VOL. 21 NO.

Electronic Design 15

FOR ENGINEERS AND ENGINEERING MANAGERS

JULY 19, 1973

Electronics for nuclear reactors is needed for control, safety and surveillance. This equipment has to be highly accurate, fail-proof and capable of functioning in a rugged environment. With nuclear facilities now under construction the need for innovative design is urgent. For an inside look at this challenging field, turn to p. 26.

Technology Marketing Inc. asked us to prove our network capability.

Now it's your turn.

Respected computer systems developers like Technology Marketing Incorporated are making good use of Dale's thick film network capabilities. The network above is used to set threshold voltage and provide termination for two sense windings in a P.C. layout compatible with 7500 Series memory sense amplifiers. It has been used effectively in high volume production memory and computer systems developed by Technology Marketing Inc.

Standard or Special, Dale can provide the resistance function you need...in the quantities and at the price you require. Make us prove it.

Models immediately available for these and many other standard functions:

- MOS/ROM pull-up/pull-down
- Open collector pull-up
- "Wired OR" pull-up
- Power driver pull-up
- High speed parallel pull-up
- TTL unused gate pull-up
- TTL input pull-down
- Digital pulse squaring
- Line termination
- Long line impedance balancing
- LED current limiting
- ECL output pull-down resistors
- TTL input

Power Rating: 1/8 watt max./resistor; 2 watts/package (single in-line); 1-1/2 watts/package (DIP).

Resistance Range: 10 ohms to 1 Meg., depending on tolerance.

Tolerance: 1%, 2%, 5%, 10%, 20%.

T.C.: ±200 ppm/°C.

Packaging: Flame retardant epoxy coating or sandwich-type ceramic construction.

Double width and discrete networks also available in standard or special designs.

For complete information, call your Dale representative or phone 402-371-0080.

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INFORMATION RETRIEVAL NUMBER 246

Electronic Design 15

VOL. 21 NO.

FOR ENGINEERS AND ENGINEERING MANAGERS

JULY 19, 1973

NEWS

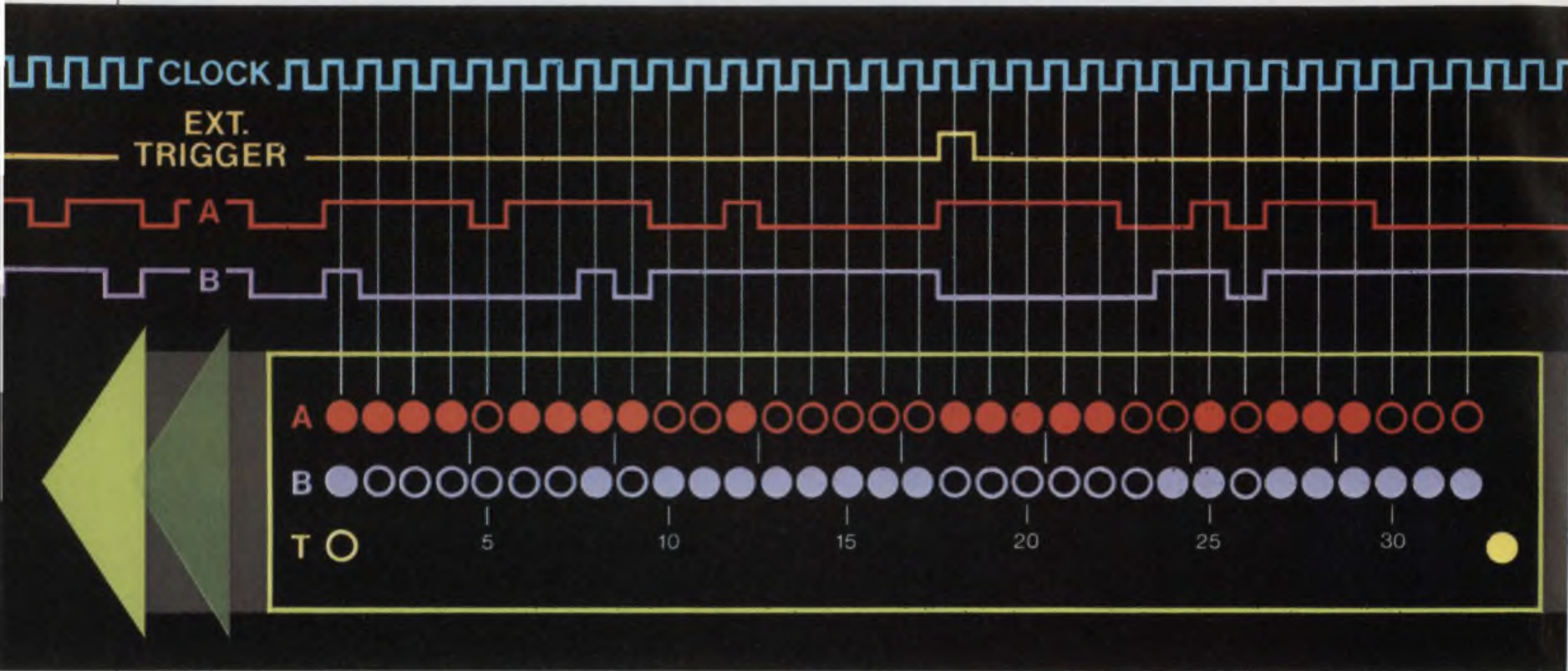
TECHNOLOGY

PRODUCTS

Departments

Cover: Nuclear reactors of the future will be operated from consoles like General Electric's Nuclenet. Inset shows Commonwealth Edison's Dresden I in Morris, Ill., one of the first operating nuclear reactors in the United States. The Dresden reactor was also built by GE. The Nuclenet photograph was supplied by GE; the Dresden photograph was taken by John F. Mason.

ELECTRONIC DESIGN is published biweekly by Hayden Publishing Company, Inc., 50 Essex St., Rochelle Park, N. J. 07662. 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., postage pending Rochelle Park, N. J. 84,392 copies this issue.



The ordinary way of looking at digital

Introducing the HP 5000A Logic Analyzer. At last, a fast, simple, easy – and above all – accurate way to look at digital signal streams. Highs and lows are displayed by "on" and "off" states of LED's that make intuitive sense when you're working with truth-tables or timing diagrams.

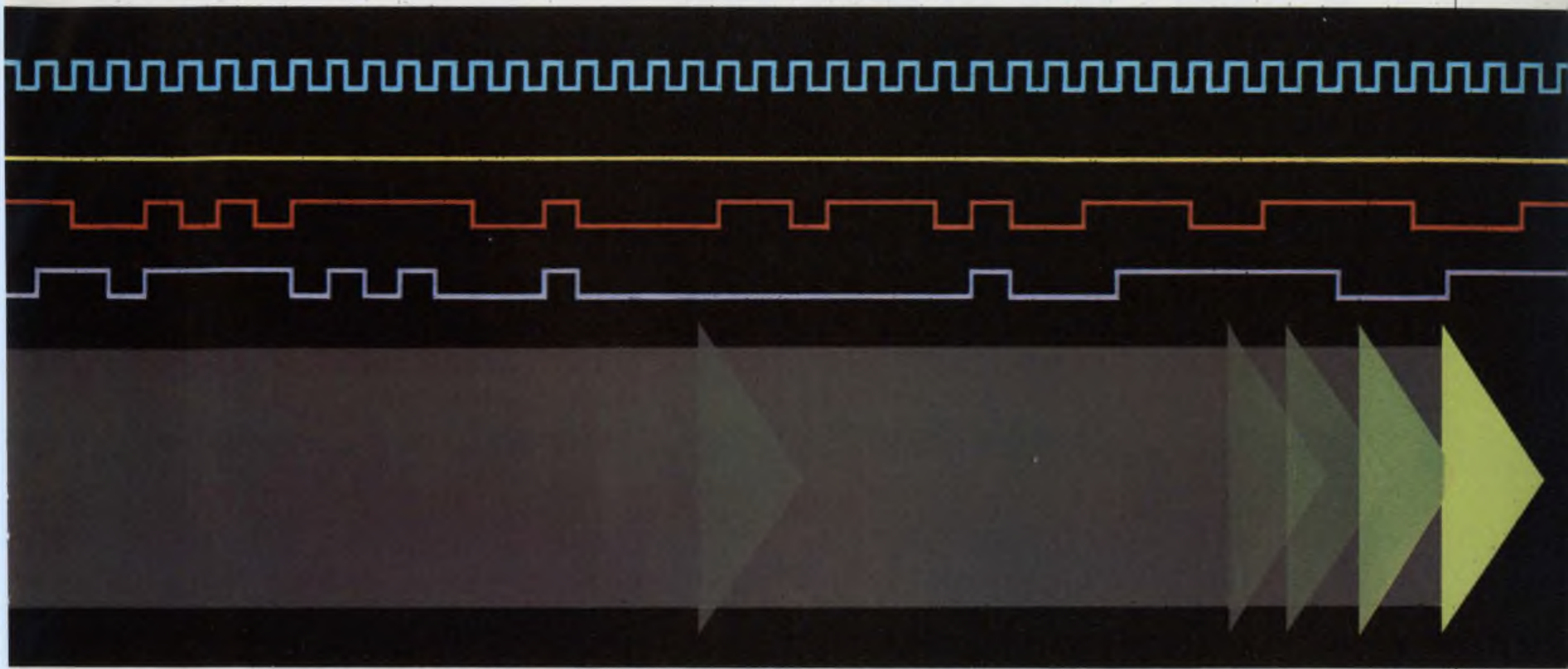
For the first time ever you can look backwards as well as forwards in time from a trigger event. Plus, fast, easy-to-use waveform storage lets you conveniently capture single-shot or transient bit streams. Add to this straight-forward, almost self-explanatory controls and you have an ease of operation and display interpretation unmatched by any other method of monitoring digital bit streams.

The HP 5000A can be effectively applied anywhere digital signals are used. A capture rate of up to 10 Megabits/sec., adjustable threshold, and 1 megohm impedance let you use it with any existing logic family. In addition, its unique digital triggering lets you select any AND combination of three inputs as the trigger word. This feature gives you wide latitude in defining the event or failure state to which you wish to key the display.

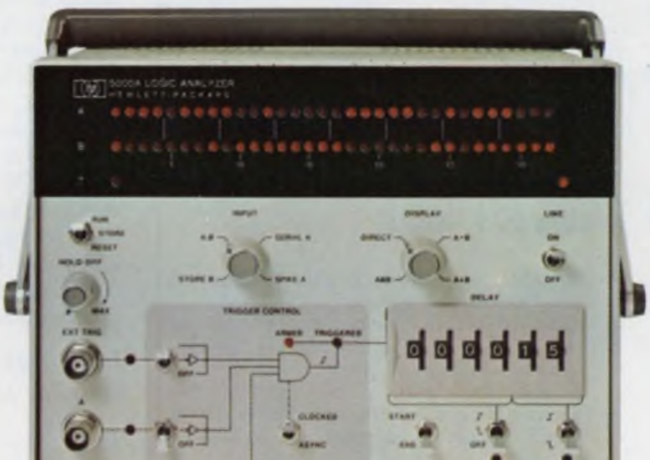
Precise digital delay makes algorithm-checking and accessing of particular data in long streams incredibly easy. Simply by dialing delay into the front panel thumbwheels, you can move the 32- or 64-bit display "window" forwards from your selected trigger up to 999,999 clock pulses – or backwards as many as 64 clock pulses. Because timing and display are keyed to your clock signal, absolute repeatability is assured. You're always certain exactly which pulses you're looking at in the data sequence.

That's a lot of performance for $1900.* But the HP 5000A has still more features to make your work easier in the lab, on the production line, or in the field. The facing page tells more of the Logic Analyzer's revolutionary story and what it can do for you. To arrange for a demonstration, call your local HP field engineer today. Or, write us for complete specifications.

*Domestic USA prices only. 02304



bit streams has just become obsolete.



What led up to a failure? What resulted from it? The HP 5000A can be quickly set up to show data both immediately preceding and following your selected trigger.

Keep the display as long as you need it; store it indefinitely at full brilliance or just until the signal changes.

The LED display can show you *simultaneous* 32-bit segments of any two signal streams. Or, you can set it up to look at one 64-bit stream.

Another display mode allows you to hold a data pattern in one channel while continuously monitoring an on-going data stream in the other.

If you choose to use the HP 5000A for production or quality control instead of in the lab, yet another feature permits you to compare production units against a known good circuit *and have only the "bad" data bits show up on the display.*

Short pulses due to noise or other causes are no problem for the 5000A. It not only detects these "spikes," it indicates where in the data stream they occur, and even tells you their polarity.

Portable, the 5000A is ideal for field service. With its negative delay and single-shot storage capabilities, you can perform "on site" analysis of the causes of intermittent errors — even those frustrating once-an-hour, or once-a-day events.

You get safeguards against wasted effort too. LED's light up at each input connector to show signal activity; two other LED's indicate arming and triggering. You never spend time looking for pulses that aren't there.

HEWLETT *hp* PACKARD

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INFORMATION RETRIEVAL NUMBER 4

across the desk

Fringe benefits: Boon or bane?

In Ed Reamer's article ("Raises: How Often and How Much?" ED No. 8, April 12, 1973, p. 110), he mentions that the engineer's benefits at his company, besides raises, are (1) The opportunity to present ideas to top management; (2) Being advised of the company plans; (3) Freedom to attend society meetings on company time; (4) Opportunity to obtain an advanced degree; (5) Titles; (6) A chance to speak at sales and technical meetings; (7) A private telephone; (8) A partitioned office; (9) Christmas week off and (10) A day in Disneyland—in that order.

Aren't the first eight "benefits" necessary conditions to maximize the engineer's work effectiveness, which contributes directly to company profits? And are these the benefits Mr. Reamer's employees want or consider important? Or did he bother to ask?

S. E. Roberts
6740 Maysvulle
Fort Wayne, Ind. 46802

Ed Reamer's article struck me as a clear picture of what's wrong with so much of business. A day at Disneyland is hardly a fringe benefit. An article based on the premise that it is not what an individual does that counts but how he fits into the team staggers the mind. All the clear behavioral data from MIT, UCLA, Stanford and other sources show that man does not work for raises or days at Disneyland but for a sense of self-accomplishment and self-fulfillment.

