TRXP-2017	200	200	5V @ 5MA	> 20 @ 1A, 10V	200	1.5V	3V	15MHZ
TRXP-3017	300	325	5V @ 5MA	> 20 @ 1A, 10V	300	1.5V	3V	15MHZ
TRXP-4017	400	400	5V @ 5MA	> 20 @ 1A, 10V	400	1.5V	3V	15MHZ

	V CER	V CEO	V EBO	hf E	ICEX < .25MA @ VCEX	VCE (SAT) @ 1A, .100MA TYP	VCE (SAT) @ 1A, .100MA MAX	ft
TRXP-2027	200	200	5V @ 5MA	> 10 @ 2A, 10V > 30 @ 1A, 10V	200	1.5V	3V	15MHZ
TRXP-3027	300	325	5V @ 5MA	> 10 @ 2A, 10V > 30 @ 1A, 10V	300	1.5V	3V	15MHZ
TRXP-4027	400	400	5V @ 5MA	> 10 @ 2A, 10V > 30 @ 1A, 10V	400	1.5V	3V	15MHZ



TO-3 PACKAGE

The Industro TRXP series are PNP triple diffused Silicon Power Transistors for use in high voltage applications. The high VCBO and VCEO ratings make it practical to operate directly from a rectified 117 volt or 220 volt AC line. This device is ideal for use in switching applications of all types. The case is electrically connected to the collector, and the package is hermetically sealed. Mechanical construction conforms to the standard JEDEC TO-3 outline.

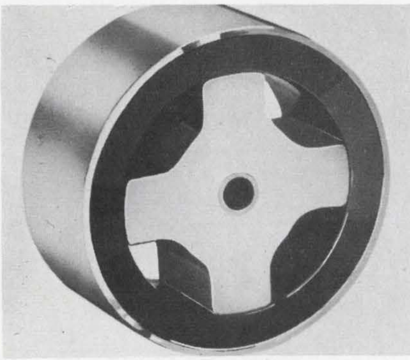
it CORP.

INDUSTRO TRANSISTOR CORPORATION

35-10 36th AVENUE/LONG ISLAND CITY, NEW YORK 11106, (212) EX 2-8000

ON READER-SERVICE CARD CIRCLE 67

Brushless dc motor produces 6 oz. in. torque

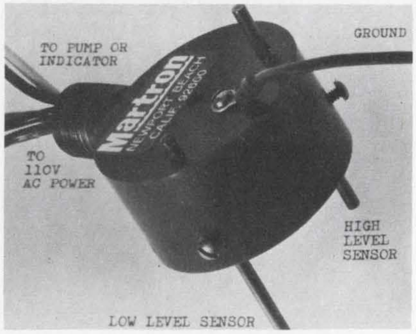


Aeroflex Labs., Inc., South Service Rd., Plainview, N.Y. Phone: (516) 694-6700.

Brushless dc torque motor that provides 6 oz in. continuous torque for 8 W of power over a 50° angle has infinite resolution. The series TQ18 has a linear torque output vs current input, and a peak torque capability as high as 20 oz. in. A special stator winding enables the TQ18 to develop smooth, step-free torque without friction.

CIRCLE NO. 279

Liquid level control senses 0.0001 in.

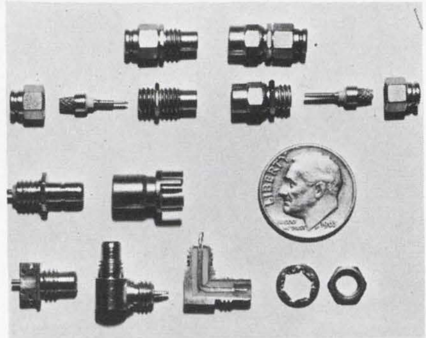


Martron, Inc., 875 West 15th St., Newport Beach, Calif. Phone: (714) 646-7151.

Liquid level control with no moving parts automatically senses and controls levels of liquids to within 0.0001 in. in any environment. When the control's sensor-probes are set at the desired high and low liquid levels a 110 V ac switch functions automatically to activate or deactivate electrical devices. Control options from 4 to 150 A, 220 or 440 V ac.

CIRCLE NO. 280

Miniature connectors meet MIL C 22557

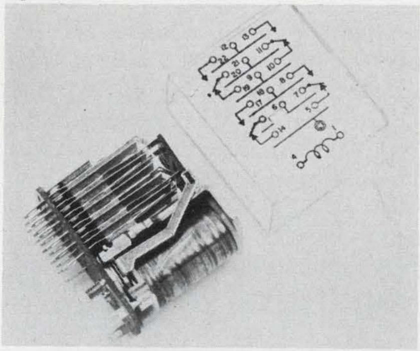


Mi-Kro Connector Corp., 40-09 21st St., Long Island City, N.Y. Phone: (212) 392-8814.

The connectors take three mating forms: screw-on, push-on and slide-on. Variations in the basic design include straight bulkhead and right-angle cable connectors, as well as printed circuit board and tee connectors. Parts are virgin teflon, brass and beryllium copper. All metal parts are copper flash and gold plated. All meet MIL C 22557.

CIRCLE NO. 281

Instrument relays span 6 to 115 V dc

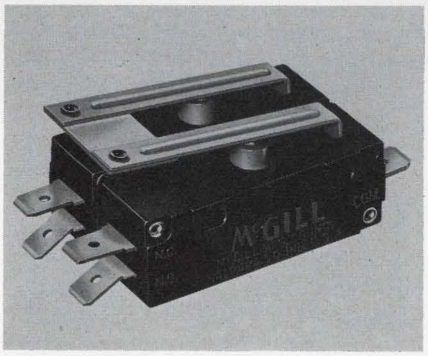


Parelco, Inc., 26181 Avenida Aeropuorto, San Juan Capistrano, Calif. Phone: (714) 493-4507. Price: $9.60.

The model R11 instrumentation relay has a guarded construction which keeps the capacitance between contacts to a maximum of 0.15 pF. A separate guard plate is located between each set of contacts. Each guard has an isolated terminal allowing connection to an instrument guard to maintain high common-mode rejection in the instrument. The relay contacts are rated to 200 mA with a thermal emf of less than 1 μV.

CIRCLE NO. 355

DPDT switch passes 25 A

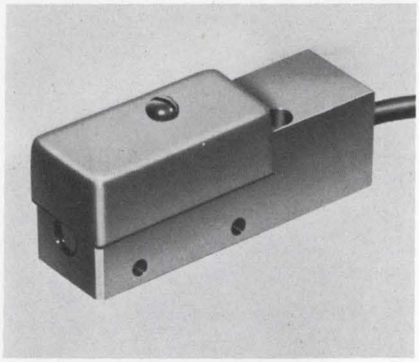


McGill Manufacturing Co., Inc., Valparaiso, Ind. Phone: (219) 462-2161.

A tandem arrangement of two 2650 series 20-A snap action switches with a common actuator provides a 25 A, DPDT assembly. They have a differential travel of less than 0.005 in. Other features include: high-strength beryllium copper springs, heavy-duty silver contacts and dimensionally stabilized housings.

CIRCLE NO. 356

Detector switch needs no contact

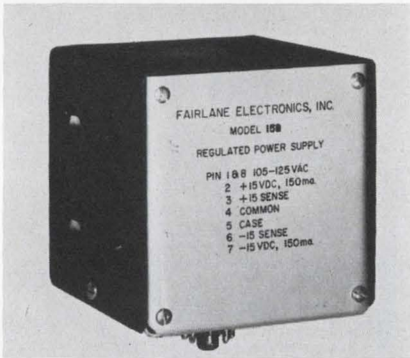


Electro Tec. Corp., P.O. Box 667, Ormond Beach, Fla. Phone: (904) 677-1771.

A line of magnetic detector switches designed to sense ferrous metals operates because of the proximity of magnetic metals, and no physical contact is necessary. Operating medium is the smallest possible to give maximum air gap, and switching repeatability is generally ±0.002. Switches are sealed housing units completely water, oil, spray, dust, and dirt proof.

CIRCLE NO. 282

Dual power supply has two 9 V outputs

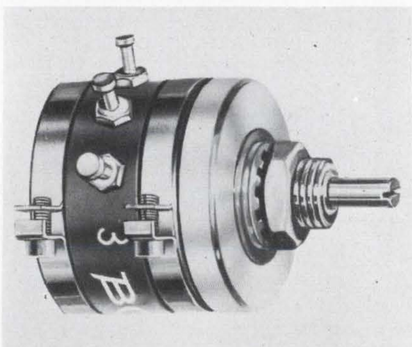


Fairlane Electronics, Box 335, Long Valley, N.J. Phone: (212) 691-2530. P&A: $100; stock.

The model-150 power supply is designed for use with operational amplifiers. Two separate outputs of ±9 V dc at 600 mA each are floating and either polarity may be grounded. The dual supplies track each other to within 0.01%. Regulation is 0.05% with zero to full load changes. Long term stability is less than 10 mV with a ripple of less than 1 mV.

CIRCLE NO. 283

Potentiometers use conductive plastic

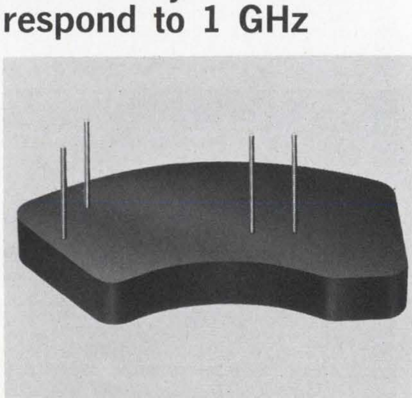


Bourns, Inc., 1200 Columbia Ave., Riverside, Calif. Phone: (714) 684-1700. Price: $39.12 up.

The new models 3536 bushing mount and 3586 servo mount single-turn potentiometers have Infinitron conductive plastic elements. The conductive plastic element provides a dither life of 1000 hours at 60 Hz and a rotational life of 50,000,000 shaft revolutions. They have a resistance range of 100 Ω to 1 MΩ and a power rating of 1 W at 70°C.