Wayne C. Stevenson
Marketing Manager
United Detector Technology, Inc.
1732 21st St.
Santa Monica, Calif. 90404

It's 'like phase,' not 'opposite'

In your article "Reject Common-Mode Noise" (ED No. 9, April 26, 1973, p. 120) is the statement:

"At the receiving end, induced noise will tend to be of equal magnitude and opposite phase on receiver terminals. A receiver that responds only to a differential signal and has high common-mode rejection will eliminate the common-mode noise."

The phrase "opposite phase" should have been "like phase." Common-mode noise, by definition, appears *in phase* on both receiver terminals. Since a differential input responds to the difference between the two inputs, it is relatively blind to signals that present like phase and amplitude to both inputs. Therein lies the "rejection" quality.

R. A. de Forest, MSEE
Consulting Engineer
Route 1, Box 267A
Sheridan, Ore. 97378

Amdahl Corp. requests some editing changes

In your article, "Gene Amdahl Competition Plan: Make The Machine Big, But Keep It Simple"

(continued on page 8)

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

ACROSS THE DESK
(continued from page 7)

(ELECTRONIC DESIGN 11, May 24, 1973), there are several inaccurate statements which may be misleading to your readers.

In the lead paragraph, a comparison of our machine suggests it will be "more powerful than . . . the ILLIAC IV, Control Data's STAR and Texas Instruments' Advanced Scientific Computer." Although you did point out that ours will be a business machine, the comparison to the large, special-purpose computers is misleading. Our machine is far more realistically compared to the IBM System 370 Models 195, 165, 168, and the CDC 7600, to which ours will be superior.

Your fourth and fifth paragraphs seem to infer that our machine will be a multiprocessor or have some new, exotic structure. It won't be—its organization and architecture will be simple and straightforward.

Your sixth paragraph may confuse the reader. Our machine will start or stop on a byte, but it will work with more than one byte at a time.

The last sentence in the first paragraph of the righthand column (p. 67) is incorrect. We will not have to rework our circuits if IBM changes software. Rework will be necessitated only if IBM changes the interfaces which affect its customers.

Ricardo J. Alfaro
Director of Communications
Amdahl Corp.
1160 Kern Ave.
Sunnyvale, Calif. 94086

Achtung: A touch of Teutonic pride

I agree with the statement in your editorial "We've Got to Run Faster to Stay in Place" (ED No. 3, Feb. 1, 1973, p. 45) that European and Japanese engineers are catching up and are in many cases not at all "underdeveloped" in comparison with their American colleagues. However, my main fuse blew when I read the first sentence of the editorial: "For as long as anybody can remember, we in the U.S. have been the technological leaders of the world."

That statement is OK only if you restrict your memory to the last 10 or 20 years. If you go back about 40 years, Germany was absolutely leading in the following fields: rf ceramics; rf iron cores and ferrites; cathode-ray oscilloscopes; television receivers with cathode-ray tubes (1930); electron microscopes and scanning electron microscopes (1937); radar (1936); FM radio networks; magnetic tape recording—even the world's first programmable digital computer (Zuse).

Take other fields: Where did the first gasoline combustion motors come from? The first diesels? The first electric locomotives? The very first jet planes? The first submarines? The first big rockets (Von Braun)?

And I add recent inventions, like the TV disc, the digital ignition system, the Wankel engine.

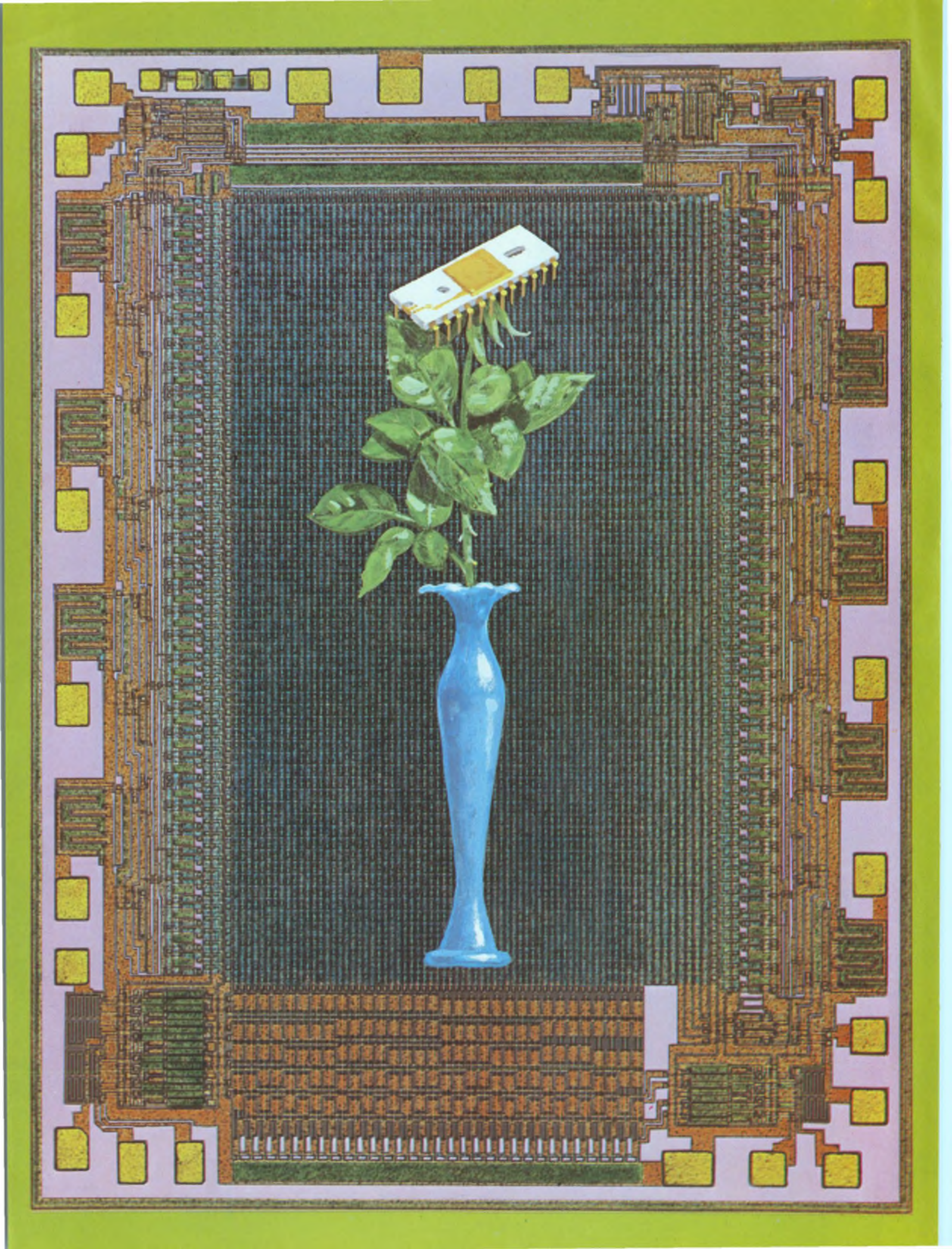
Germany has never been underdeveloped technically, but it lost Hitler's criminal World War II and was thrown back 20 years. Our best engineers left the country. Big projects, like flying to the moon or launching satellites, were only feasible in the U.S., the world leader in MOS and many other modern techniques. We in Germany admire your advanced technology, but we are a little bit sensitive about statements that put us back to the Middle Ages.

Hans J. Wilhelmy
Editor-in-Chief
Electronik
8 Munchen 37, Karlstrasse 37
West Germany

A livestock approach to engineering detected

Your regular interview articles with managers in the electronics industry provide an interesting insight into why many an engineer would not recommend his son to follow him in his profession. Almost without exception, these managers come over as heavy-

(continued on page 16)



Say It With NMOS

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It's the start of something big. 8192-bit NMOS ROMs, the first of Motorola's new line of standard NMOS products. They've already been joined by several companions, and more are waiting in the wings for introduction. And now, in a big way, you truly can "Say It With NMOS."

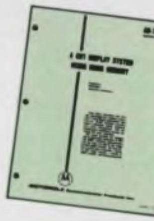
Motorola's MCM6570. The mask programmable 8K Row-Select Character Generator with 128 high resolution 7 x 9 matrix characters, and internal character shift for below the line display. Fast typical access time of 350 ns is even less if the device is programmed without shifted characters. Operating unit power dissipation is a comfortably low 600 mW. What's more, like its companions, the MCM-6570 is *fully* TTL compatible and requires no clocks. Static operation makes all these new NMOS ROMs easy to use.

NMOS' economic advantages are evident in the $18.00 (100-999) price of this and all Motorola 8K NMOS ROMs. Naturally, a reasonable mask charge also goes with mask-programmable versions. The MCM6571 used here for demonstration is a pre-programmed version of the 6570, with a modified USASCII code. A pre-programmed version without shifted characters will be available later.

Even faster than the Row Select units are the MCM6580 and 6581, a pair of Column Select Character Generators, and the MCM6560 series, three 8K binary ROMs. Typical access time for all five is 225 ns. Character shifting in the MCM6580/81 is achieved with external circuitry. Of the binary ROMs, the 6560 is a 1K by 8 mask programmable device, the 6561 is organized as 1K by 8 with ASCII, Hollerith, Selectric, and EBCDIC conversion codes, and the 6562 is 2K by 4, customer programmable.

In CRT system applications, it is necessary to have an appropriate storage device for refreshing the CRT image, so we introduced the MC6565 quad 80-bit NMOS static shift register. It is designed for use as main storage in small systems, or as buffer storage in larger systems. The 6565 operates from dc to 5.0 MHz, with maximum power dissipation of 650 mW. Full TTL compatibility is provided. The register uses a single TTL level clock input, and the recirculate logic is on the chip. Three-state outputs also enhance this device.

Proving out the theoretical advantage of NMOS prompted the development of a simple CRT display system built on six PC boards containing Counter and Retrace Control, Memory, Character Generation and CRT Drive, Input Address and Data and Cursor Generation, Communications I/O and Memory Select, and the Power Supplies. The TTL compatibility and convenient power requirements of NMOS parts used for both storage and character generation led to a simplified system. The capability of generating 128 characters in 7 x 9 matrices, with automatically shifting descender characters meant a substantial reduction in external circuitry. Interface simplicity is demonstrated as the memory section inputs are driven by TTL gates. The three-state feature of the MC6565 allows the outputs to be bussed together.



Data on the 8K ROMs and the MC6565 quad 80-bit shift register is available from Motorola Semiconductor Products Inc., P.O. Box 20912, Phoenix, Arizona 85036. So is a brand new application note describing the CRT Display System in detail. Or for any or all of this information, just circle the reader service number.

This *is* big. And it's the start of something even bigger, with more ROMs, some exciting RAMs, and some things even bigger on the way. So say it with NMOS, and when you say NMOS, look to Motorola.

MOTOROLA MOS

Expanding Dimensions In Digital Design

INFORMATION RETRIEVAL NUMBER 9


easy does it
START
STRIP

WE TOOK A SIMPLE IDEA AND MADE IT SIMPLER.

We put a whole GHz into a low-cost universal counter. By uncomplicating a basic design. For $775 you get superversatility and 100MHz. For $1070, 500MHz. And for $1370, you get 1GHz plus.

Our new Model 700 Counter measures frequency from DC to 1 GHz, period, period averaging, time interval, frequency ratio, totalizing and time (stopwatch). Standard features include frequency range to 100 MHz, proportional oven-controlled time base (1 x 10^{-8}/day), 7 digit Sperry planar display, BCD outputs and remote control of Mode and Time Base.

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INFORMATION RETRIEVAL NUMBER 11

(continued from page 8)

handed and mean-spirited, with attitudes toward their subordinates more related to those of a livestock farmer towards his cattle.

One of them, taking advantage of the increased supply of unemployed engineers, shepherds his herd back into a bull pen with three-foot walls; those who object are shown the gate. Another posts weekly scorecards above each engineer for all to review his performance, rather like the records kept above each cow in a milking parlor. And now another castigates an employee, who has regularly been putting in 10-hour days, for arriving late in the morning.

They are a hard-boiled lot, your engineering managers, and the only mitigating thought might be that they, too, have to impress their superiors. Perhaps they are not really so inhumane as your articles suggest.