CIRCLE NO. 284

Time delays respond to 1 GHz

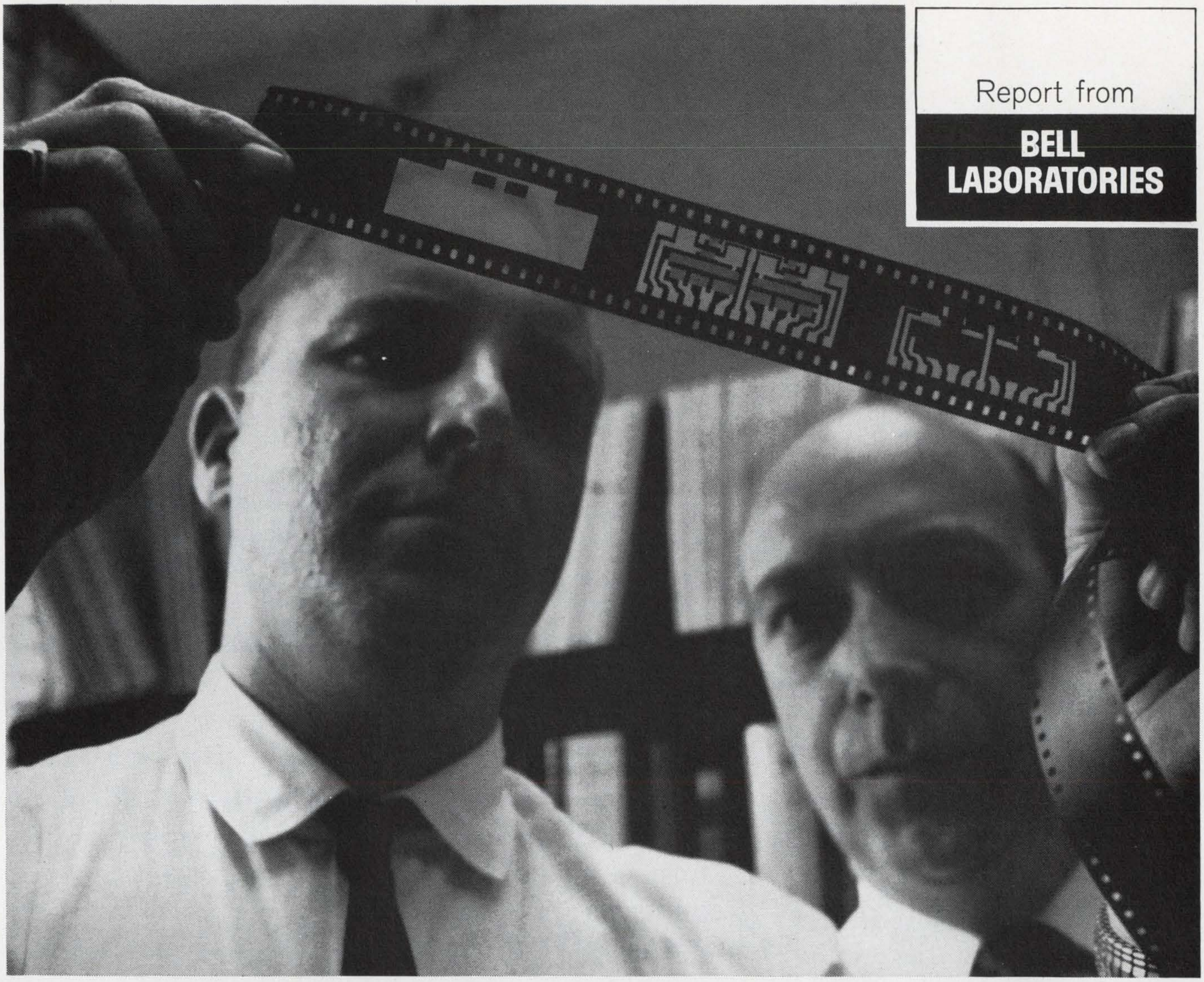


RCL Electronics, Inc., 700 South 21st St., Irvington, N.J. Phone: (201) 374-3311.

These delay packages have a delay time range from 1 ns to 1000 μs. The devices have a frequency response greater than 1 GHz and a range of impedance from 50 to 2000 Ω. Delay tolerances of ±2% or better, are available, with a full temperature range from −55 to +125°C. Output pulse distortion of +10% maximum is maintained with coefficients of less than 50 PPM/°C.

CIRCLE NO. 285

Report from
BELL LABORATORIES

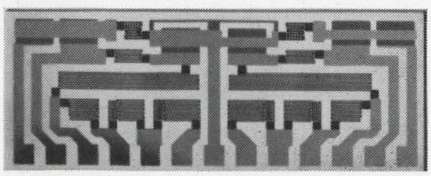


Thin films: faster by computer

Arthur G. Gross and Harry M. Kalish of Bell Telephone Laboratories have developed a computer program whose end product is a set of correctly sized photographic "masks" for making prototype thin-film networks. The masks control the deposition and shapes of various widths and thicknesses of conductive, resistive, and dielectric materials that make up such circuits. (These frequently begin as tantalum, deposited onto a glass or ceramic substrate and chemically treated to produce desired electrical properties.)

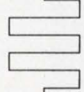
Controlled by the new program, a computer feeds a precision microfilm plotter which prints the masks on 35mm film (photo above).

With this system, a prototype can be ready in a day, as against the weeks that may be involved in making high-precision masks for volume circuit production. Usually, for example, a draftsman must make rough sketches and prepare a list of numbers (coordinate points) accurately describing the geometry of the final circuit. Then the actual shapes—greatly enlarged—are cut into plastic sheets on a "coordinatograph." Later, the plastic patterns are photographically reduced to circuit-sized masks, perhaps ½ by 1 inch.



An experimental thin-film filter network—in actual size—made from 35mm film masks. In the top photo, A. G. Gross (left) and H. M. Kalish hold three of the masks used. Each mask controls the formation of a layer of conductive, resistive, or dielectric material. The circuit is built up of a number of such layers.

In addition to reducing time and handling, Bell Laboratories' new program relieves the engineer of another tedious job: designing the meandering lines that constitute resistors in these circuits. And the computer resistors are "optimized" . . . fitted into the smallest possible area.

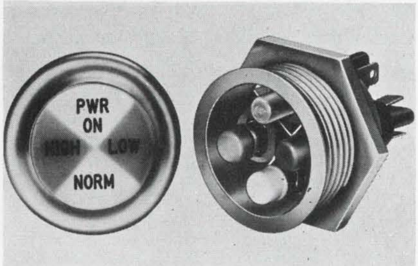


MEANDER RESISTOR

To give the engineer freedom to use irregular plane shapes, the program includes a subroutine which closely approximates geometric figures used in making thin-film circuits.

Bell Telephone Laboratories
Research and Development Unit of the Bell System

Segmented lamp indicates 4 messages

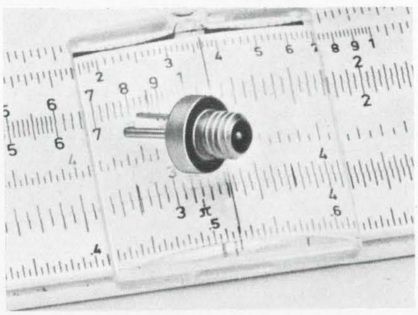


H. R. Kirkland Co., 8-10 King, Morristown, N.J. Phone: (201) 538-2777.

Four-lamp indicator has a 1 in. dia lens and up to four different messages can be shown on a single face. Each S600 unit consists of a housing in which four separate and independent sockets are mounted. Partitions in the lens cap provide for the segmets. Lamp bulbs are available from 6 to 120 V, eliminating the need for external voltage dropping devices. Markings on the lens is by engraving or Mylar inserts.

CIRCLE NO. 286

Rf connector withstands 100 g

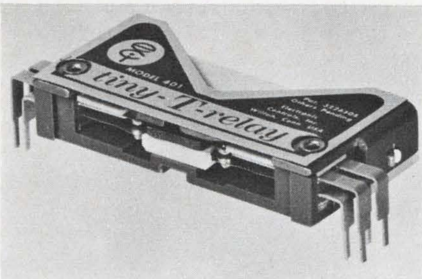


Glass Technology, 1644 Whittier Ave., Costa Mesa, Calif.

A subminiature, hermetically sealed, coaxial rf connector designed for the C5A, services as the input connector from an accelerometer to an amplifier in a vibration monitoring system, and mates with an encased socket. It will withstand vibration in excess of 1.8 g^2/Hz from 400 to 2000 Hz and shock in excess of 1000 G. Other specifications include an insulation resistance of 1000 M Ω at 50 Vdc, a leak rate of 1 x 10^{-9} cc of helium/s.

CIRCLE NO. 287

Four pole relays flat pack mounted

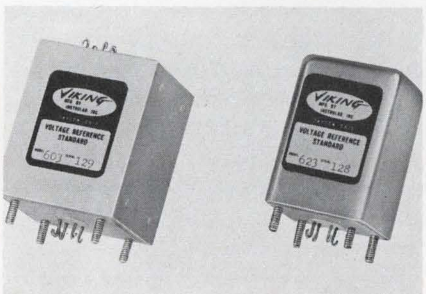


Electronic Controls, Inc., Danbury Rd., Wilton, Conn. Phone: (203) 762-8351. Price: $5.35 form A, $6.85 form C.

In 4-pole make or transfer arrangement, the series 401 printed-circuit mounted relay stands 0.34 in. off the board. The units use an electromagnetic arrangement that allows it to transfer 3A at 28 Vdc., or interrupt up to 1000 V ac at 100 mA. Typical dry circuit resistance is from 10 to 20 m at 1 mV and 1 mA. Life at 100 mA is 100 million cycles.

CIRCLE NO. 288

Voltage standards isolate 0.01 pF

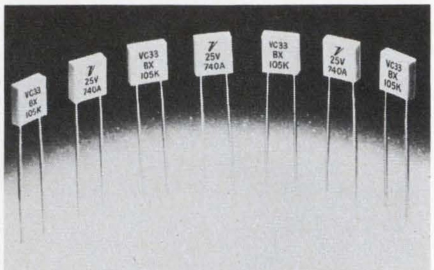


Instrulab, Inc., 1205 Lamar St., Dayton, Ohio. Phone: (513) 223-2241.

Reference standard model 603 offers line isolation of less than 0.01 pF. Model 623 shown in case style 24 offers line isolation of less than 20 pF. Both models offer 0.0003% regulation, 0.0002%/°C temperature coefficient and 0.001% month long term stability. They have electrostatic shielding, are short circuit roof, and operate over a temperature range of —25° to +75°C. The units operate from an ac source of 117 V.

CIRCLE NO. 289

Ceramic capacitors span 0.12 to 1 μF

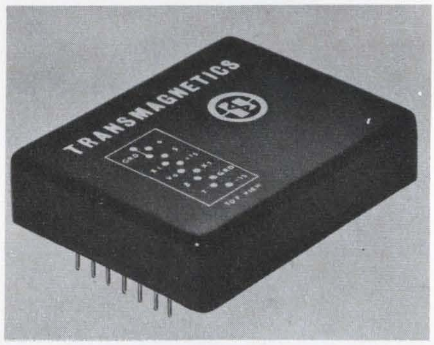


Vitramon, Inc., Box 544, Bridgeport, Conn. Phone: (203) 268-6261.

VEE CAL ceramic capacitors have capacitance values from 0.12 to 1 μF in a 0.3 x 0.3 x 0.1 in. envelope. The units have no external encasements. The devices operate within the temperature range of —55 to +125°C. Voltage ratings are 100, 50 and 25 V dc, and capacitance tolerances are ±10% and ±20%.

CIRCLE NO. 290

Analog multiplier responds to 4 MHz

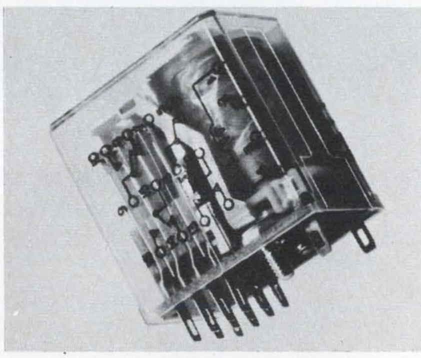


Transmagnetics, Inc. 134-25 Northern Blvd., Flushing, N.Y. Phone: (212) 539-2750.

An analog multiplier offers a frequency response of dc to 4 MHz. The device is for multiplexing telemetry data, video signals and scope-presentation drives. Gain unit is flat to 0.8 dB at 1 MHz and 3 dB at 4 MHz. Phase is less than 1 at 1 MHz and 30° at 4 MHz. Its input impedance is 10 kΩ resistive shunted by 50 pF maximum.

CIRCLE NO. 291

Sensitive dc relay reacts to 20 mW

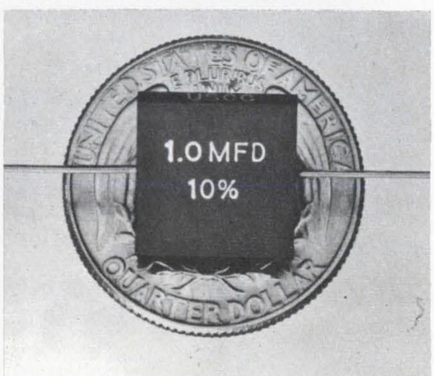


Parelco, Inc., 26181 Avenida Aeorpuorto, San Juan Capistrano, Calif. Phone: (714) 493-4507. Price: $3 to $6.

20 mW per role is required to pull in this relay. At this power level, the relay can be driven directly by existing microcircuits. A variety of contacts are available to switch low level to 2-A loads. Coil voltages range from 2 to 48 V dc. No-charge samples are available to qualified designers.

CIRCLE NO. 292

Ceramic capacitors in 100 V dc W package



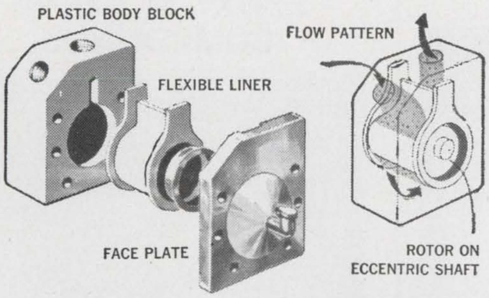
U.S. Capacitor Corp., Burbank, Calif. Phone: (213) 843-4222. P&A: $1.46 ea.; 10 days.

Designated the C27 series, the units are available in either 50 or 100 V dc W versions. The 50 V dc capacitors range from 0.01 μF in a 0.2 x 0.2 x 0.1 in. thick package, to 2.5 μF in a 0.5 x 0.5 x 0.25 in. thick package. The 100 V dc units range from 0.01 to 2.5 μF, in slightly larger sizes. Temperature range is —55 to 125C. Standard tolerance is 10%; 5% and 20% types are also available.

CIRCLE NO. 293

PLASTIC SEALLESS PUMP

Standard capacities are from 1/3 to 40 gpm



A rotor, mounted on an eccentric shaft in this plastic pump, rotates within a liner to create a progressive squeezing action on fluid trapped between the liner and the body block. All metal parts and mechanical action takes place inside the liner where fluid never reaches. This completely eliminates the need for stuffing boxes or shaft seals, guaranteeing no leakage.

The pump is self-priming, operates wet or dry and is suitable for extremely corrosive fluids, abrasive slurries or viscous materials. Applications include pumping of acids, alkalies, distilled water, diatomaceous earth slurries, electroplating solutions, ceramic tile glaze as well as shear sensitive emulsions.

Standard capacities are from 1/3 to 40 gpm with discharge pressure up to 50 psi. Materials of construction include Teflon, PVC, linear polyethylene, Buna-N, Bakelite or stainless steel for body blocks and Viton-A, Kel-F elastomer, Hypalon, Neoprene and Buna-N for the liner. These are the only parts in contact with the fluid.

For additional information, write Vanton Pump & Equipment Corporation, Hillside, New Jersey or telephone Area Code 201 Murdock 8-4120.

ON READER-SERVICE CARD CIRCLE 75

ON READER-SERVICE CARD CIRCLE 76

ON READER-SERVICE CARD CIRCLE 77

COMPONENTS

Electronic delay triggers devices

Atlas Chemical Industries, Inc., Aerospace Components Div., Valley Forge, Pa. Phone: (215) 666-0700.

A solid-state electronic time delay firing module can be used for triggering explosive actuated units for locking devices, releasing devices to permit linear or rotary motion, pushing mechanical loads, cutting wires, cables, rods or bolts, firing a primer, indicating the presence of unwanted electrical pulses, operating a gyroscope and disconnecting a plug. The time delay can be specified to be set at the factory anywhere between 50 ms and 45 s, with an accuracy of +5% in the temperature range from −65 to 200°F. It will function reliably during or after rigorous shock, vibration or acceleration up to 200 g.

CIRCLE NO. 294

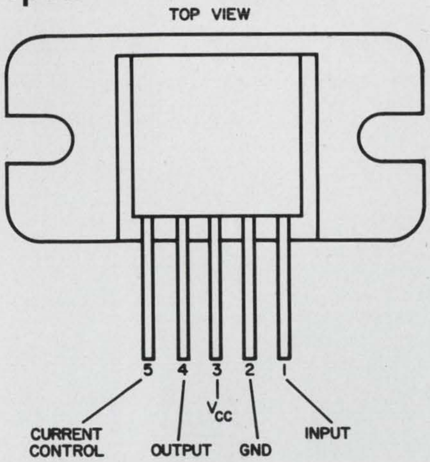
Subcarrier oscillators span 500 Hz to 100 kHz

Industrial Electronetics Corp., P.O. Box 862, Melbourne, Fla. Phone: (305) 723-5382.

Subcarrier oscillators identified as the SCO 10 are packaged in a solid molded cylinder 1¾ in. in dia. by ¾ in. long. The units, available in a range of subcarrier frequencies from 500 Hz to 100 kHz, provide data bandwidths up to 30 kHz. Powered from any 9 V source and using a period linear frequency modulation technique these provide accurate data at ambient temperatures from –40 to +175°C, at accelerations to 20,000 g. Applications include single channel or multiple channel data transmission systems using either wire lines or radio links. The systems will provide data to 5% of full scale over the full range of environments.

CIRCLE NO. 295

Adjustable coils span 1 to 100 μH



North Hills Electronics, Inc., Alexander Pl., Glen Cove, N.Y. Phone: (516) 671-5700. P&A: $4.50; stock.

Subminiature adjustable coils designated the 600 series, are shielded and designed for printed circuit applications. These inductors cover the inductance range from 1 to 1000 μH and can be employed over the 100 kHz to 30 MHz range. Typical standard values are 1 μH, Q 90 at 7900 kHz and 1000 μH, Q 90 at 790 kHz. Adjustment is +10% of nominal value.

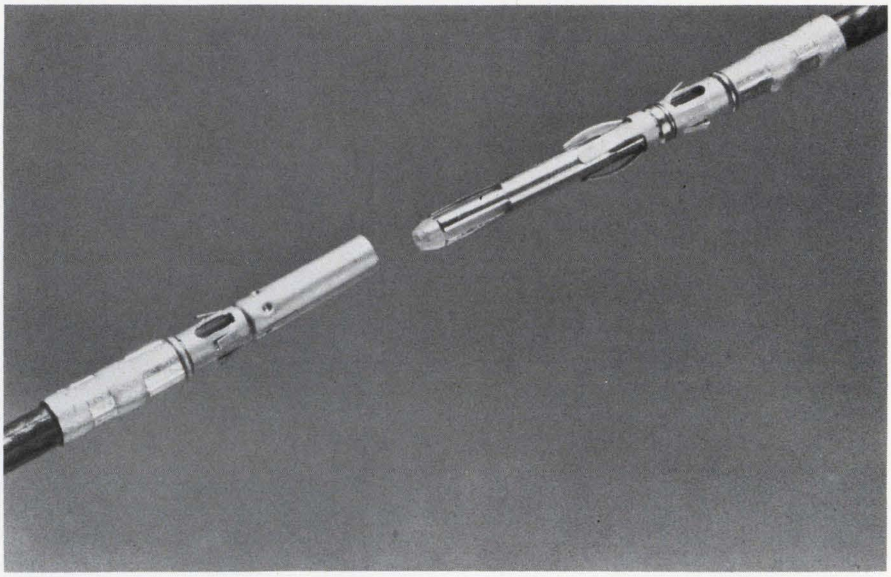
CIRCLE NO. 296

Rectifier stacks handle 20 A

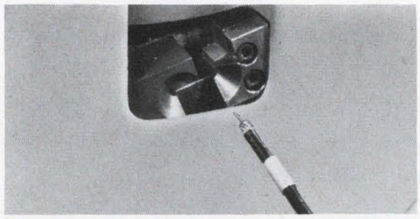
Amperex Electronic Corp., Slatersville, R.I., Phone: (401) 762-9000.