A. M. Nicolson, Ph.D
Member of the Technical Staff
Sperry Research Center
100 North Rd.
Sudbury, Mass. 01776

In defense of Janice

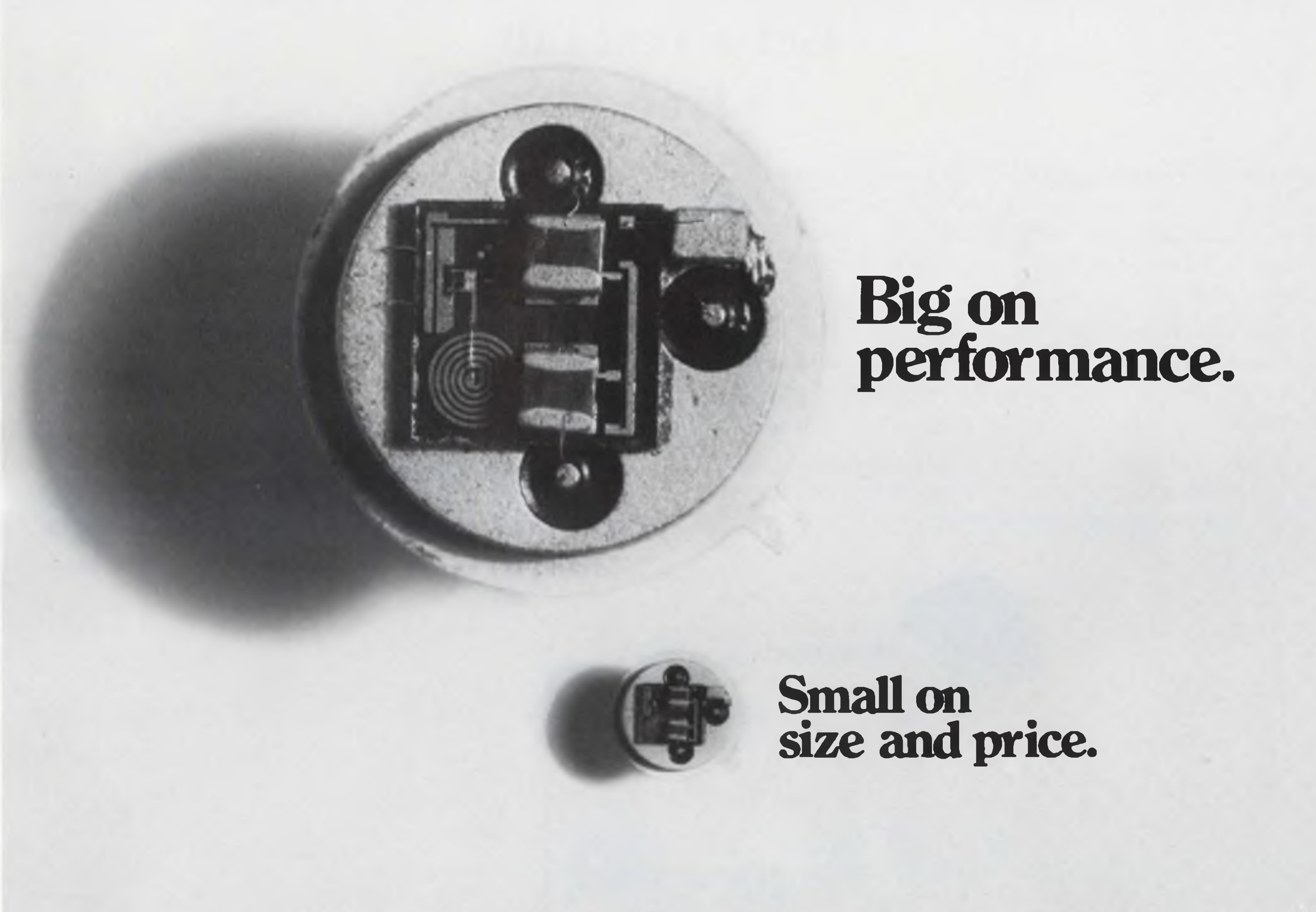
I very seldom comment on articles written in trade magazines, but the reader commenting on "Janice" begged for a reply with his use of the word "prostitute" (see "Turned Off by Janice," ED No. 12, June 7, 1973, p. 7).

I cannot see where a woman who makes money with her good looks, which she was born with, is any more prostituting herself than someone who makes money using his mind. They're both physical traits.

Possibly H.J.M. [the reader who criticized Janice] is concerned because he suspects Janice is making more money?

Steven S. Zimmerman
New Products
Honeywell Info Systems
Box 6000 (B-14)
Phoenix, Ariz. 85005

The Avantek GPD amplifying device.



Imagine, a complete 5-400 MHz transistor amplifier, featuring over six octaves of flat bandwidth, thin film sapphire construction, complete cascadability and a miniature TO-12 package, for $30 and under.

The Avantek GPD has to be the best miniature amplifier buy available today. Check the prices below and consider the performance per dollar. You're probably paying too much right now even if you are building your own.

Find out more about the Avantek GPD by phoning your regional sales office or the factory direct. Or, use the readers' service number below and receive a complete data sheet and our 18-page applications brochure, *Designing with GPD's*.

Avantek, Inc. Eastern Regional Office, Falls Church, Virginia (703) 533-2260 Central Regional Office, Shawnee Mission, Kansas (913) 362-9511 Western Regional Office, Santa Clara, California (408) 249-1354 Corporate Headquarters, Santa Clara, California (408) 249-0700.

Model	Frequency Response (MHz) Minimum	Gain (dB) Minimum	Flatness (dB) Typical	Noise Figure (dB) Typical	Reverse Isolation (dB) Typical	Power Output for 1 dB Gain Compression (dBm) Typical	Avantek Intercept Point for IM Products (dBm) Typical	VSWR (50-ohms) Typical In	VSWR (50-ohms) Typical Out	Input Power Volts DC	Input Power Current (mA) Typical	Storage Temperature (°C)	Weight (grams)	Price (Qty 1-99)
GPD-401	5-400	13	1.0	4.5	−20	−2	+8	2.0	2.0	15	10	−65 to +200	1.0	$30
GPD-461	Same as GPD-401, except three external capacitors are required to establish low frequency roll-off.													27
GPD-402	5-400	13	1.0	6.0	−20	+6	+18	2.0	2.0	15	24	−65 to +200	1.0	29
GPD-462	Same as GPD-402, except three external capacitors are required to establish low frequency roll-off													26
GPD-403	5-400	9	1.0	7.5	−20	+15	+26	2.0	2.0	24	65	−65 to +200	1.0	30
GPD-463	Same as GPD-403, except three external capacitors are required to establish low frequency roll-off													27

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INFORMATION RETRIEVAL NUMBER 121

INFORMATION RETRIEVAL NUMBER 122

Pertec's out to beat the devil at his own game.

For starters we've developed the most technologically advanced and complete disk drives on the market. They're available and deliverable *now* at Pertec.

Diablo's incensed. And for good reasons.

Because Pertec's D3000 disk drives are available in top and front loading versions, plug-compatible, and identical in interface and size (8¾" x 26"). Both offer 35 msec access time, margin testing, a choice of electronic or mechanical sectoring, an optional fixed platter. And a built-in power supply—all within the drive and identical in both configurations.

And you get the same assistance in design, development and maintenance of your system with our disk drives as you do with our tape drives . . . Factory training for your service people. Backup by a service and support network spanning 30 U.S. cities and 20 foreign countries.

All at surprisingly low prices.

Pertec is serious about satisfying your disk drive requirements, and we're proving it.

Find out more. Call us collect in the area nearest you: Boston (617) 890-6230; Chicago (312) 696-2460; Los Angeles (213) 996-1333; London (Reading) 582-115. Or write us at 9600 Irondale Avenue, Chatsworth, California 91311.

The best values in computer peripherals come from

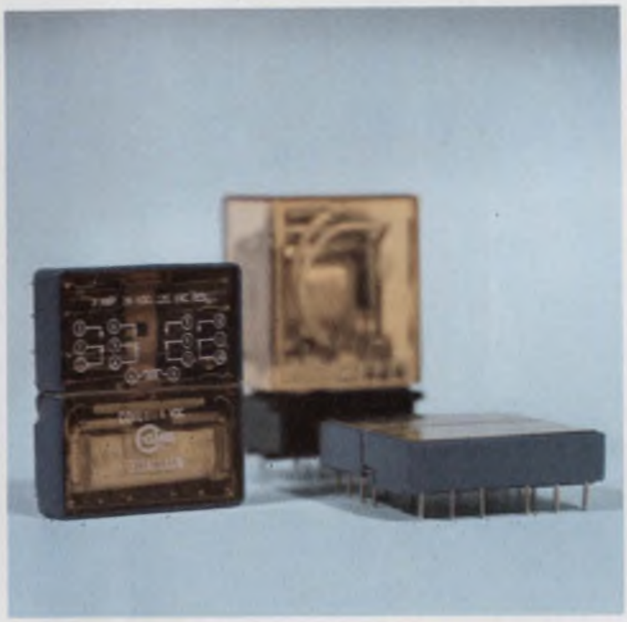
PERTEC

Already the world's largest independent manufacturer of tape transports.

INFORMATION RETRIEVAL NUMBER 123

INFORMATION RETRIEVAL NUMBER 124

"We wanted to go right from keyboard to disc, right? But space was critical. GP relay specs were OK, but I didn't have any room. Besides, we had to flow solder and dip clean the assemblies to get volume up and cost down. What I needed was a new kind of relay-- and some help-- right now..."



PROBLEM: The market for computer periphery is wide open. And equipment that takes you directly from keyboard to disc is a fantastic idea—if you can make it small enough and cheap enough to sell. And that's tough. Relays are one problem. They've got to be dependable (nothing radical, something available) yet small enough to fit your P.C. design. And they've got to maintain reliability under the effect of high speed production. You can't afford any weak links in your final package, but you have to make your decision fast because of competition.

SOLUTION: Clare's new 311 Series General Purpose Relays saved the day. They offer 3 amp switching in an extremely low-profile package with .5" mounting centers. They sit a mere 0.350" above the board and take up less than 0.7 cubic inch space. The Lexan® dust cover and pins molded in the base fully protect the relay during wave soldering and partial dip cleaning. And the pins are mounted on a .1" center grid, to add flexibility and save you money. The new 311 also has excellent voltage breakdown ratings and shock resistance, gold plated steel terminals, and fine silver contacts.

Clare's expertise lies in the design and manufacture of relays. That's why we can give you so much in a single low-profile relay. Right now.

But our energy lies in the application of relays to help you solve specific problems. We specialize in getting down to work.

If you need help—or just some specific information about our new low-profile 311 series relay—get in touch with us. The "right now bunch" is ready to go to work for you.

Contact your local Clare Distributor or Sales Engineer. C. P. Clare & Co., 3101 Pratt Avenue, Chicago, Ill. 60645. 312/262-7700.

QUALITY/SERVICE/RELIABILITY

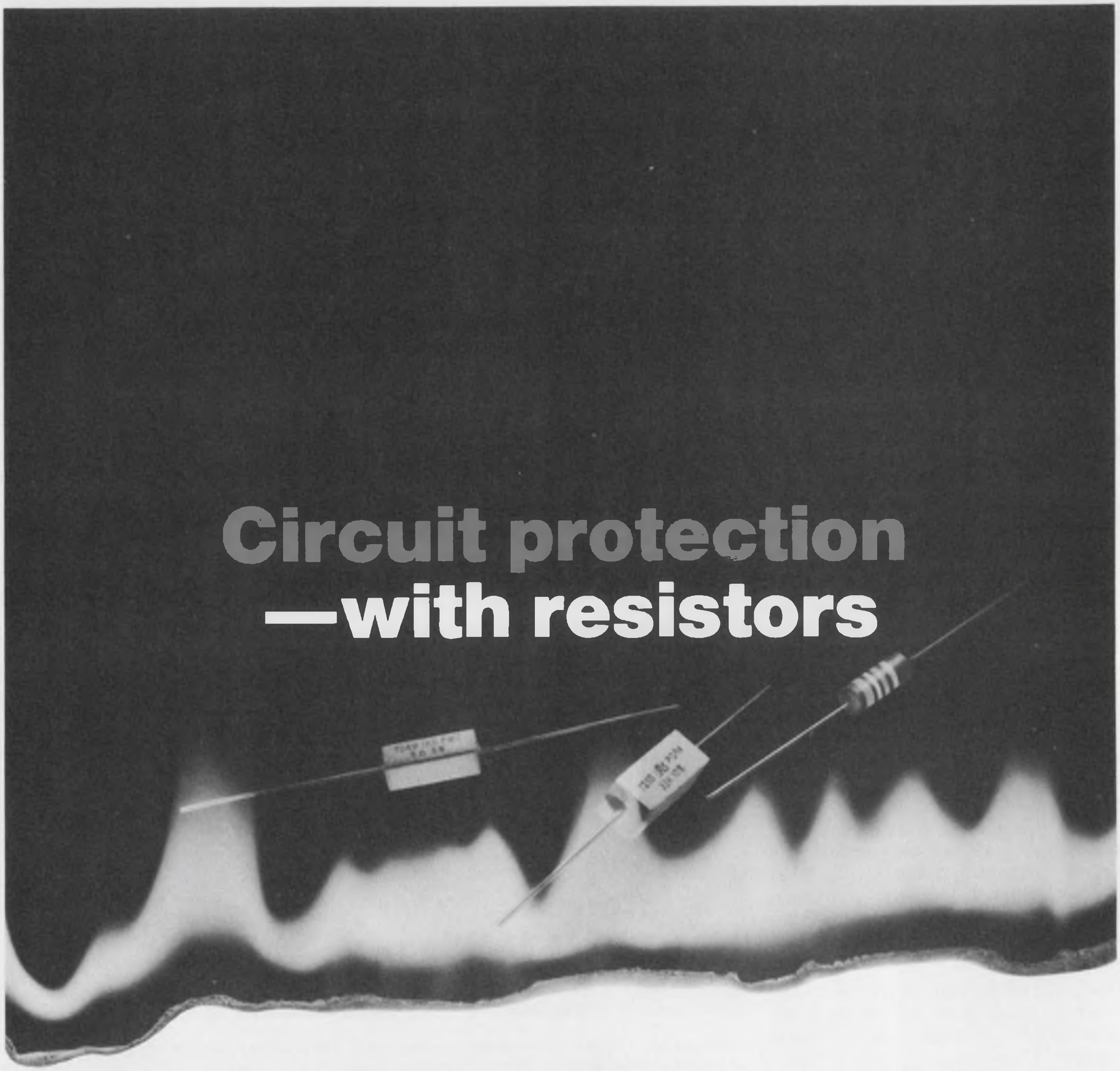
we help. get in touch with us. CLARE the "right now" bunch.

a GENERAL INSTRUMENT company

GENERAL PURPOSE RELAYS   MERCURY-WETTED RELAYS   REED RELAYS   SOLID STATE RELAYS   TELEPHONE RELAYS   STEPPING SWITCHES

INFORMATION RETRIEVAL NUMBER 14


PIHER
3003 A
MC
150
PC100



Where your circuits require resistors with built-in fault protection, TRW may have a solution. Specifically:

IRC Type PW. Wirewound power resistor, 2-50 watts. Inorganically constructed. Use as a standard power resistor. Or use as a *fusible* resistor. Highly effective where you need a versatile, low-cost power resistor, or specific fusing characteristics.

IRC Type BWF. Economical 2-watt wirewound resistor in the familiar 1-watt size molded jacket. For years an industry standard for high-volume, automated assembly application. Now available with fusible flameproof feature for hazard applications up to 1000 X overload or 1000 V.

IRC Type PGR. Ceramic-insulated, semi-precision film resistor, 1-5 watts. Famous Metal Glaze™ construction—rugged and stable. A low-cost, universally applicable flameproof resistor in ranges up to 100K ohms—far beyond wirewound resistor capability.