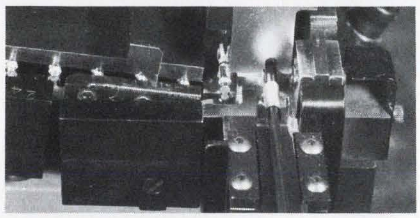
Silicon rectifier stacks consist of three families designated as the OSB-9210, OSM-9210 and the OSS-9210. The OSB-9210 can be used in single phase full circuits or two-phase half-wave circuits. The OSM-9210 can be used in single phase or three phase bridges or in voltage doubler circuits. Both the OSB-9210 and the OSM-9210 are available with peak reverse voltage ratings from 2 to 15 kV in 1 kV steps. The OSS-9210 can be used in single phase half wave circuits and is available with peak reverse voltage ratings from 3 to 30 dV in 1 kV steps. The OSS-9210 family can also be used to construct any circuit configuration.

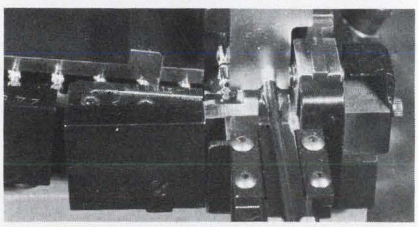
CIRCLE NO. 297

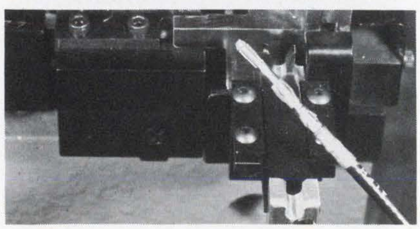


Miniature coaxial contacts start to finish in 20 seconds









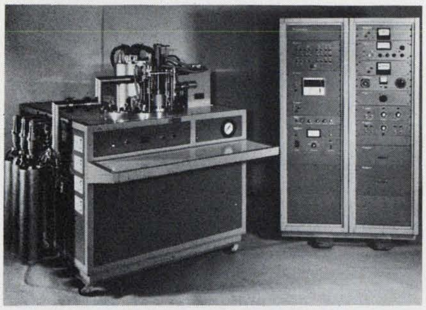
Start with a cable insertion. It comes out stripped with the ferrule applied. Next it is positioned in the die. The center conductor, braid, and outer conductor are crimped to give a good coaxial connection.

AMP, Inc., Harrisburg, Pa. Phone: (717) 564-0101.

Not too long ago it was necessary to prepare coaxial cable laboriously before assembling it to a solder-type coaxial connector. Now, in 20 seconds, it is possible to prepare subminiature coaxial cable (strip jacket, cut and flare braid, strip and trim center conductor) and install a coaxial connector. The contacts are supplied on reels of 5000 for use in a bench-mounted crimping press. A companion machine, called a ferrule applicator, prepares the cable for crimping. Designed for high-density multiple circuit connector applications, the 0.11-in. OD Coaxicon contact will fit into any AMP connector housing that accepts size-16 pin-and-socket contacts. Either pin-and-socket or coaxial contacts will fit into any of the 14 to 156 positions of the 19 connector styles. The contact body, or outer conductor, is stamped and formed from strip brass conforming to MIL-B-50. Usable over a temperature range of −55° to +85°C, the impedance of these contacts is rated at 50 Ω nominal. The capacitance per mated pair is 4.36 pF max (inner conductor to outer conductor) and the contact has a VSWR of less than 1.3 at 500 MHz.

CIRCLE NO. 311

Encapsulation system uses cold welds



Varian, 611 Hansen Way, Palo Alto, Calif. Phone: (415) 326-4000.

An automatic vacuum encapsulation system capable of hermetically sealing as many as 1000 crystals or other components every seven hours employs a cold weld technique, is fast cycling, and is automatic. Crystal units are pre-heated to a temperature of 125°C before cold welding. This guarantees cleanliness without the extremely high, and sometimes harmful, temperatures required by other vacuum encapsulation sealing techniques.

CIRCLE NO. 313

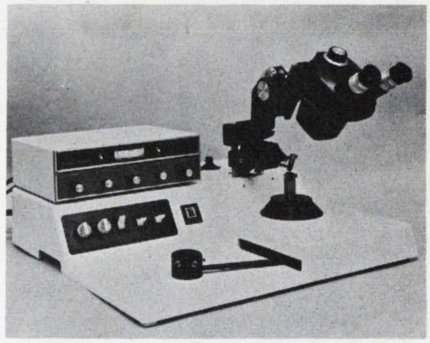
Impedance comparator matches within 0.05%

Electro Scientific Industries, 13900 W. Science Park Dr., Portland, Ore. Phone: (503) 646-4141. P&A: $250; 30 days.

A solid-state impedance comparator bridge for resistor, capacitor and inductor comparison checking measures within 0.05% of the reference standard value. The comparator may be used for sorting resistors with values of 10 Ω to 2 M Ω, capacitors from 0.001 to 100 μF and inductors between 30 mH and 5 kH. The deviation range selections are +1%, 5% and 25%. Operating speed is limited by the rapidity with which components can be inserted and sorted.

CIRCLE NO. 314

Wire bonder uses ultrasonics

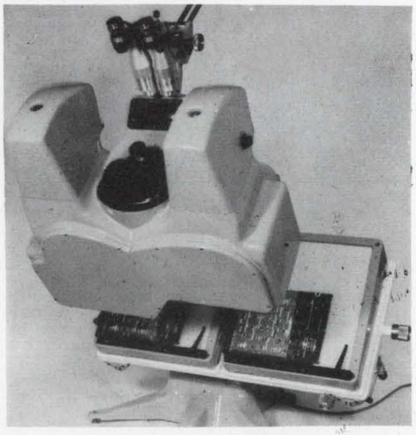


Hugle Industries, 750 N. Pastoria Ave., Sunnyvale, Calif. Phone: (408) 738-1700.

This device enables ultra-sonic bonding techniques to be applied to the production of hybrid microcircuits. In automatic operation, the unit bonds at constant heights at a typical speed of 16,000 bonds per shift. In the manual mode, bonding height can be governed with a motorized control with an accuracy of ±100 mils. Stitch bonding is possible.

CIRCLE NO. 315

Optical comparisons to find errors

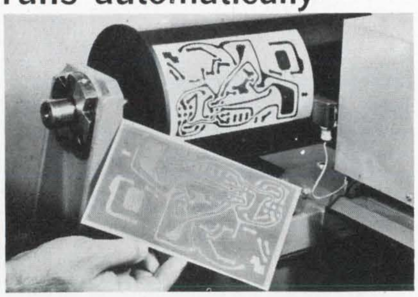


Radiation Equipment Co., Inc., 1825 Willow Rd., Northfield, Ill. Phone: (312) 446-4406. Price: $4500.

The comparascope makes use of a split beam polarized optical system with a variable rate scanner, or chopper that visually superimposes, alternately, the master assembly on the test assemblies. The intermittent viewing of one, and then the other, creates a continuous image — except for the points of difference (errors) where a flickering image is easily identified as to a variance from the master.

CIRCLE NO. 316

Circuit engraver runs automatically



Graphic Electronics, Inc., La Salle, Ill. Phone: (815) 223-1489. Price: $3,750.

The boards are produced by placing hand-drawn pen and ink or pencil copy on a cylinder, scanning the image and simultaneously cutting it into a copper clad epoxy or fiberglass blank sheet that has been attached to a second revolving cylinder. Because the machine takes about 3 to 4 hours to scan the 12 × 18 in. area, the machine is for producing prototype and test boards.

CIRCLE NO. 317

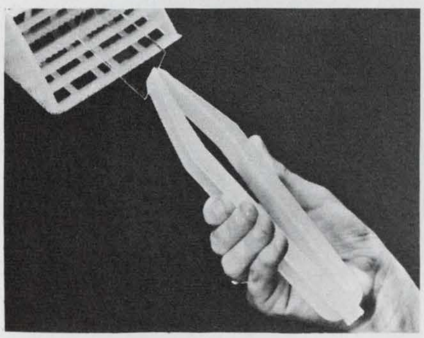
Flat-pack sealer works through thick and thin

GTI Corp., 1399 Logan Ave., Costa Mesa, Calif., Phone: (714) 546-0411.

The GTI model FP-VP-1 bench-type, single-head, flat-package sealer seals ICs and thin and thick film packages. It will seal glass, Kovar, and ceramic packages and will handle, with proper tooling, packages from 1/4 × 1/8 in. through 1-3/4 in. A data sheet containing a description of the sealer's operating procedures, features and specifications is available.

CIRCLE NO. 319

Fluorocarbon tongs handle substrates

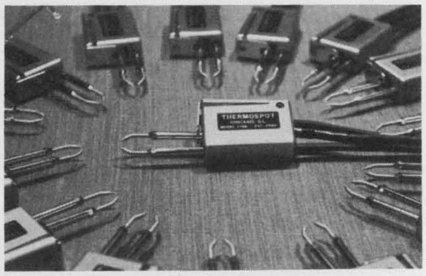


Fluoroware, Inc., Chaska Industrial Park, Chaska, Minn. Phone: (612) 448-3131. Price: $8.50.

Multiple-purpose tongs, 10 in. in length are molded of CTFE (a fluorocarbon material with special heat and acid resistant properties). The tongs have square off 3/4 in. wide tips suited to handling large substrates and similar components during chemical processing operations. Also manufactured is a complete line of specialized tanks, trays, dippers, tweezers and racks.

CIRCLE NO. 318

Pincer gun welder operates from ac or dc

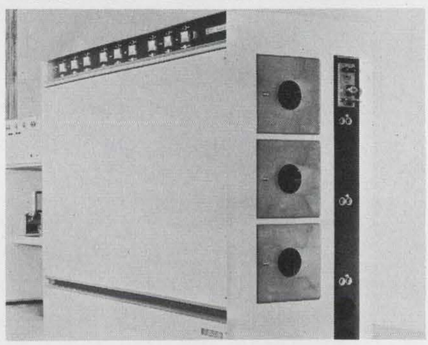


Thermospot, Inc., 7713 S. Western Ave., Chicago, Ill. Phone: (312) 778-0766.

The model 1766 hand-operated pincer gun is one of a group, consisting of pincer, series, probe and push guns, which can be used with either stored-energy (dc) or ac welding supplies for resistance-welding. It features a single quick-adjust to preset electrode force. The electrode diameter is 0.125 in., and the unit weighs 8 oz.

CIRCLE NO. 320

Diffusion furnace handles 24-in. wafers

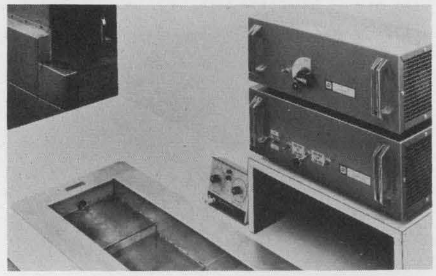


Thermco Products Co., 1465 N. Batavia St., Orange, Calif. Phone: (714) 639-2340.