Complete resistor choice. Remember, TRW/IRC offers a total resistor capability—wirewound, carbon comp., metal film, functions.

For technical data, flameproof specifications or specific application needs, contact your local TRW sales representative. Or write TRW/IRC Resistors, an Electronic Components Division of TRW, Inc., Greenway Rd., Boone, N.C. 28607. (704) 264-8861.

TRW® IRC RESISTORS

INFORMATION RETRIEVAL NUMBER 16

Comparator Supermarket

Variety that lets you pick exactly what you need.

SIGNETICS COMPARATOR SELECTION LIST								
Check Need	Part Type	Operating Supp Range (V)	TTL Fan Out Capability	I Offset (μA)	I Bias (μA)	V Offset (mV)	Propagation Delay (nS) Typical	Propagation Delay (nS) Maximum
	NE521	±5	10	5.0	20.0	7.5	8	12
	NE522	±5	10	5.0	20.0	7.5	10	15
	NE526	±5	10	5.0	35.0	5.0	40	48
	NE527	±5 to ±12	10	0.75	2.0	6.0	16	26
	NE529	±5 to ±12	10	5.0	20.0	6.0	12	22
	μA710	+12, −6	1	5.0	25.0	5.0	40	—
	μA711	+12, −6	1	15.0	100.0	5.0	40	—
	LM311	+5, GND to ±15	5	0.05	0.250	7.5	200	—

Life sweetens a little. When you can get everything in comparators, from the fastest TTL to the finest precision with one call, you save a lot of migraine and a lot of bucks.

The chart also tells you something else. You can choose exactly the device you want for each of many different requirements. So you can optimize your systems, which gives you one kind of economy. And you can combine your comparator orders to get more economy. Known as smart-money thinking.

Say one of your interests is speed. You look at the four listed comparators that go from the NE527 with 16nS propagation delay down to the NE521, an 8nS dual. That's a spectrum you'd be looking in if you're building MOS memory sense amps, or maybe a Schottky line receiver.

If you turn around and go to the other end, precision, the nastiest you'll probably specify is the LM311. When you want it, you've got it.

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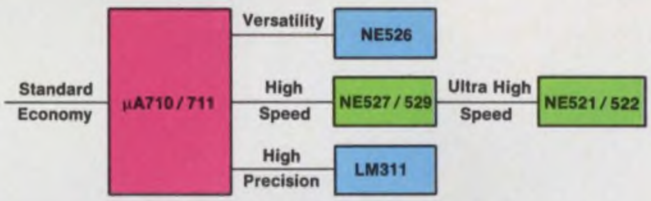

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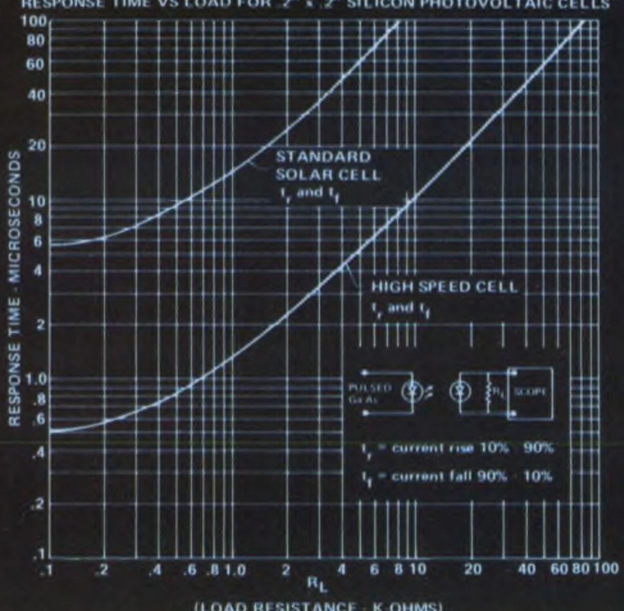

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INFORMATION RETRIEVAL NUMBER 18

8-k CCD memory chips due to replace discs

After repeated promises, the long-awaited charge-coupled-device (CCD) memory is about to become a reality. It will take the form of an 8-k memory chip designed for disc-replacement applications.

The chip is being designed by Bell-Northern Research, Ottawa, Canada, and according to Karl Mayer, the company's manager of silicon device development, it will contain 32 shift registers, each 256 bits long. The end of each shift register will be connected to charge-refreshing circuitry to regenerate the stored information.

The new memory chip is expected to become available in small quantities in September, but Bell-Northern is not interested in selling individual chips, Mayer says. It is looking for a partner to manufacture a CCD replacement for fixed-head disc memories.

Such a memory would be an order of magnitude faster than discs, Mayer reports. Since a 1-MHz clock will be used in the CCD memory and since each shift register is 256 bits long, the average acess time for the disc replacement will be 128 μs. This compares favorably with the 2 ms presently required for fixed-head discs.

As far as cost is concerned, Mayer notes that it should be about the same as that of a disc memory. He points out, however, that even if it is a little more expensive, it will still be viable so long as the cost is between two and four times less than main memory.

Tiny TV antenna has beam rotator

A miniaturized electronic TV antenna that incorporates a beam rotator and a new broadband traveling-wave ring antenna has been introduced by RCA. The antenna, which looks like a miniature flying saucer, is the result of a four-year development effort at the company's Laboratories in Princeton, N.J., and Deptford, N.J.

Previous similar antennas have used fixed, instead of rotating, elements (see "Small Active-Electronic Antenna Offers Big League Reception," ED No. 19, Aug. 5, 1971, p. 22).

The RCA unit, which is 21 inches in diameter and seven inches in depth, weighs but six pounds, including the rotator. According to Robert M. Wilson, manager of the engineering laboratory in Deptford, the antenna has been tested in winds up to 80 miles an hour. The unit, which lists for $99.95, is enclosed in a sealed plastic radome that protects the internal elements from the weather. It may be mounted indoors as well as outside, and it has a maximum range of 35 miles. The antenna was designed for use in metropolitan and suburban areas, which, according to RCA, contain some 73.5% of the nation's TV households.

Directional patterns of both the vhf and uhf sections are good, says Wilson. These patterns have high front-to-back ratios. To provide interference rejection, the vhf has a null depth of 30 dB and the uhf a depth of 25 dB.

The vhf antenna is a newly developed, broadband terminated traveling-wave ring with tuning slots. This antenna is in the form of a two-inch aluminum band that encircles a round, low-loss plastic foam platform in which an amplifier and the uhf antenna are embedded.

The output of the vhf antenna is boosted by a special transistor amplifier that has a 4.5-dB noise figure. The gain of this amplifier is tailored to complement the gain of the vhf antenna, so that at the amplifier output there is a uniform gain for all the vhf channels.

The uhf section is a seven-element linear array of flat aluminum elements. The output of this section is not amplified but is fed to a combining filter from which the vhf and uhf signals are fed to the set's coaxial cable.

The rotor controller uses a specially designed hand-held unit. In contrast with six or eight wires that would normally be required to control the motor and transmit directional indicator signals back down to the operator, the RCA control has but three wires in a shielded cable.

AF tests radio waves in 'whispering gallery'

In a hunt for improved propagation regions for military communications and the operation of detection systems, Air Force scientists positioned balloons 1000 miles apart at an altitude of 23 miles and tested the feasibility of propogating medium-frequency radio waves through the D layer of the ionosphere. Very low transmission losses and freedom from radio blackouts, particularly in the Arctic, resulted.

The new propagation mode occurred along the underside of the D layer, 37 miles above the earth's surface. The method was proposed originally by two researchers at the General Electric Laboratories in Syracuse, N.Y.—Len Humphrey and Clayton Roberts.

Referred to as the "D-layer Whispering Gallery" mode of transmission, the phenomena of radio waves traveling long distances inside the curved surface of the ionosphere produces an effect similar to the behavior of sound inside the dome of St. Paul's Cathedral in London, according to Dr. Gary Sales, a physicist at the Air Force Cambridge Research Laboratories in Bedford, Mass. The radio waves travel around the earth with very little attenuation, since they are held within a duct-like path by interactions with the ionosphere.

Dr. Sales and John Videberg of the Air Force Ionospheric Physics Laboratory in Bedford teamed with a ballooning expert, Frank Doherty of the Air Force Instrumentation

Laboratory, and the two GE researchers to carry out the experiment. Signals were sent well beyond the line of sight from a balloon over Chico, Calif., to a receiver in a balloon over Alamagordo, N.M., 1000 miles away. The received signals were telemetered to the ground for analysis.

Future experiments will be tried at a range of at least 2000 miles, Dr. Sales says, before any operational use of the concept is considered.

New TV setup allows programmed learning

Amid the rush to introduce a home video cartridge, disc or cassette player comes an entry with a new twist: a Super-8 film player that converts images and a magnetic sound track into standard television format and a keyboard-modem combination that allows the television set to become a display device for a time-shared remote computer. The computer and the film player can operate together for programmed learning applications.

Produced by Cassette Sciences Corp. of Los Angeles, the film player and the keyboard modem unit will each sell for less than $500 when placed on the market later this year.

Designed by Special Purpose Technology Corp. of Van Nuys, Calif., the film player accommodates up to 1200-foot cassettes or open reels of film for up to 60 minutes of playing time. According to Meier Sadowsky, president of Special Purpose Technology:

"The film player uses a small flying-spot scanner to detect the image on the film. The information then modulates an rf carrier, which is fed to the normal antenna terminals of the TV set."

The flying-spot scanner has an estimated life of 2000 hours and will cost about $20 to replace.

In a demonstration for ELECTRONIC DESIGN, a prototype film player showed disturbing vertical distortion and horizontal jitter. Color rendition was only fair, as was focus. Sadowsky contends that these problems will not exist on production models.

Dr. Wilbur H. Highleyman of Mini Data in Parsippany, N.J., a consultant on the computer terminal design, says the unit contains a standard teleprinter keyboard, an acoustic coupler with telephone cradle, a power supply, a character generator and a modem. The television screen provides an alphanumeric display medium for up to 16 lines of information with 64 characters per line.

Edward Gruskin, executive vice president of Cassette Sciences, notes that a 16-mm version of the film player will be available in mid-1974 and that both the film player and the terminal will be available on lease-purchase options as well as for direct purchase. Computer programming is in Basic, and Cassette Sciences will set up time-shared computer facilities in different parts of the country.

FM-cw radar detects atmospheric pressure

A frequency-modulated, continuous-wave radar has been built to make extremely high-resolution (1 meter) studies of atmospheric physics at distances as close as a few hundred meters. Traditionally FM-cw radars have been limited to less precise studies at long range only; they have been used in studies of the more distance ionosphere.

"This new second-generation FM-cw radar sounder is sensitive enough to examine in detail the refractive structure of the lower atmosphere—the first 6000 feet above the ground," says Juergen Richter, project manager for the radar at the Propagation Technology Div. of the Naval Electronics Laboratory Center in San Diego.

Also, Richter says, the radar can study the fine-scale structure of rain and the role of internal gravity waves in generating turbulence. It can detect air pollution, and it can be useful in the investigation of the dynamics of convection.

The Navy's sounder has already been checked out for one important atomospheric function: Alongside a laser radar, developed by Stanford Research Institute in Menlo Park, Calif., the sounder was used to detect and analyze clear-air turbulence, and to study the boundary layer and processes involved in the formation of low-level inversions.

Because of the radar's sensistivity, Richter says, the Dept. of Agriculture is interested in using it to study the flight patterns of insects.

The high sensitivity was achieved by using backward diodes instead of the usual i-f systems with their inherent noise limitations, Richter reports.

The high linearity was obtained by using a custom, YIG-tuned oscillator, built by Watkins-Johnson, that concentrates on the narrow operating band of frequencies between 2.8 to 3.0 GHz.

Waveguide coupler developed for OICs

One requirement for controlling and guiding light in optical integrated circuits (OICs) is the ability to confine the light to narrow channels or optical waveguides. An optical waveguide directional coupler, behaving very much like its microwave counterpart, has been produced by scientists in a joint research project of Hughes Research Laboratories, Malibu, Calif., and the California Institute of Technology in Pasadena.

The optical directional coupler consists of a series of parallel optical waveguide channels spaced to permit light energy to transfer from one channel to another. In this experimental coupler, which operates in the near-infrared, the parallel waveguides were formed by proton bombardment of the surface of a GaAs substrate. The bombardment increased the index of refraction of the guide region, creating the optical interface to guide the light energy.

Further development of this technique is expected to allow the coupling between waveguide channels to be controlled by an applied electric field—leading to the possibility of optical modulation and electrically controlled light multiplexing.

Dr. Robert G. Hunsberger, member of the Hughes technical staff and closely involved in this work says: "The ultimate goal of this project is to develop fully integrated monolithic optical circuits."