Semiconductor diffusion furnaces are designed for high-volume production of large-diameter wafers. This unit features uniform heated zones of 20 to 24 in. within ±1/2°C, using process tubes up to 4-1/2 in. in dia. Modular power components simplify servicing. The furnace has throw-away heating chambers, convenient tube heights and second-generation all-solid-state control instruments.

CIRCLE NO. 321

Ultrasonic cleaner has 2 frequencies

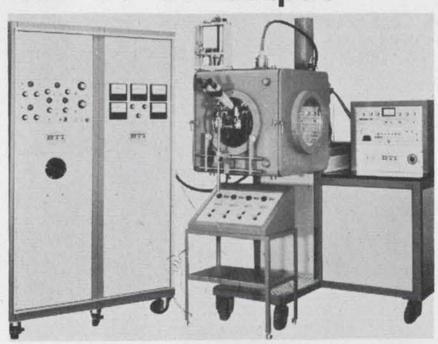


Delta Sonics, 12918 Cerise Ave., Hawthorne, Calif. Phone: (213) 772-1409.

The equipment is available with any number of tanks, though 3 to 5 is most usual. Sizes range from 1 to 10 gallons per tank. The tanks have thermostatically controlled heaters, and recirculating and filtering systems. Two frequencies, 25 kHz or 45 kHz, are available. Some of the models have dual frequency. This system is applicable to the semiconductor industry.

CIRCLE NO. 322

Electron beam welder has 50 kV output



Brad Thompson Industries, Inc., Box CCCC, Indio, Calif. Phone: (714) 347-0637.

A 10-in diffusion pump is standard in this system and is adequate for 10 kW of beam power. A choice of several mechanical pumps is offered, including 50 and 140 ft^3/min. Electron guns in several sizes and shapes are available: 0 to 30 and 0 to 50 kV with ratings of 5, 10, 15 and 20 kW. The power package provides automatic regulation of the beam for constant kilovolts, current and focus.

CIRCLE NO. 323

MULTI-PURPOSE & ELECTRICAL

INVENTORY TAGS
TOOL CHECKS
PROPERTY TAGS

Aluminum, Brass, Steel, Colored Aluminum, etc. Consecutively or special sequence numbered.

Write for Free Complete Catalog

SLOT & TONGUE

Single or double slot and tongue patterns.
Identify groups of wires positively.

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For items of large diameter.

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ON READER-SERVICE CARD CIRCLE 87

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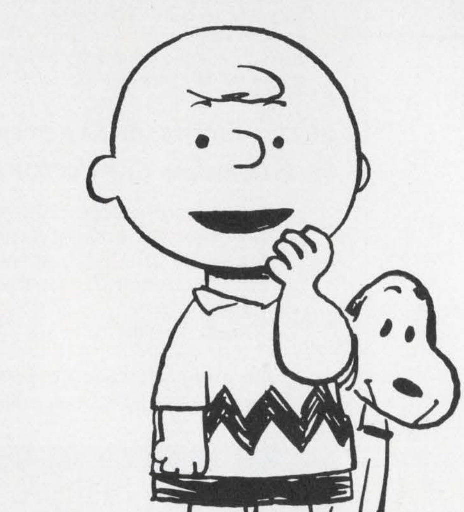
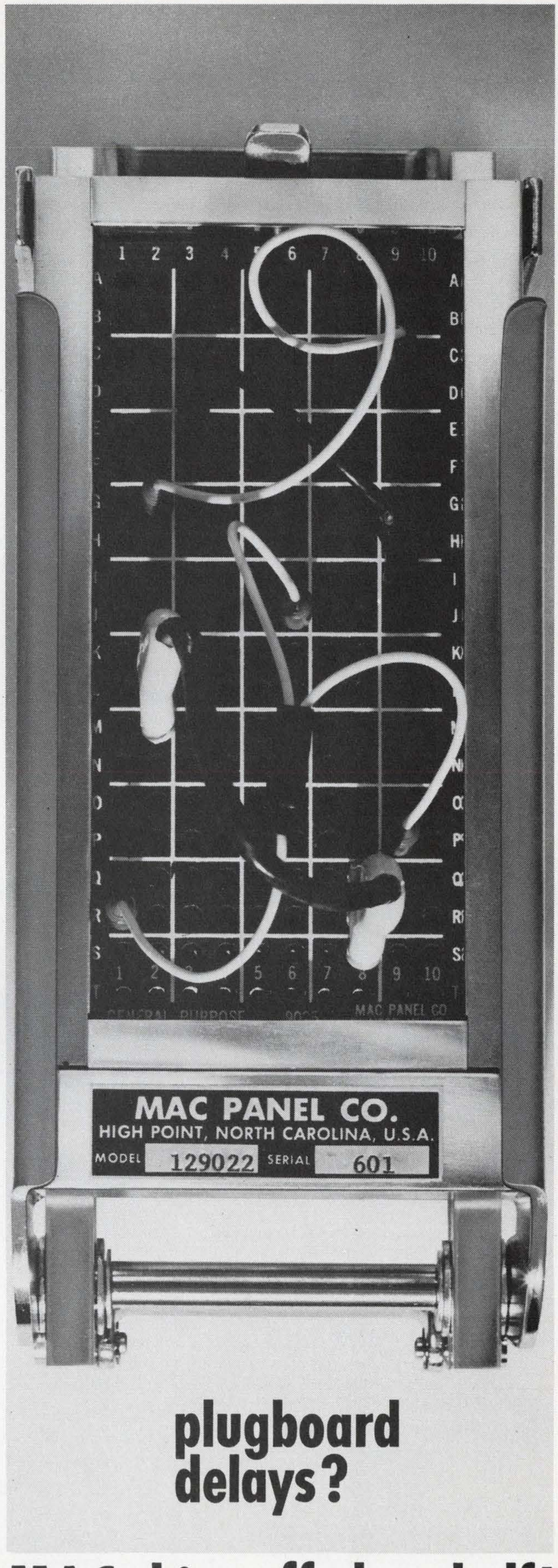
TO HIRE THE HANDICAPPED."

ISN'T THAT A GREAT IDEA, SNOOPY?



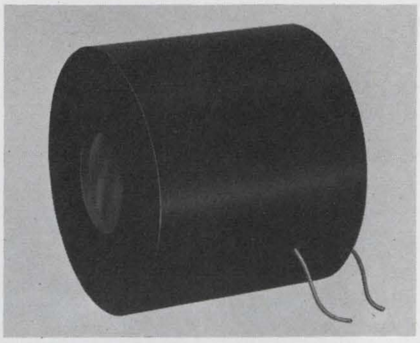
THE PRESIDENT'S COMMITTEE ON EMPLOYMENT
OF THE HANDICAPPED, WASHINGTON, D. C.



MAC ships off-the-shelf!

ON READER-SERVICE CARD CIRCLE 88

Color filter passes 12 kV

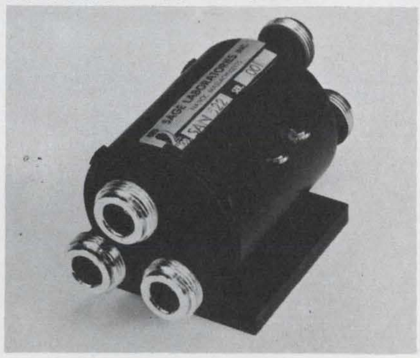


Electrochrome Corp., 11 Commercial St., Plainview, N.Y. Phone: (516) 433-0808. P&A: $350; 3 wks.

Electronically variable optical color filter is useful in the field of lasers, television, optical data processing, graphic arts and display systems. It is voltage tuneable over the visible spectrum and can be modulated from dc to 8 MHz. Capacitance is approximately 6 pF. The model 755S passes cyan from 0 to 2 kV, magenta from 5 to 7 kV and yellow from 10 to 12 kV.

CIRCLE NO. 324

Coax switches function to 4 GHz

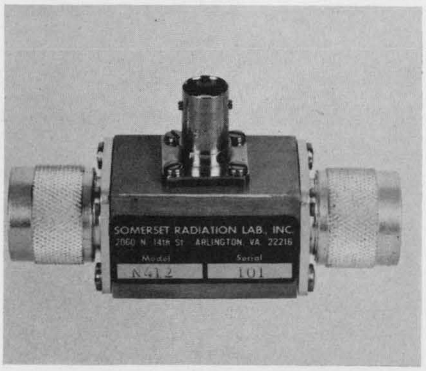


Sage Laboratories, Inc., 3 Huron Dr., Natick, Mass. Phone: (617) 653-0844. P & A: $150 to $165.75 ea.; stock.

Linear solenoid fail safe coaxial switches cover dc to 4 GHz. Over the full range, the insertion loss is less than 0.2 dB and VSWR is less than 1.3. Isolation is greater than 40 dB from dc to 2 GHz, and greater than 20 dB to 4 GHz. Power capability is 50 W CW and 3 kW peak. These units feature 10 ms switching time. Available connector types are female N, TNC, BNC, HN and C.

CIRCLE NO. 331

Diode switch has 12 ranges

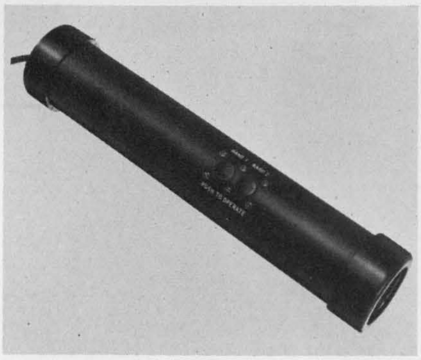


Somerset Radiation Lab., Inc., 2060 North 14th St., Arlington, Va. Phone: (703) 525-4255. P&A: $330; 20 days.

The N412 diode switch with Type N plug connectors cover the WR75, WR90, WR112, WR137, WR159, WR187, WR229, WR284, WR340, WR430, WR510 and WR650 waveguide bands. From 1.12 to 15 GHz the device has 45-dB isolation, 2 dB insertion loss and 2 W CW and 100 W peak power. It is hermetically sealed for radar, satellite, missile, and target enhancement service.

CIRCLE NO. 332

Radar simulator checks receivers

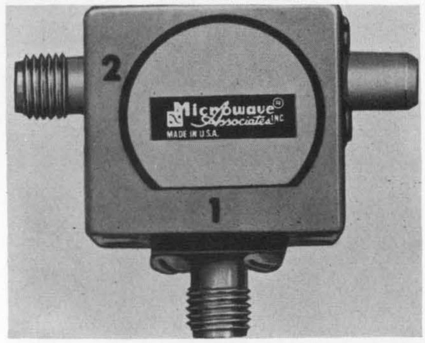


Trak Microwave Corp., Tampa, Fla. Phone: (813) 884-1411.

This radar transmitter simulator eliminates the necessity of turning on the radar transmitter to check receiver performance. It is self contained, except for the dc power requirement of 28 V at 1 A and can be hand held. The 2960 includes two oscillators plus power supply/modulator and antenna. It operates on two microwave bands which are selected by momentary on switches.

CIRCLE NO. 333

Diode switch covers 400 to 1100 MHz

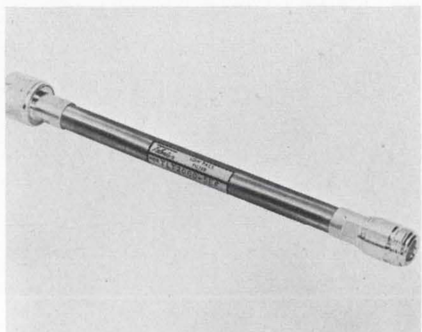


Microwave Associates, Burlington, Mass. Phone: (617) 272-3000.

The MA 8307 IL3S switch has been designed to protect radar receivers from high-power pulses. It operates in the 400- to 1100-MHz frequency range with a max insertion loss of 0.5 dB, VSWR of 1.4 max and isolation of 80 dB max. In the isolation state peak power is 20 kW and average power is 50 W; in the receive state peak power is 300 W and average power is 50 W. Switching speed is 2 μs max.

CIRCLE NO. 334

Low-pass filter cuts from 20 to 10 GHz

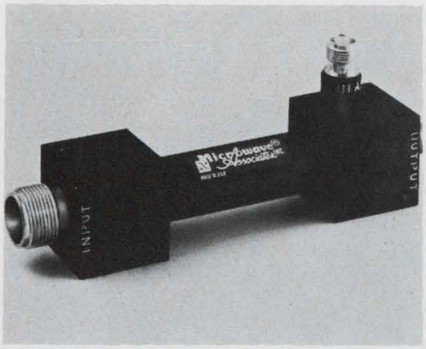


Telonic Engineering Co., Box 277, Laguna Beach, Calif. Phone: (714) 494-9401.

This low-pass filter may be specified for any cutoff frequency from 2 to 10 GHz, and is available in standard, off-the-shelf versions with cut-offs every 1000 MHz. The devices have a passband of 0.4 f_c to f_c, impedance 50 Ω, max passband VSWR 1.5:1, and insertion loss from 0.23 dB to 1.13 dB, depending on the number of sections.

CIRCLE NO. 335

X-band isolators span 7.5 to 10 GHz



Microwave Associates, Burlington, Mass. Phone: (617) 272-3000.

This subminiature terminated circulator is for operation in the frequency range between 7.5 and 10 GHz. Featuring 20 dB isolation, 0.3 dB insertion loss, the model MA 7K 275 measures 1-1/4 × 19/32 × 27/32 in. overall. The isolator is capable of handling power levels up to 10 W with operation guaranteed over a temperature range from −40 to +75°C.

CIRCLE NO. 336

Crystal detector spans 18 GHz

Hewlett Packard, 1501 Page Mill Rd., Palo Alto, Calif. Phone: (415) 326-7000. P&A: $160; 2 wks.

Frequency range of this detector, HP model 8472A, is from 10 MHz to 18 GHz, and its frequency response over this full band is better than ±1 dB. In the lower portion of this band (below 8 GHz), response is ±0.2 dB per octave. At 12.4 GHz, response variations are less than ±0.5 dB. The detector's VSWR is less than 1.2 at 4.5 GHz, below 1.35 at 7 GHz, under 1.5 at 12.4 GHz and less than 1.7 at 18 GHz.

CIRCLE NO. 337

Vinyl aerosol protects and seals

Quelcor Inc., Box 33, Media, Pa. Phone: (215) 544-7710.

When the aerosol is applied, it dries in minutes, encasing parts or surfaces with a film of Vinyl Copolymer. It seals out moisture and corrosive fumes, provides excellent moisture resistance, self adheres, has a built in ultraviolet ray absorber, and high dielectric strength for insulation. It is available clear and in 12 colors and furnished in bulk for larger surface applications.

CIRCLE NO. 338

Tailored graphite in 10 sample grades

POCO Graphite, Inc., P.O. Box 1524, Garland, Tex. Price: $16.50.

Ten grades of graphite, each tailored for a specific semiconductor or metallurgical process, are available for testing. Applications for the graphites include crystal growing and zone refining expitaxial headers, connectors and hot pressing. They also find use in transistors and other alloying, diodes and flat package ICs. Each new grade has been laboratory and field tested.

CIRCLE NO. 339

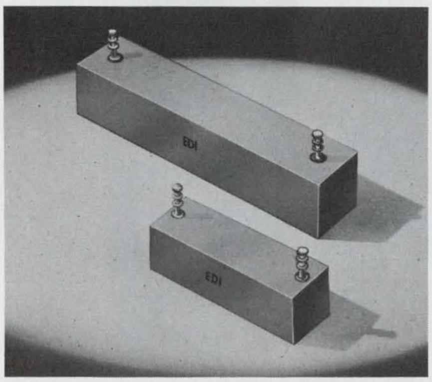
TO 99 op amps operate on +24 V

Union Carbide Electronics, 365 Middlefield Rd., Mountain View, Calif. Phone: (415) 961-3300.

The UC 709 and UC 4200 are a family of operational amplifier ICs in 8 lead TO-99 packages. The UC 4200 IC op amp is a high-voltage circuit that makes it usable for aerospace and airframe applications. It will operate from a +24 V power supply. The UC 4200 has supply current of 2.3 mA. Both devices have an input impedance of 3 MΩ, are short circuit proof, have an average temperature coefficient of input offset voltage of 6 V/°C typical, and operate in the temperature range of −55 to +125°C. The UC 709 is designed for 709 application requirements. Significant features of this device are a power dissipation of 48 mW; operating supply voltage of +15 V; and supply current of 1.6 mA.

CIRCLE NO. 340

Power rectifiers handle 50,000 PIV

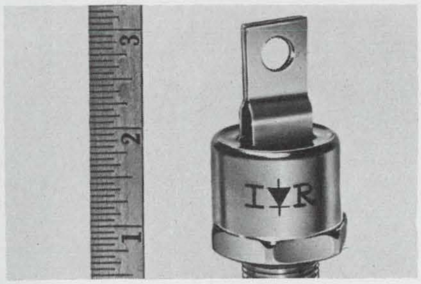


Electronic Devices, Inc., 21 Gray Oaks Ave., Yonkers, N.Y. Phone: (914) 965-4400. P&G: $19.30 · (100 lot).

RVP series of silicon rectifiers have peak inverse voltages from 5,000 to 50,000 V and forward currents of 600 to 800 mA at 50°C ambient. The rectifiers feature 300 ns recovery time when measured from 500 mA forward current to 250 mA reverse current. Available in molded block form, they are suitable for lasers, radio and radar transmitters.

CIRCLE NO. 341

200-A rectifier comes with heat-sink

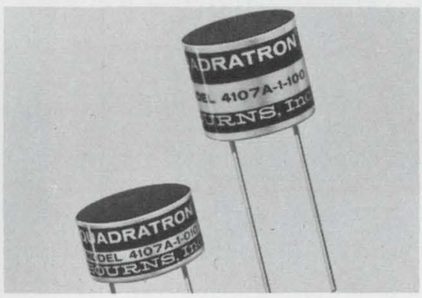


International Rectifier, 233 Kansas St., El Segundo, Calif. Phone: (213) 322-3331. Price: from $6.50 to $17.80 (1-9).

A unique package has been designed for 200-A silicon rectifiers that are capable of handling 3500 A of surge current. The silver-plated, flat-tab anode terminal provides an excellent heat sink, as well as a convenient electrical connection. This allows cable to be connected directly to the device rather than to terminal or terminal blocks.

CIRCLE NO. 342

Square-law generator uses silicon carbide

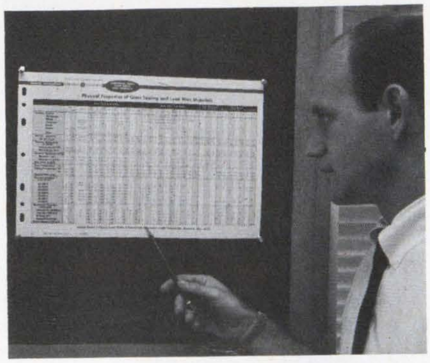


Bourns, Inc., 1200 Columbia Ave., Riverside, Calif. Phone: (714) 684-1700.

The model 4107 Quadratron square-law function generator affords an accurate and economical means of obtaining a large class of nonlinear mathematical functions. The 10-V version, measuring 5/8 in. in dia and 21/64 in. high, and the 100-V version, measuring 5/8 in. in dia and 35/64 in. high, are applicable at low cost over a wide dynamic range. The device is capable of generating square-root, sine, cosine, tangent and many other functions.

CIRCLE NO. 343

Design Aids



Glass and wire properties

A chart of physical properties for glass sealing and lead wire materials includes data on composition, density, thermal and electrical conductivity, electrical resistivity, curie and melting temperatures, specific heat, thermal expansion, mechanical properties, and elastic modulus for glass sealing materials, metal alloy lead wires, clad materials, and pure metals. GE manufactures tungsten, molybdenum, and Dumet wire, and furnishes these and other materials in lead wires for lamp, electronic semiconductor and other applications. General Electric Co.

CIRCLE NO. 344

Probability slide rule

A rule that allows you to obtain numerical answers to a wide variety of problems in statistics and probability, especially useful to statisticians, mathematicians, students of probability and engineers is being offered. It provides computations to three or four decimal places, depending upon the scale used. It is useful for analysis of random data, testing of hypothesis and prediction of results.

Available for $7.95 from TAD Products Corp., 639 Massachusetts Ave., Cambridge, Mass.

Application Notes

Applications for stainless wire

A brochure describing the use of a permeable mesh for boundary layer turbulence control around aerodynamic surfaces also cites triggering lanyards for aerial flares, the use of fine wire bundles in precise lengths for electronic clouds, and current research in super tensile stainless steel wire. Listed too are developments in high-resiliency wire used for wildlife radio-tracking antennae, fatigue-resistant wires used in medical applications, and high-temperature materials for space-vehicle parabrakes. Fort Wayne Metals, Inc.