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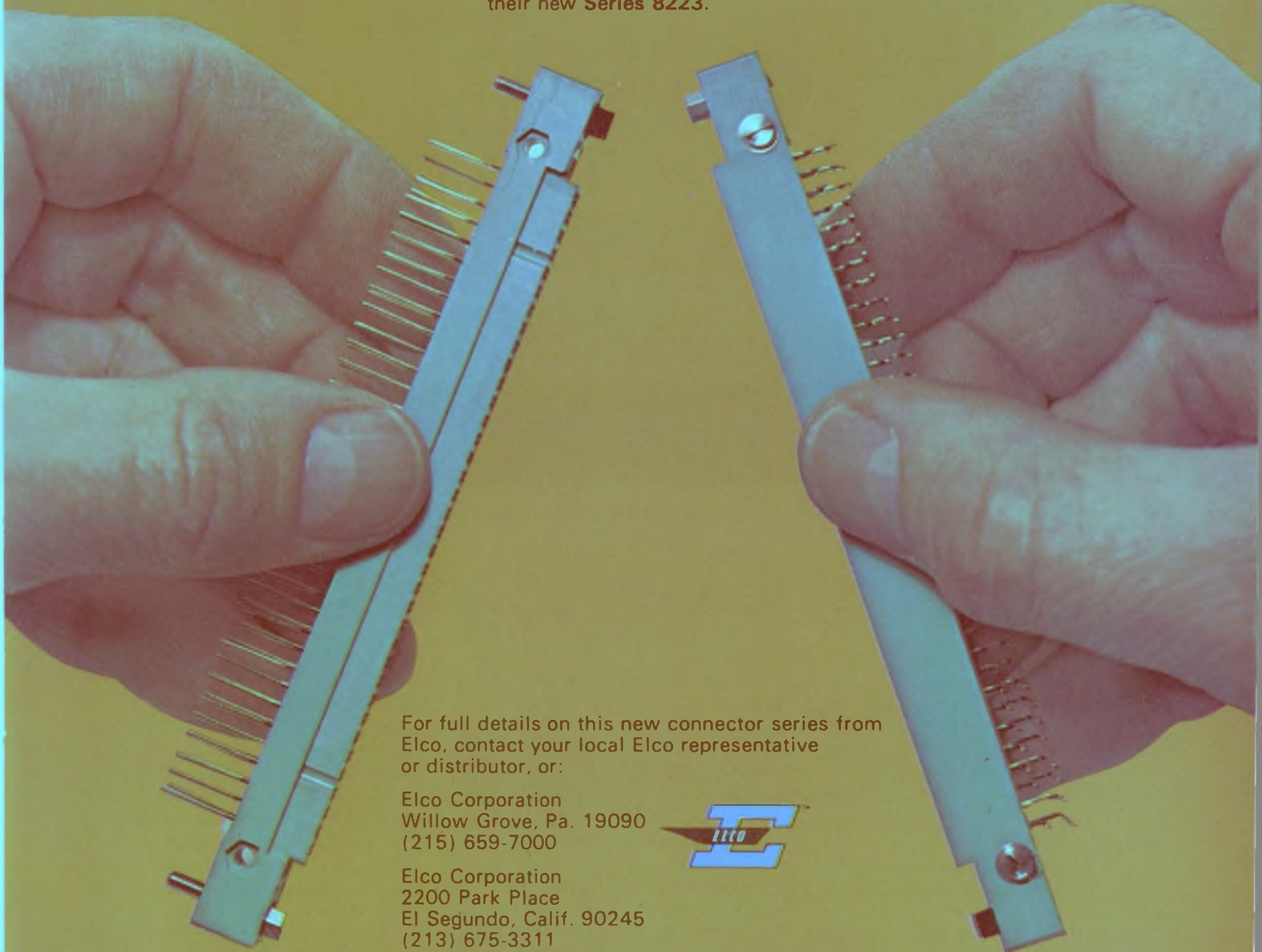

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INFORMATION RETRIEVAL NUMBER 19

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Nuclear power electronics: Industry with a long future

Article and Photographs by John F. Mason, Associate Editor

Commonwealth Edison's new plant at Zion, Ill., uses Westinghouse pressurized water reactors.

Designing electronic instrumentation and controls for nuclear reactor plants is both challenging and frustrating.

It's challenging to meet the nuclear power industry's stringent performance and safety demands. It's frustrating to satisfy a traditionally conservative and now apprehensive customer—the embattled electrical utility, watched like a hawk by the public and the highly cautious Atomic Energy Commission.

But it is rewarding to design the electronics for nuclear power. The industry is big, has just begun to move, and it has a long way to go.

Today 31 nuclear power plants are operating in the United States—a fact that many environmentalists probably don't know. They account for 16 million kW of power, or about 4% of all U.S. electrical production. There are 59 more nuclear plants under construction and 75 more on order.

By 1985 nuclear plants will provide 300 million kW of electrical power in the U.S.—32% of the total capacity estimated for that year—and by 1990, 500 million kW will be nuclear-generated—44% of the total estimated U.S. supply.

Overseas 68 nuclear power plants are already in operation, with hundreds on order. While foreign producers of electricity face the same fossil-fuel shortages that U.S. utilities do, they are not hampered by local environmentalists protesting the construction of more nuclear plants. As a result, the growth of foreign plants may prove to be more dramatic than domestic. Sales to this foreign market, which already represent 25% of U.S. shipments, are therefore expected to make considerable strides.

The action for the electronics industry is in three broad areas.

1. More accurate and more rugged sensors are needed for today's reactors and tomorrow's fast breeders for measuring conditions vital to the reactor's operation and also for plant and personnel safety. And sensors more resistant to heat and radiation must be developed for the fast breeder. Water reactors subject their in-core instrumentation to 700 F, while fast breeders will operate at 1500 F or even higher. And the neutron flux in the fast breeder will be a couple of orders of magnitude greater than in today's light water reactors.

2. Display concepts are changing quickly. Consoles are beginning to emerge that use CRTs for calling up readings and reports. These TV-like screens will eventually replace the long walls of meters and dials that are standard equipment in all nuclear plants operating in the U.S. today (see cover and photos on p. 28).

3. The use of data processing in nuclear plants is growing. While automation, or computer-control, is moving in, it is so gradual and so piecemeal that few are aware of the change.

Europe moves ahead

Computerized control of nuclear reactors is *not* being used in the United States, as it is in Canada and Britain, because both the AEC and U.S. utilities are still wary of letting computers initiate vital operations—like controlling fuel rods—automatically. Both the AEC and the utilities in this country favor letting the computers monitor the performance and display it for action by humans.

Systems Engineering Laboratories of Fort Lauderdale, Fla., installed a computer system in a 250-megawatt, boiling-water reactor station in Quebec that handles all the Canadian plant's critical functions. But in the U.S., the average utilities engineer says: "Computers are good for monitoring and logging, but a man must control the reactor."

The number of things to monitor in a nuclear reactor is rapidly growing. For the liquid-metal fast breeder now being designed jointly by the AEC and public and private utilities in a Chicago-based organization called the Project Management Corp., "there'll be 2000 measurements or conditions to monitor, as opposed to 400 to 500 in today's water plants," says W.J. Shewsky, the corporation's general manager.

The computer will keep an eye on these conditions in the breeder, but the plans at this stage of the game still don't yield any authority to the computer. Eventually the sheer volume of tasks the operator must perform will undoubtedly erode this position and allow the computer to do more, some engineers believe.

General Electric's very advanced control-room console, called Nuclenet, gets closer to automation. "Nuclenet is GE's effort to move out a little bit into plant control," says David J. Crowley, a marketing representative in GE's Nuclear Energy Div., Campbell, Calif.

The computer that feeds into the

A computer displays diagnostic data from thermocouples on these giant pumps at the Commonwealth Edison plant in Zion. The pumps pull in 1.5-million gallons of water a minute from Lake Michigan to condense steam.

Hundreds of electronic sensors feed signals to these accumulator tanks of nitrogen. If conditions call for it, one or all of the tanks will release gas to insert the fuel rods into the core and shut down the reactor.

Control room at Commonwealth Edison's Dresden reactor in Morris, Ill., was built by General Electric. It displays data from sensors throughout the plant.

For the future, GE's Nuclenet 1000 control complex uses computer-driven CRTs to replace the hundreds of display meters that now line lohg control-room walls.

Remote radiation monitors contain sodium-iodide crystals and photomultiplier tubes. Gulf Electronic Systems, San Diego, builds them.

console makes a large number of complicated calculations centering on the performance of the fuel and the positioning of the rods, Crowley says. "If the operator has 100 or so rods to maneuver, all of different configurations, the computer will tell him what sequence he must follow in moving them up or down. If he deviates from the right sequence, the computer won't permit him to proceed until he moves the right one," he explains.

Use of the computer by Gulf Energy and Environmental Systems, a manufacturer of reactors and nuclear-power instrumentation, is also strictly an aid to the operator at this time, says Harold A. Thomas, manager of the Nuclear Instrumentation and Control Dept. in San Diego. Information is received through buffers, so the computer will not reflect data or instructions back into the system.

General Electric forecasts that by 1980 the computer will have as-

The world's most expensive hot-water maker

Nuclear reactors have been called the most elaborate and expensive water heaters in the world. Each takes up to eight years to build and costs $500 for each kilowatt of electrical production capability, or $500-million for a 1-million-kW plant.

The reactor and instrumentation portion of the cost is approximately 20%. And as automation increases, this percentage will, too.

Like electrical utilities run by fossil fuel—oil, gas or coal—fission-produced heat makes steam to turn a turbine-generator, which produces electricity. But nuclear fuel has definite advantages over fossil fuel: it's cheaper, it's compact and it creates no pollution or bulk combustion products. One ton of uranium has the same energy potential as 3 million tons of coal. And tomorrow's technology promises an even more remarkable ratio.

On the minus side, nuclear plants being built today eject more heated water into nearby rivers or lakes than fossil plants do, and this could harm the ecology. Future plants, however —such as the breeder—will not emit as much heated water.

Today's reactors also produce toxic waste, but the amount is small, and since it is packed and buried, nuclear specialists say it is no problem. Future breeder reactors will have even less waste to dispose of. Though not quite a perpetual-motion machine, a fast breeder uses fuel left over by conventional reactors and by-products from these facilities. It can also produce more fuel than it consumes.

Development of the fast-breeder reactor has the highest priority of any Atomic Energy Commission or nuclear industry project in this decade. Sponsoring a two-pronged approach, the AEC, under a contract with Westinghouse, is constructing a fast flux test facility near Richland, Wash. A light-metal, fast-breeder reactor demonstration plant is being designed and will be constructed near Oak Ridge, Tenn., by a joint effort of private and public utilities and the AEC.

Dominating the domestic market at this time are two types of nuclear plants: boiling-water reactors (BWR), built by General Electric, and pressurized-water reactors (PWR), manufactured by Westinghouse Electric, Combustion Engineering and Babcock & Wilcox.

A contender for the commercial market, with a demonstration plant already operational and several on order, is the high-temperature gas-cooled reactor (HTGR), built by Gulf Energy and Environmental Systems.

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INFORMATION RETRIEVAL NUMBER 20

Waste disposal panel at the Commonwealth Edison plant in Zion collects data via Geiger-Mueller sensors from radioactive liquids throughout the plant. If preset limits are exceeded, the panel halts the operation.

Electrical penetration conductors at Gulf take data from sensors inside a reactor's core through the containment wall to a display.

sumed a greater share of the noncritical control activities. Only those parameters that call for human judgment and analysis will require the operator's direct attention.

An area where automatic control is used, although the nuclear industry doesn't call it that—the word "control" is reserved exclu-

Printed-circuit board triggers an alarm when a seismic device settles on its newly installed base.

sively for control of the reactor—is in safety or protection devices. More than 20 kinds of sensors—in the reactor core, outside it, or anywhere in the plant—can automatically shut down the plant, or a part of it, at the drop or rise of a needle. While these channels do not pass through the computer, they are logged and displayed by it on either a console or on a meter.

Gulf, for example, uses a moisture monitor tripping device that will shut down a portion of a plant if 1000 parts of water are present in one-million parts of gas. This event will be duly reported to the computer, but the shutdown is done by simple hardwire logic.

Sensors in nuclear plants carry out a wide variety of assignments and function in extreme environments. The all-important condition—moment by moment—of the nuclear fuel inside the core is measured by sensors that are actually inside the fuel-containment vessel and also by sensors just outside. Enough neutron flux leaks through the containment to make sensors outside the vessel useful in determining what's going on inside.

To protect the plant and its personnel, a radiation-monitoring system collects radiation level data from sensors placed throughout the facility. If these levels exceed predetermined values, alarms are set off.

A typical channel in Westinghouse's multichannel radiation-monitoring system contains a radiation detector, a check source and an impedance-matching network mounted at the sampling point; a remote indicator and an annunciator alarm mounted on, or near, the detector assembly; and a computer/indicator, power supplies and controls in a control console.

Seven basic types of detectors are used: an air-particle sensor, in-line and off-line radioactive gas detectors, in-line and off-line liquid-sample monitors, area monitors and a stack-gas detector.

All seven use either a Geiger-Mueller tube or a scintillation detector.

Wanted: new sensor designs

Improvement in many sensors is needed.

"In protective devices where speed is the No. 1 criterion, we've gone about as far as we can go with electromechanical relays and are moving into solid state," says Jim Maley, systems station electrical engineer at Commonwealth Edison's headquarters in Chicago.

"We need electronic devices that are more temperature-resistant than those available—and also less sensitive to electromechanical and electromagnetic noise.

"We would like," Maley continues, "devices to monitor and to anticipate problems. We'd like to monitor a switching operation before, during and afterwards—the current, voltage, magnitude and frequencies printed out on tape."

When New York City had its big blackout, it took a week before they had details on what had happened sufficiently to understand it.

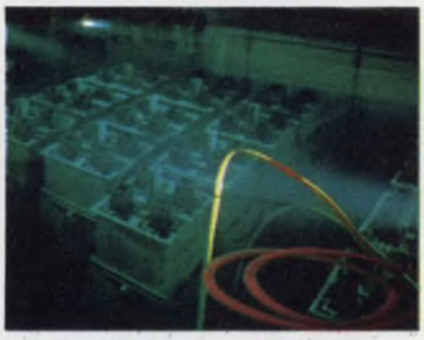
The delicate process of revitalizing used nuclear fuel is displayed in this control room in General Electric's Midwest Fuel Recovery Plant, Morris, Ill. A GE 4020 process computer logs the operation but does not control it.

Gulf's present high-temperature, gas-cooled reactors don't use in-core neutron detectors, but its new systems will. The company is consequently looking for detectors that will hold up under 1500 F heat.

"We're starting with a self-powered detector which has been used on pressurized water reactors at much lower temperatures, reports Gulf's Harold. A. Thomas. "With some improved design and a lot of qualification testing, we hope to qualify this detector for higher temperature work. The detector consists of an Inconel outer jacket, a magnesium-oxide insulation and a central emitter wire of rhodium. The rhodium absorbs neutrons and, as a result, emits beta rays, which are high-energy electrons. When exposed to neutron flux, this type emitter puts out a beta ray current that is proportional to the neutron flux to which it is exposed."

A number of new sensors are under development at the Argonne (Ill.) National Laboratory. Acoustic sensors are being studied for several diagnostic applications. They may be useful for detecting disturbances in coolant flow or in the movement of components inside the vessel.