CIRCLE NO. 345

Alloy guide

The shirt-pocket-size booklet contains the metal composition, physical properties, mechanical properties, fabrication characteristics and suggested applications for 22 commonly used alloys. Included are twelve common brasses and bronzes, tinned brasses and bronzes, a group of phosphor bronzes and a nickel-silver alloy. A special section discusses custom alloys designed to meet specific requirements and unusual specifications. Bridgeport Rolling Mills Co.

CIRCLE NO. 346

Basic circuits

Certain basic relay combinations and characteristics achieve specific circuit results in telephony. These basic circuits have become the building blocks of automatic telephone switching. Adaptable to other automated tasks, they are finding new and increasing uses in industry every day. This book depicts a few such basic circuits. It is recommended that the information in this book be used only as a guide to determine the availability of a circuit and its components. Automatic Electric Co.

CIRCLE NO. 347

New Literature

RFI/EMI Kit

A designer's kit is available to assist engineers in the proper selection of rfi/emi and magnetic shielding materials. The kit contains samples of a wide variety of rfi/emi magnetic shielding materials, and is available free of charge. Primec Corp.

CIRCLE NO. 357

Thermal relays

An insert-type brochure which describes the manufacturer's line of hermetically sealed thermal relays, details reference curves, operational details, time ranges, applications and specifications. Included in the presentation are T, T, and H series miniature time delays, LT series subminiature time delays, and PT series high-precision time delays. G-V Controls, Inc.

CIRCLE NO. 264

Oscillators and testers

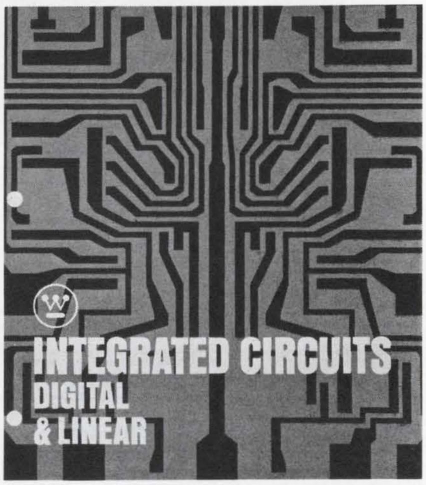
Recently published is a brochure describing the manufacturer's line of microwave oscillators, turnable coherent synchronizers, discrete frequency synchronizers, microwave stability testers, pulse jitter testers and MTI radar test sets. The catalog relates electrical specifications for models, pointing out the features of each instrument. A description of the development of the instrument line is also given. LFE Electronics.

CIRCLE NO. 265

Vacuum tubes treatise

A 19-page catalog containing charts and illustrations discusses special purpose vacuum tubes. Also covered in the presentation are multiplier phototubes, vacuum photodiodes, image dissectors, electron multipliers, image converters, correlation devices and accessories. ITT, Industrial Laboratories.

CIRCLE NO. 266



Digital and linear circuits

An 8-page reference guide presents schematic diagrams, design features, and model designations of various digital and linear ICs. The digital circuit line includes a range of DTL, TTL, and E^2CL circuits such as NAND gates, flip-flops, line drivers, level detector/Schmitt triggers and diode arrays. The linear circuit line includes operational and differential amplifiers, power circuits, high-speed gates, and the resonant gate transistor. Westinghouse Molecular Electronics Div.

CIRCLE NO. 267

Guide to silicones

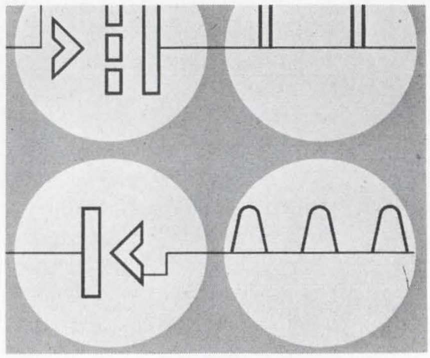
Contained in a recently issued brochure are products having federal stock numbers. The 56-page reference includes indexes of federal stock numbers, military specifications, products and product descriptions. The catalog is presented in an easily comprehended manner. Dow Corning.

CIRCLE NO. 268

Tube replacement release

A 16-page brochure on direct replacement of high-voltage, high-current rectifier tubes with the manufacturer's stackable silicon doorbell rectifier modules mated with tube-type bases and anode caps has been made available. Contained in the publication are: a listing of the advantages of using solid-state doorbell modules over rectifier tubes, details of the modules construction, a case history, and direct replacement data on over 50 rectifier tubes which includes the tubes' maximum ratings. Charts, schematics and illustrations are included in the presentation. Unitrode Corp.

CIRCLE NO. 269



Power tubes treatise

Described in an illustrated 20-page quick reference guide is a line of high vacuum amplifiers, pulse tubes and diodes. A series of tables listing the electrical and mechanical characteristics of different tube types that comprise the power tube line is included. The types included in the booklet are amplifier and pulse tubes, both triode and tetrode; and rectifier, clipper and charging, control and current-limiting diodes. A dimensional diagram is given for the tubes listed. A cross reference lists each tube by number, gives the class of service in which it is normally used, and the page on which it is described. Westinghouse Electronic Tube Div.

CIRCLE NO. 270

40378
7A RMS current, 200V
(Surge current = 80A)
(2-lead TO-5)

2N3228
5A RMS current, 200V
(Surge current = 60A)
TO-66

2N3528
2A RMS current, 200V
(Surge current = 60A)
TO-8

These 3 RCA SCR's sell for only 98¢* each

... and offer circuit capability of devices that cost many times more!

ONLY FROM RCA... one low price plus a choice of current ratings *and* packaging... for a broad range of 120-V line-operated control circuits. For low-current power control without use of a heat sink, ask for the 2N3528... for medium-power loads with the lowest dollars per kilowatt ratio, ask for the 2N3228... and for a really small package adaptable to semi-automatic or batch mounting, ask for the 40378. They all offer cost and performance advantages that should be built into *your* control circuits!

400-volt versions of these SCR's are also available for as little as $1.40*. Your RCA Field Representative will be happy to give you more details. *And ask him, too, about RCA's special heat-sinking techniques for TO-5 packages which gives you the power-handling capability of a press-fit without the added cost.* For additional technical data, write RCA Commercial Engineering, Sec. RG 12-1, Harrison, N.J. 07029.

See your RCA Distributor for his price and delivery.

**Prices in quantities of 1,000 and up*

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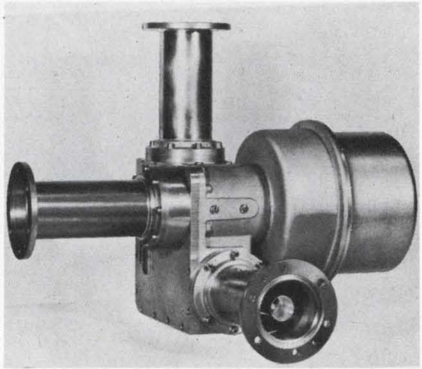
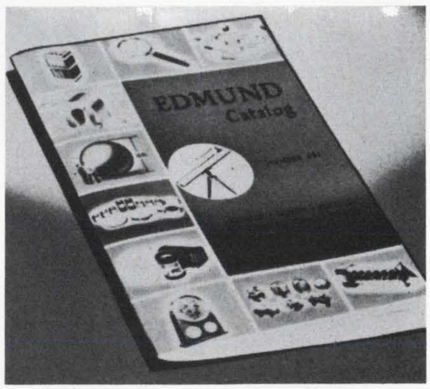


Coaxial switches

A comprehensive 106-page volume, covering instruments and components includes specifications and prices. The presentation covers a discussion of high-power coaxial switches for motor driven or manual applications, including militarized switches designed to withstand shock, vibration, extreme temperature ranges, humidity and salt spray. The CW rf power rating of the switches is equal to that of the mating transmission line with peak power ratings up to MW. Alford Manufacturing Co.

CIRCLE NO. 271



Engineering, design and research reference

A publication containing 4,000 chapters is directed at personnel in engineering, design, production, research and development departments. Instrument quality diffraction grating replicas reproduced from high quality imported masters, a six-power pocket comparator, and nickel cadmium batteries and cells, rechargeable and having almost unlimited lives, are among the subjects covered in the presentation.

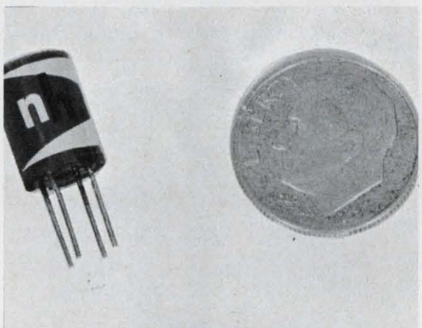
Available on company letterhead from Edmund Scientific Co., 301 E. Gloucester Pike, Barrington, N.J.

MATERIAL	TENSILE STRENGTH (PSI)	CHARPY IMPACT RESISTANCE (IN. LBS.)
Alumina	18,000 to 35,000	6.5 to 8.0
Zirconia	10,000 to 12,000	5.5
Mullite	11,000	5.5
Steatite	10,000	4.0 to 5.0
Forsterite	10,000	4.0
Elec. Porcelain	6,000 to 8,000	4.0

Alumina and beryllia

A 17-page color catalog discusses ceramics and their specific characteristics. Such features as strength, hardness, stability, thermal conductivity and nuclear and electrical properties of the alumina and beryllia ceramics are detailed. Property charts and graphs are included in the presentation. Coors Ceramics.

CIRCLE NO. 272



Relay lamp driver

A data sheet describing an integrated relay lamp driver is described in a literature being offered. The folder gives a description of the driver, contains schematic and connection diagrams, typical applications ratings and electrical characteristics. Also included are performance curves and definitions of terms. National Semiconductor Corp.

CIRCLE NO. 273

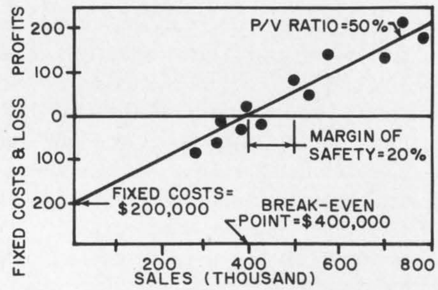
Instrumentation reference

A 32-page reference guide covers the manufacturer's line of electronic measuring and recording products. It provides information on instruments built by the division's three manufacturing plants. The guide can be used as a file folder or can be converted to a three-ring binder for bookshelf use. Special fasteners permit insertion of additional product information for up-dating purposes. The catalog also contains information about the division's nationwide network of meteorology laboratories that provide repair and calibration service to users of such equipment. Honeywell, Test Instruments Div.

CIRCLE NO. 274

Answer to problem on p. 109

The figure below shows the plot for 12 months of operating results, as given in the problem's profit-and-loss statement:—five months of loss below the zero intercept and seven of profitable operation above the zero intercept.



With these plotted points, we use the least-squares formula (see ED 23, Nov. 8, p. 99) to draw the line of best fit. This line intersects the Y axis below the zero ordinate at $200,000, the company's estimated monthly fixed costs.

We now have the three factors needed to do a P/V analysis:

1. Monthly sales volume is
$$\frac{\$6{,}000{,}000}{12} = \$500{,}000$$
2. Monthly profit is
$$\frac{\$600{,}000}{12} = \$50{,}000$$
3. Monthly fixed costs are $200,000 (estimated).

We can now calculate the following:

1. P/V Ratio =
$$\frac{\$50{,}000 + \$200{,}000}{\$500{,}000} = 50\%$$
2. Breakeven Point
$$= \frac{\$200{,}000}{0.50} = \$400{,}000$$
3. Margin of Safety ($)
$$= \$500{,}000 - \$400{,}000. = \$100{,}000.$$
Margin of Safety (%)
$$= \frac{\$500{,}000 - \$400{,}000}{\$500{,}000} = 20\%.$$

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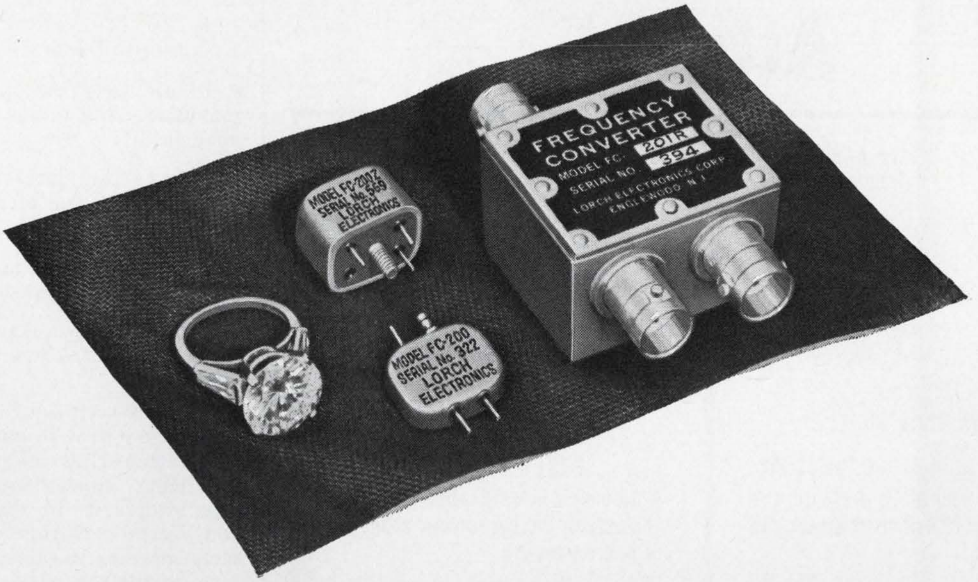
Advertisers' Index

Mixer Gems



QUALITY FREQUENCY CONVERTERS from a DEPENDABLE SOURCE

Lorch Electronics manufactures a series of broad band frequency converters (double balanced mixers) for applications requiring high isolation, low intermodulation distortion and high signal handling capability. Although these mixers measure typically as little as 0.17 cubic inches (some considerably less), they have RF power handling capability to 16 dbm, dynamic range to 135 db and excellent isolation characteristics (50 db to 400 MHz). And conversion loss is only 6-8 db, depending on model and frequency.

Careful manufacturing techniques and painstaking quality control assure the reliability of Lorch frequency converters in mixer, phase detector, product detector, switch, attenuator and modulator applications. For printed circuit use they are furnished as miniature pin packages, for laboratory or systems work, with BNC or TNC connectors. Other connector types are available.

Tabulated are seven of the many models we manufacture and stock for immediate delivery. We have many more... on our shelves and in our heads. Among them is one suited to your particular needs.

And our prices are right.

SPECIFICATIONS

Model No. — Pin Package / Connector Version	FC-200 FC-201	FC-200R FC-201R	FC-200T FC-201T	FC-200W FC-201W	FC-200Y FC-201Y	FC-200Z FC-201Z	FC-210* FC-211*
Frequency Range*	0.25 to 225 MHz	0.2 to 500 MHz	0.2 to 600 MHz	0.2 to 600 MHz	0.05 to 200 MHz	2 to 1000 MHz	0.25 to 120 MHz
Conversion Loss	0.4-150 MHz: 6db Total range: 7db	0.4-150 MHz: 6db Total range: 8db	0.4-150 MHz: 6db Total range: 8db	0.4-150 MHz: 6db Total range: 9db	0.2-100 MHz: 6db Total range: 8db	50-400 MHz: 7db Total range: 8db	0.4-50 MHz: 7db Total range: 7.5db
Isolation LO at RF	50db to 10 MHz 40db to 40 MHz 25db to 225 MHz	60db to 10 MHz 50db to 50 MHz 35db to 500 MHz	60db to 10 MHz 50db to 50 MHz 30db to 600 MHz	50db to 400 MHz 40db to 600 MHz	50db to 30 MHz 35db to 200 MHz	40db to 500 MHz 30db to 1000 MHz	25db
Isolation LO at IF	50db to 10 MHz 40db to 40 MHz 25db to 225 MHz	60db to 10 MHz 5Cdb to 50 MHz 25db to 500 MHz	60db to 10 MHz 50db to 50 MHz 25db to 600 MHz	50db to 40 MHz 40db to 200 MHz 30db to 600 MHz	40db to 30 MHz 25db to 200 MHz	30db to 500 MHz 25db to 1000 MHz	25db
Isolation RF at IF	35db to 100 MHz 25db to 225 MHz	20db to 500 MHz	25db to 50 MHz 15db to 600 MHz	30db to 50 MHz 20db to 600 MHz	20db to 30 MHz 15db to 200 MHz	25db to 500 MHz 12db to 1000 MHz	25db
Compression Level (for 2db compression)	+6dbm	+6dbm	+6dbm	+6dbm	+6dbm	+6dbm	+16dbm
LO Power	+7dbm	+7dbm	+7dbm	+7dbm	+7dbm	+7dbm	+20dbm
Dynamic Range (in 3KHz Bandwidth)	125db	125db	125db	125db	125db	125db	135db

*On all models except FC-210 and FC-211 one of the ports goes down to DC. Special versions of these two models are available with a DC port as Models FC-210DC and FC211DC.

Also available are Lorch broad band hybrid junctions and power splitters, from 80 KHz to 400 MHz, featuring low insertion loss, high isolation, low VSWR and good balance. These components can also be supplied from stock.

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Jan. 16-18
Reliability Symposium (Boston)
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CIRCLE NO. 349

Jan. 16-19
Dynamic Measurements in Ocean Sciences (Cocoa Beach, Fla.)
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Jan. 22-26
Marine Sciences Instrumentation Symposium (Cocoa Beach, Fla.)
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CIRCLE NO. 351

Jan. 27
Quality Control Conference (Pomona, Calif.) Sponsor: San Bernardino Section of the American Society for Quality Control; W. J. Willey, 327 Cimmeron Trail, Glendora, Calif. 91740.

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Jan. 28-Feb. 2
Winter Power Meeting (New York) Sponsor: IEEE; IEEE Headquarters, Technical Conference Services, 345 E. 47 St., New York, N.Y. 10017.

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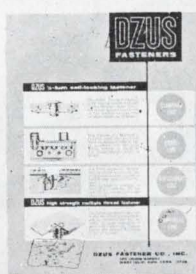

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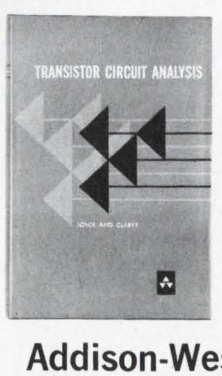
Transistor Circuit Analysis



Here is a practical text and reference used successfully in more than 120 industrial classes across the country. (Adoption list available upon request.) Written by the late Maurice V. Joyce and Kenneth K. Clarke, Polytechnic Institute of Brookyn, this book gives you the basic methods of analysis essential to the understanding and design of junction transistor circuitry. 461 pp, 362 illus (1961) $11.75.

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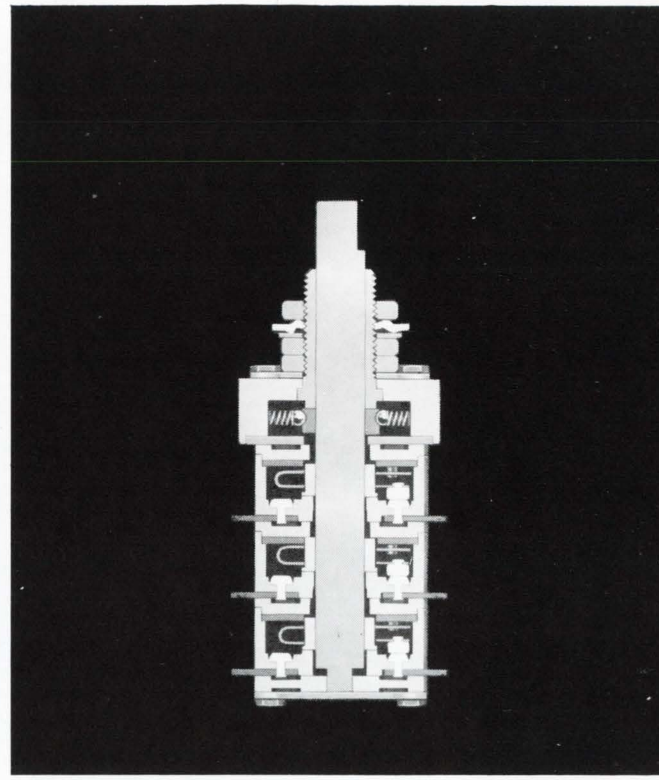

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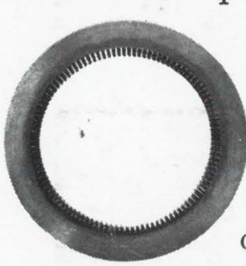

Electrical Machining Tool

G-1 "Cup"

RCA-4628

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