Argonne determined that the sensors could be placed either on top of acoustic waveguides extending above the reactor core or immersed in the coolant near the core.



"Hot" fuel casks wait in distilled water in the cask unloading pool while their fuel is reprocessed.

Immersed sensors offer advantages of more frequency bandwidth at high and low frequencies, and they may discriminate more readily the acoustic emissions from boiling. But acoustic sensors that can produce a reliable output signal under gamma and neutron irradiation at temperatures up to 650 C are not commercially available. Therefore Argonne is designing one.

The laboratory looked at three types: capacitive, magnetostrictive and piezoelectric acoustic sensors. Piezoelectric won out because of its broad frequency response, which extends from the parallel capacitance-resistance leakage at the low cutoff frequency to the crystal-resonance frequency. The crystals were made of lithium niobate, which is resistant to radiation.

Argonne is also working on a way to measure sodium flow in the core, where there is both high neutron flux and extreme temperature (1200 F). Electromagnetic devices have traditionally been used to measure flow; but "no magnet we know of will survive 1200 F very long," an Argonne researcher notes. "At 1000 F you might get a year's operation, but at 1200 F, only a month," he says.

An alternative that Argonne is examining is an eddy-current probe sensor. Basically the sensor consists of three closely spaced coaxial coils. The center coil is the primary, or excitation, coil. The two end secondary coils are connected, series opposing, as in a differential transformer. With these coils positioned in an axially flowing fluid stream, the ac flux developed by the primary is forced downstream, creating an unbalanced condition in the secondaries and producing a net differential voltage that is nearly proportional to flow velocity.

One problem with a sodium coolant is that it becomes radioactive, and emits a very high gamma flux. Pile-up of gamma pulses produces a noise background very similar to the neutron pulses the sensor must measure. More work on detectors and circuit design is needed to overcome this problem, Argonne designers say.

Not only do sensors suffer from intense heat and radiation but the long cables extending 35 to 50 feet from the sensors do, too. "Right now we're using Polyvinyl chloride, but the solution may be to insulate them with minerals," says an Argonne engineer. "Silica and magnesia are both candidates. Part of the problem is to eliminate their impurities."

General Electric predicts that two important innovations will become standard in the years ahead. Reactor control rooms will be so designed that portions of them can be used at all times as simulators. This will eliminate the need for the elaborate and costly trainer installations now used by all utilities today to train personnel.

A second trend—utilizing a service that GE already offers—is the delivery of prefabricated control rooms to customers. ■■

Bell Labs' new thin-film hybrid may be most complex ever built

What is said to be one of the most complex thin-film hybrid circuits ever designed—incorporating no less than five manufacturing techniques—has been built at Bell Laboratories, Naperville, Ill.

The circuit is a wideband switching network that replaces an existing switching array and separate buffering and control circuits.

Four versions of the circuit, all with the same operating characteristics, were made. Differing mainly in the type of capacitors used, they involved the following:

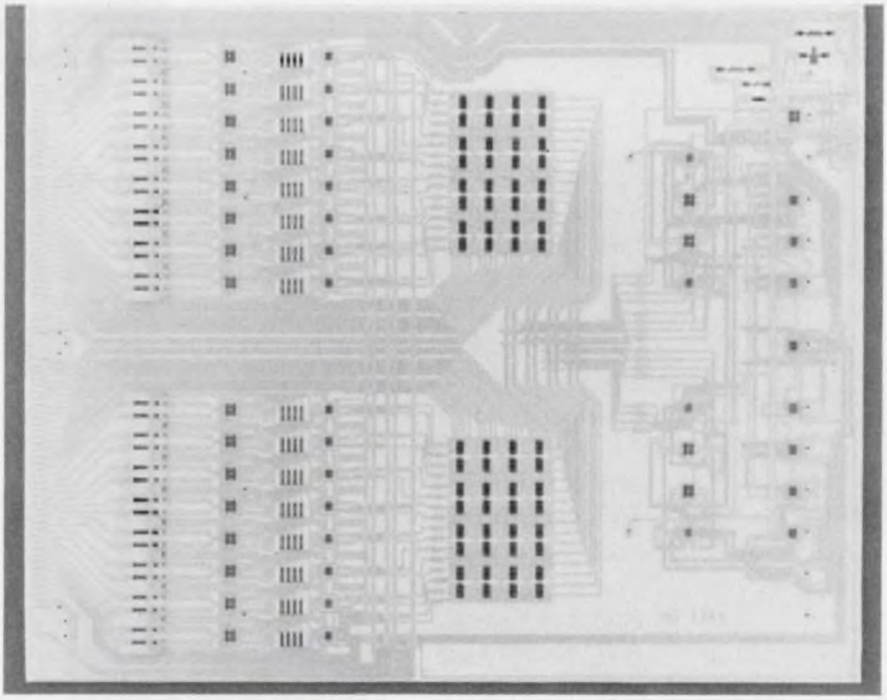
- Option 1—An anodized beta-tantalum capacitor dielectric formed on the main substrate.
- Option 2—Anodized tantalum nitride dielectric capacitors formed on the main substrate.
- Option 3—Capacitors formed on a separate glass substrate, which was bonded to the main substrate after resistors and crossovers were fabricated.
- Option 4—Discrete chip or thin-film capacitors individually installed on the main substrate.

In the first two versions, with integrated capacitors, four manufacturing processes were used in addition to simple thin-film interconnections. The processes include beam crossovers, thin-film capacitors, thin-film resistors and plated-through holes to the backplane.

Each of the four circuits was built on a 4-by-3.25-inch ceramic main substrate. Each contains a total of 32 capacitors, 101 resistors and 113 beam-lead ICs. The circuitry consists of a 256-by-256 crosspoint switch matrix and buffering and control elements.

Thomas E. Brady, who, along with David K. Hindermann, was responsible for designing the IC, says: "This IC is the most complex circuit ever conceived at this installation. It replaces three separate chips in a switching application under development here at Bell Laboratories."

Explaining why four versions of the same circuit were developed, Brady notes: "Often the capacitor choice in a circuit is limited by leakage, capacitance or matching requirements. In this case we could take practically any approach, since the capacitors were small and the leakage values not particularly critical. We used this opportunity to compare the fabrication problems, costs and yields using several different approaches."



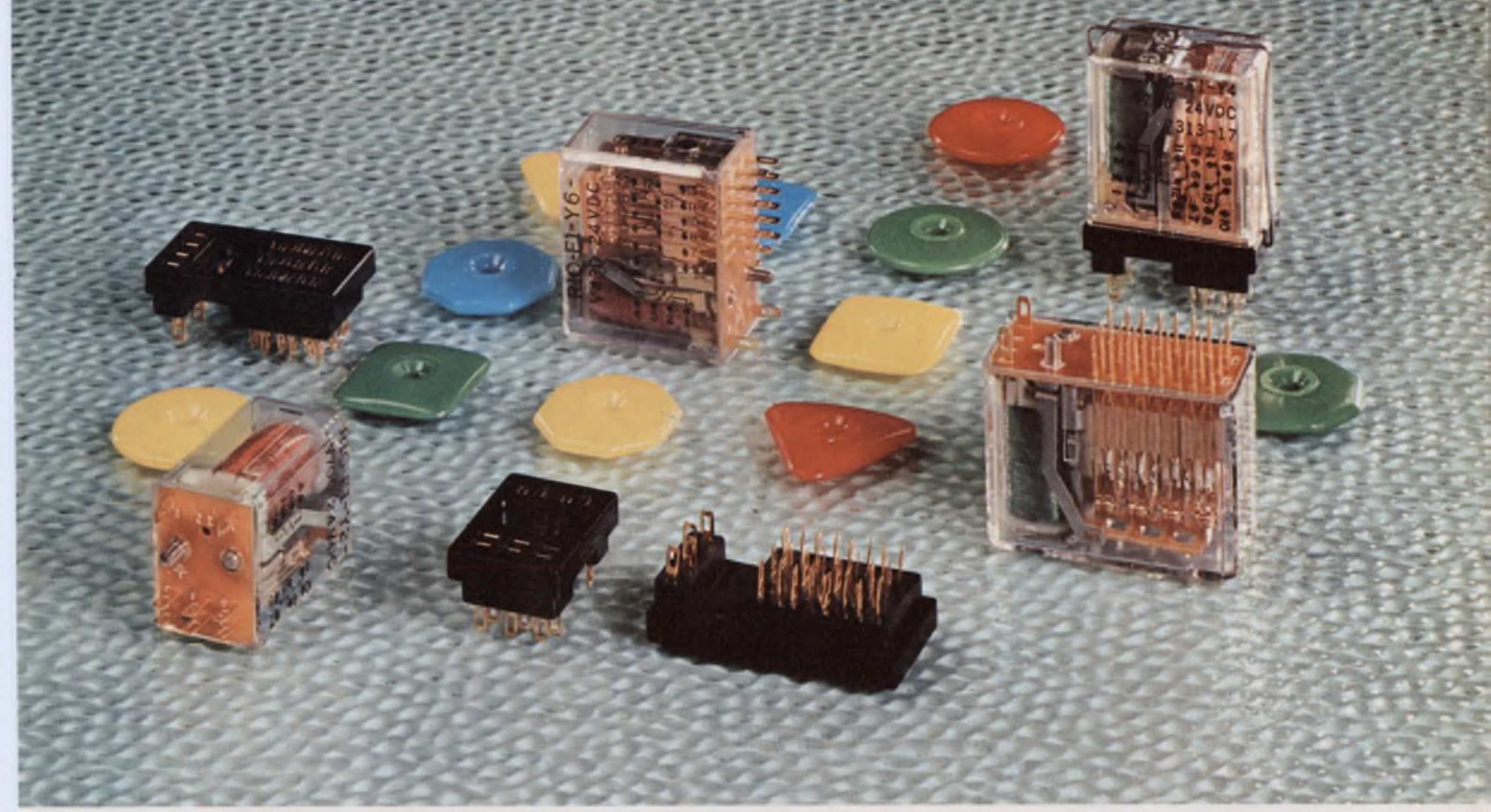
Complex thin-film circuit from Bell Labs contains 32 thin-film capacitors, 101 resistors and 113 beam-lead ICs on a 4-by-3.25-inch ceramic substrate.

Parallel processing favored

Options 1 and 2 have the most reliable connections from capacitor to circuit, since they don't require the comparatively unreliable thermocompression bonds, Hindermann explains. "Yet," he continues, "as it turns out, we lean in the direction of parallel processing—that is, building the capacitors on a separate substrate and bonding them to the main substrate [Option 3]. The problems with the more integrated options were that we couldn't fully test the resistor elements before completing the capacitors. The yields were reduced because we often found ourselves building good capacitors on bad circuits."

When asked if there were any special problems in making the circuits, both men replied no. "Actually," Hindermann says, "we had no big surprises of any kind. We have enough experience with the various techniques we used to foresee where the problems would crop up and were prepared with steps to prevent them." ■■

P&B's compact R10 relays help you solve more application problems than with any other relay.



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R10 relays can be ordered with Form A, B, C and D contacts and up to 8 Form C. Recognized by Underwriters Laboratories under file 42810. R10 relays have a continuous power dissipation of 2.2 watts maximum. Standard sensitivity is 125 milliwatts per pole (more sensitive units available on special order). Electrical life ranges from 100,000 to 100 million operations.

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INFORMATION RETRIEVAL NUMBER 23

LED-and-photodiode blend yields first reprogrammable logic array

A new type of programmable logic array can be quickly and easily reprogrammed—the first logic array to offer this capability—and it can handle up to 64 input variables.

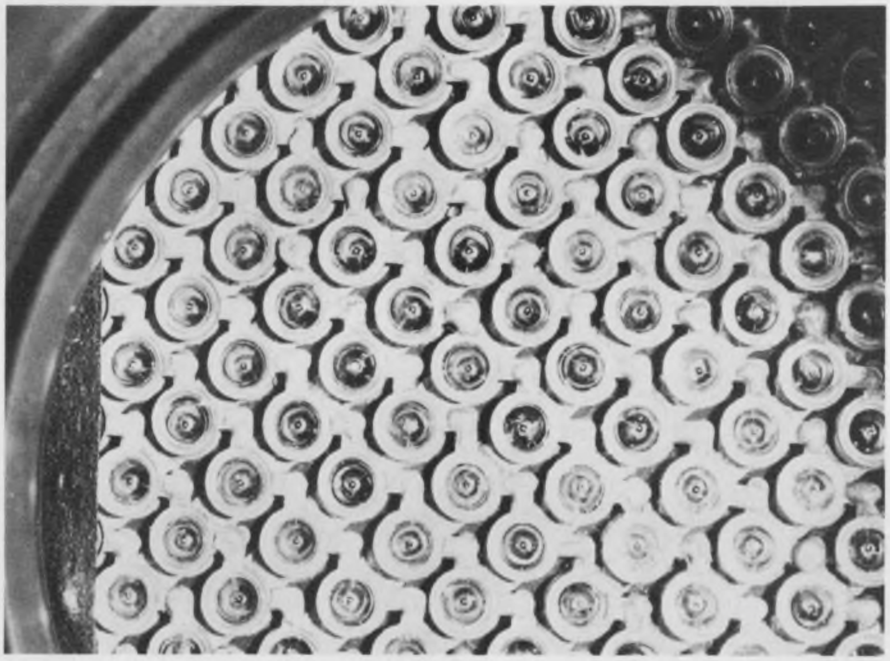
The new device, known as OLE (for optical logic element), costs more than a semiconductor programmable logic array—$1000 in OEM quantities—and it is considerably larger than IC devices. But these disadvantages are not serious problems, says its developer, the Opto-Logic Corp. of Long Beach, Calif.

According to Robert V. Morse, vice president of marketing, OLE is intended for applications where logic programs are frequently changed, such as in controllers and LSI testers; where complex logic is required but in quantities where it would not be economical to produce it as a semiconductor LSI; where design and production times are critical, and where breadboarding of IC logic functions is required.

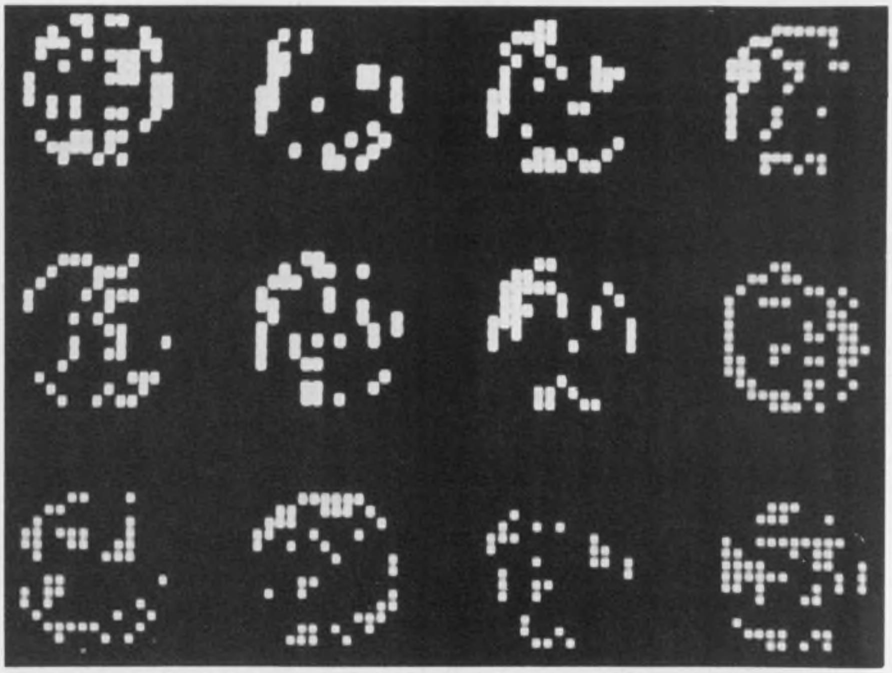
In breadboarding, a logic designer will usually set up a logic equation for his particular problem, convert that equation into a schematic diagram, wire up the phototype and then try it out. With OLE, says Morse, once the designer has the logic equation, he has the solution. He can go directly from the logic equation to the optical mask.

The OLE is especially valuable, notes Morse, because the canonical (simplest) form of the Boolean equation is implemented directly. This is not always the case with semiconductor programmable logic arrays. Because of their limited in-

Jules H. Gilder
Associate Editor



A light-emitting diode array is used to represent logic variables and their complements in the OLE—a reprogrammable logic array.



An optical mask, generated directly from the logic equation, is placed in front of each LED to determine which photodiodes become illuminated.

puts, it is often necessary to juggle the logic equation until the correct form is achieved, he explains.

Morse admits that semiconductor devices probably have an edge in applications requiring few changes and large quantities, but for the small run, it is much more economical to use OLÉ, he insists.

OLÉ consists of the following:

- An array of light-emitting diodes, used to represent logic variables and their complements.
- An array of light-sensitive PIN diodes, which act as optical OR gates for the logic variables.
- A removable optical mask that determines the light paths from the LED array to the photodiode array.

Because OLÉ can handle up to 64 input variables—more than three times the total that present ICs can—very large systems of Boolean logic equations, involving tens or even hundreds of input variables, can be solved simultaneously in less than 100 ns, Morse says.

Operation explained

In describing the operation of OLÉ, Morse explains that light from a particular diode is directed to an output sensor diode by the optical mask. Each sensor diode represents a term in the Boolean logic equation. Thus in an equation with two terms and 17 variables, there would be two photodiodes and 34 LEDs (representing the variables and their complements).

If a particular variable is included in a term, he continues, there will be a translucent area in the mask that will direct light from the LED representing that variable to the photodiode representing the term. The output of each LED is capable of illuminating any or all of the photodiodes.

To emphasize the capacity of OLÉ for solving logic equations, Morse points out that one device can replace up to 5000 three-input gates.

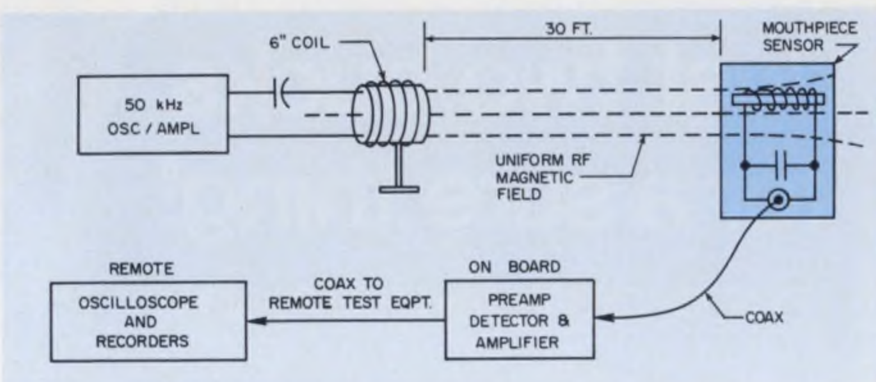
The Opto-Logic vice president also notes that the company can produce a device with a 1-k LED array. "It could handle up to 512 input variables with their complements. I don't know of any system in existence today that uses that many," Morse says. ■■

A reference axis without optics? Rf coil's magnetic field provides it

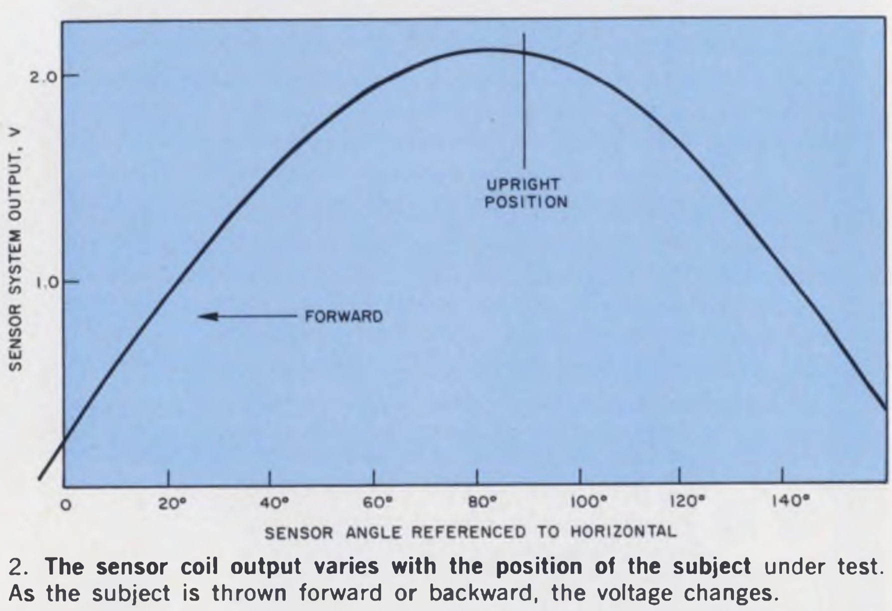
How do you establish an axis in space without using optical means from which a measure of relative angular motion can be sensed?

Researchers at the Dept. of Transportation System Center in Cambridge, Mass., were faced with that problem in measuring the forward rotational motion of the head and torso during crash decelerations when testing restraint systems for autos. A novel technique invented by two department researchers—Dr. Joseph L. Horner and Gordon R. Plank—uses as an axis in space: the axis of a 50-kHz magnetic field produced by a six-inch, multi-turn coil. This coil was mounted some 30 feet away from, but level with, the head of the test dummy (Fig. 1).

Jim McDermott
Eastern Editor



1. **The angle between the uniform rf magnetic field** of the six-inch coil and the axis of the sensor coil produces a signal related to that angle.



2. **The sensor coil output varies with the position of the subject** under test. As the subject is thrown forward or backward, the voltage changes.

The motion sensor, a pickup coil, was mounted on the dummy's head. The coil is typically an unshielded ferrite-core rf choke, which, together with a capacitor, is cast in a small plastic cube less than a half-inch on a side.

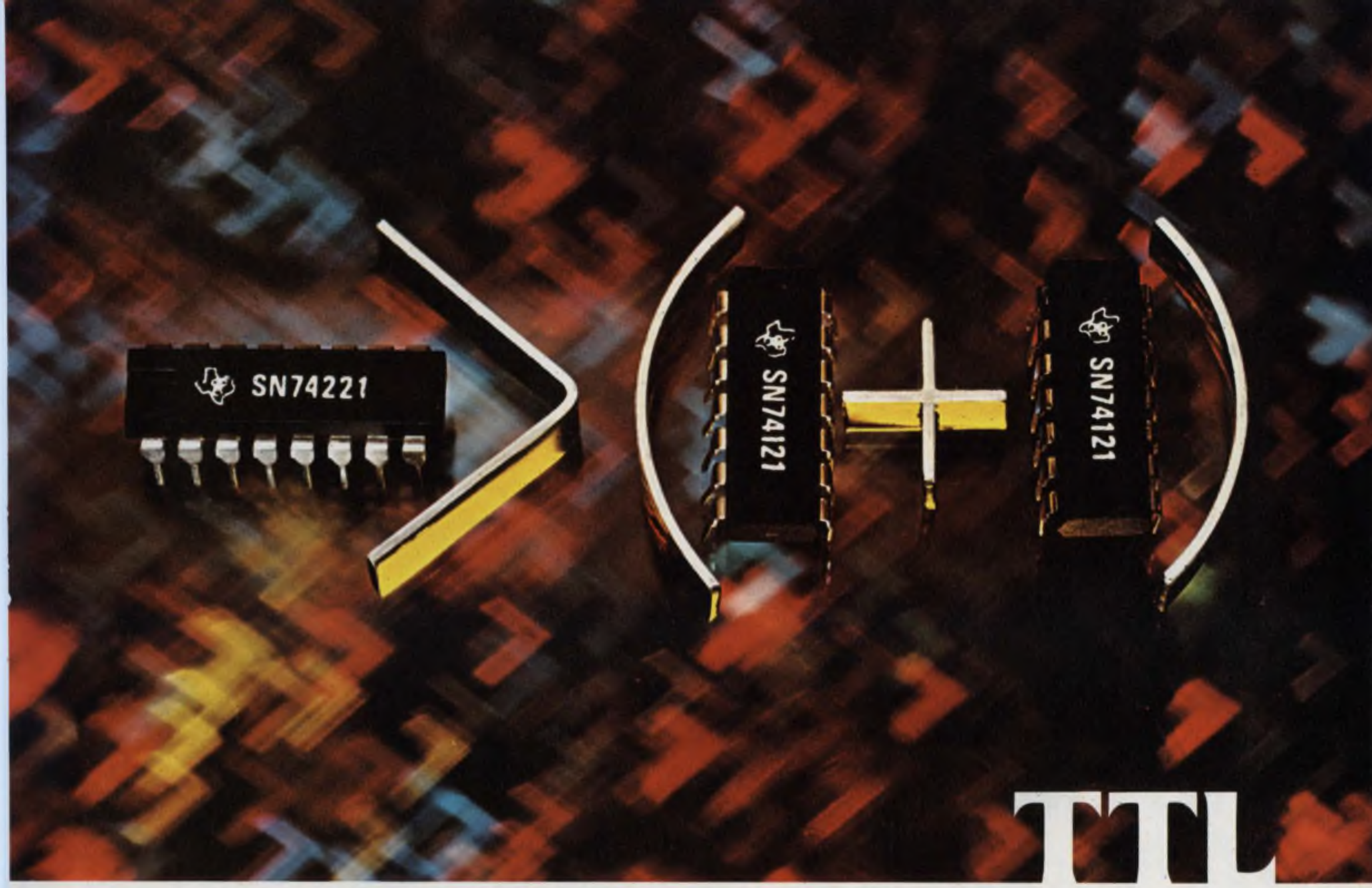
The motion of the test dummy during deceleration produced an rf signal across the pickup coil terminals (Fig. 2). This signal varied as the position of the dummy's head changed with respect to the axis of the transmitting coil.

Plank explains that the rotational, or forward-pitching, motion of the head and torso—as opposed to the purely forward linear motion—is primarily responsible for injuries to these regions. Such motion is difficult to measure with high-speed cameras or today's linear devices, he points out. A principal objection to accelerometers, he notes, is that they are heavy enough to change the dynamics of the head and torso, if attached there.

In the developmental system, 117 turns of No. 22 wire are wound on the six-inch transmitting coil form. The transmitting coil, in series resonance with a capacitor, develops about 10 kV across itself, causing very high circulating currents. These are sufficient to produce a relatively constant field that appears, at a distance, to be coming from infinity.

"This field," Plank says, "is fairly linear within plus or minus 5 degrees of the axis."

In a typical case, if the pickup coil inductance is 2200 μH and its capacitor is 4300 pF the 3-dB bandwidth is 3 kHz. In tests, with 30 feet between the transmitter and receiver coils, the peak-to-peak sensor output was 5 mV. ■■



Greater stability in a dual one-shot.

TI's new 54/74221 puts two 54/74121's in a single package.

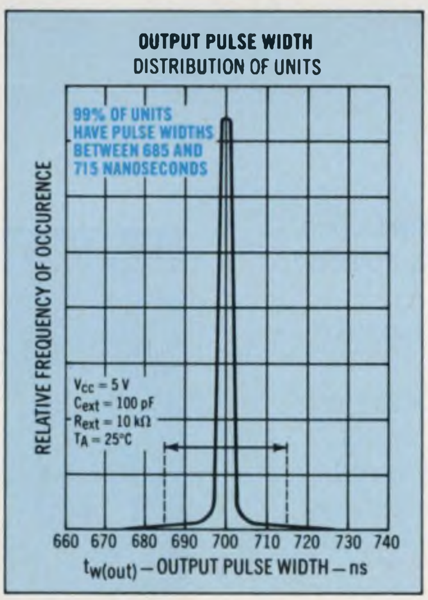
Few IC functions are as popular as the 54/74121. The industry's standard for high stability one-shots.

Now there's a new device that combines the high stability of the 54/74121 single one-shot with the pin-out of the 54/74123 dual one-shot—and outperforms them both. The 54/74221.

It's brand new. It's available in quantity. And it's from TI.

The 54/74221 features an output pulse programmable from 40 nanoseconds to 28 seconds. You can trigger it from either positive or negative going input transitions with complementary outputs available from each one-shot.

The 54/74221 has stable, jitter-free operation even in high noise environments, thanks to the Schmitt-trigger input.



Plus. The 54/74221 has direct overriding clears to terminate output pulses upon command.

If you've been attracted to the performance of the single 54/74121, but disappointed by existing dual one-shots, then the 54/74221 may be just what you're looking for.

Order SN54/74221 from your local authorized TI distributor or directly from TI. For data sheets, specify by type number and write: Texas Instruments Incorporated, P. O. Box 5012, M/S 308, Dallas, Texas 75222.

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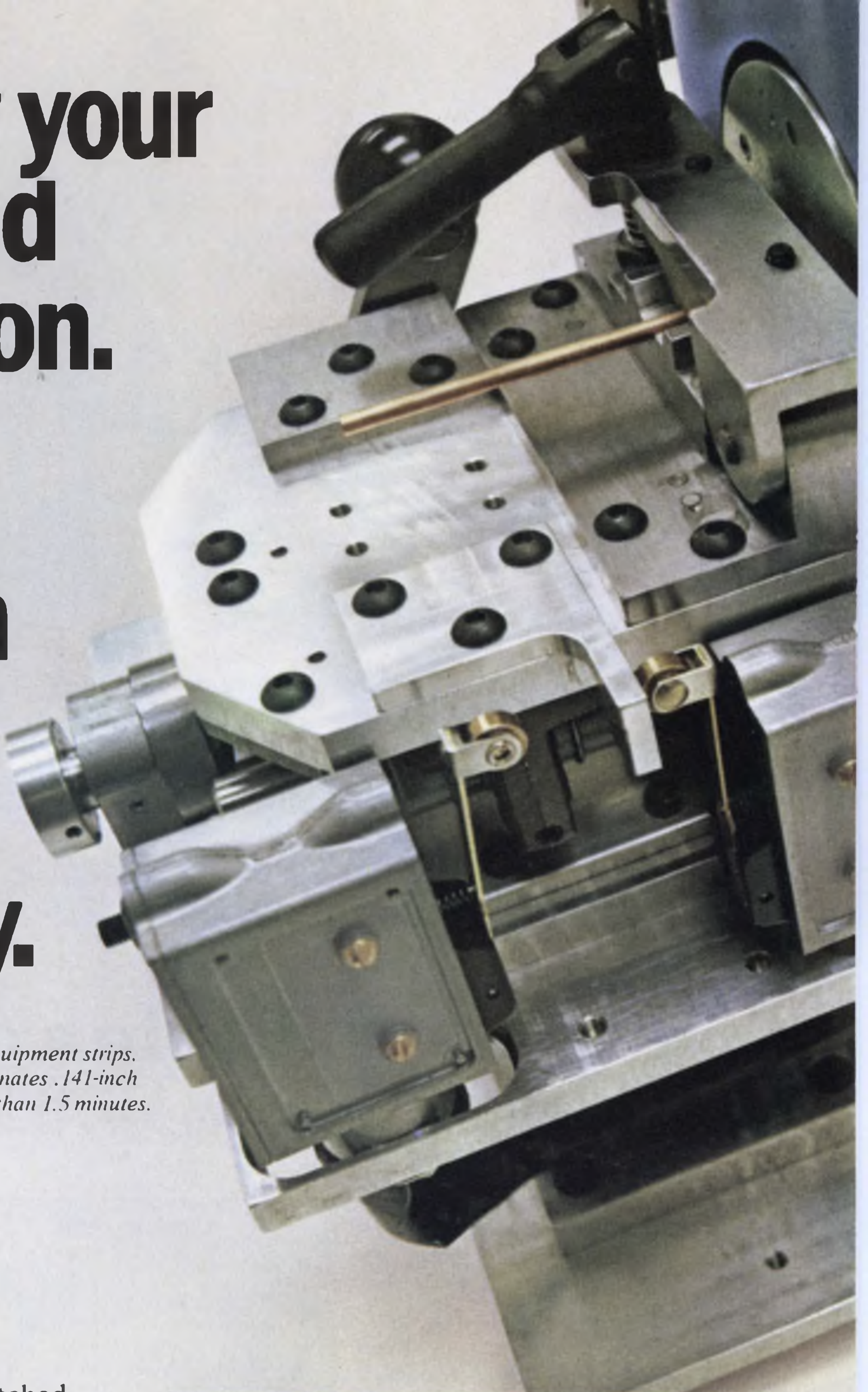

Semiautomatic application equipment strips, points and terminates .141-inch semirigid cable in less than 1.5 minutes.

AMP Moved it.

With solderless connectors and matched application tooling. And application equipment which strips, points and terminates SMA semirigid cable in less time than it used to take just to strip it.

We call it the Semiautomatic Cable Prep Machine. You'll call it one of the most useful tools you ever used, in time and money saved. And in neater, more reliable coax terminations. Without nicks or cold joints.

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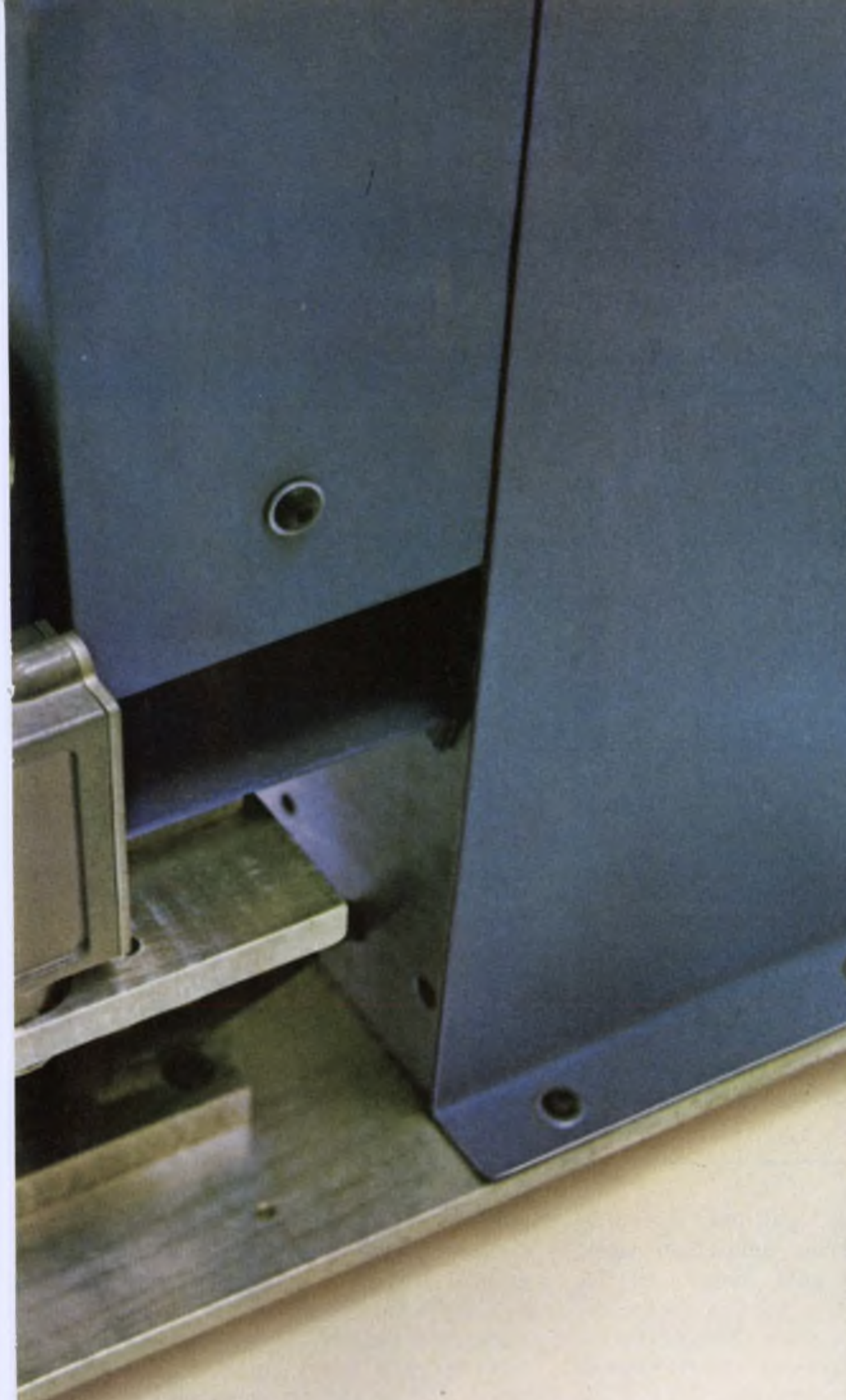

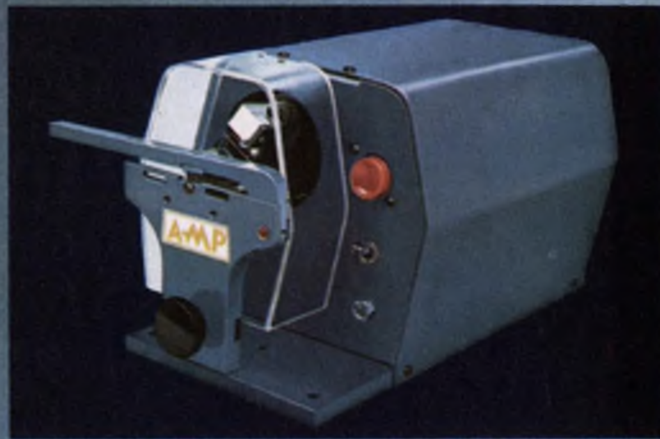

The AMP Coaxial Cable Stripping Machine provides a fast, low-cost and reliable way to prepare coax for crimp termination to AMP contacts and connectors.

For RF cable, we have SMA, SMC, BNC, TNC and N Series coax connectors and tooling. All of which are approved to MIL-C-39012.

For multiple connectors, our miniature and subminiature contacts are available for use with a variety of multiple-position connectors.

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In addition to saving time, crimp termination assures excellent RF characteristics ...broadband performance, low VSWR and excellent impedance matching. Reliability is high, too, with cable retention well in excess of MIL spec values. Characteristics are repeatable even with unskilled operators, because of precision-matched tooling. AMP crimp-type connectors are fully intermateable with solder-types.

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For more information on standard coax, circle Reader Service Number 211.
For SMA, circle Reader Service Number 212.

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technology abroad

A new process for producing thin magnetic monocrystalline layers with a very small number of imperfections has been developed at Philips Research Laboratories, the Netherlands, for application to magnetic bubble technology. The process, called predipping, resembles the dipping process used to grow epitaxial magnetic layers. The substrate is immersed in a molten salt flux in which substrate constituents have been dissolved. In this molten flux a thin layer of the substrate dissolves. Lowering the bath temperature slightly causes a new, near-perfect layer of substrate material to be deposited. A high-quality magnetic layer can then be grown epitaxially on this surface. **CHECK NO. 441**

The layout of microwave printed circuits and the presentation of drawings for the PC masks are speeded through use of a computer technique developed at Britain's Mullard Research Laboratories. The microwave circuit can be specified in terms of transmission lines of certain lengths and widths, which may be straight lines or arcs of circles, plus T-junctions. The designer makes up a data list specifying the pattern in terms of a starting point, followed by basic drawing elements of the required length and width. The computer attaches these to the starting point in correct order, builds up the pattern and produces a scale drawing plus a tape for a numerically controlled mask-cutting machine. **CHECK NO. 442**

Silicon and gallium arsenide Schottky-barrier field-effect transistors with gate lengths of 0.5 μm, have been fabricated by researchers at IBM's laboratories in Zurich, Switzerland. Conventional device technology was used, with very close control of the fabrication processes. The small gates are reported to have improved frequency response. At 10 GHz, the maximum available gain is 5.9 dB for silicon and 12.8 dB for gallium arsenide, with corresponding noise figures of 5.8 dB and 3.7 dB. These properties show a significant improvement over 1-μm gate devices. The 0.5-μm devices have a lower input capacitance and a higher transconductance, simplifying the design of broadband matching networks. The low noise figure of the gallium-arsenide device makes it attractive for low-noise applications.

CHECK NO. 443

A high-speed electro-optic modulator based on the use of an electro-optically controlled phase diffraction grating has been developed at University College, London. By shaping the phase front by "blazing" the diffraction grating, researchers found it is possible to direct most of the beam power into a high diffraction order, which makes the device suitable for multiport switching applications. The modulator uses a lithium niobate crystal as the active element, with interdigital electrode structures etched on its surface to act as the grating. The deflector should be useful in thin-film optical circuits, and its switching time should be less than 1 ns.

CHECK NO. 444

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Value and reliability are two important reasons why the Fluke 8000A has become the most popular digital multimeter ever and the standard of excellence in the low cost field.

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washington report

Heather M. David
Washington Bureau

FAA to buy interim microwave landing system

Pressure for improved aircraft landing aids has resulted in a decision by the Federal Aviation Administration to buy an interim standard microwave landing system while the agency awaits development of a more advanced system. The FAA asked manufacturers for system descriptions for evaluation. Meanwhile the agency will proceed, as planned, on its advanced development program and will make a choice next spring between doppler scanning and conventional beam scanning for the eventual FAA Defense Dept. universal microwave landing system. The Air Force is to receive two prototype models in March, 1975, for test and evaluation.

Survivable satellite stressed

The Air Force is working on advanced elements of a survivable communications satellite system, an effort that has been spurred recently by transmission problems with the Defense Communications Satellites now in orbit. Current work on the proposed "Survivsat" includes development of subsystems in the optical and advanced microwave areas and development of an advanced microwave terminal. The Pentagon is asking for funds to build the advanced terminal and test it with an experimental communication satellite in about two years.

In the meantime, the Air Force is pushing efforts to get reliable communications capability between its top commanders and its bomber force. Small uhf transponders will be installed on a number of DOD satellites to act as backup communicators in case of a failure in the Navy's Fleet Satellite Communications System, which will also be used by the Air Force. Uhf terminals will be installed on B-52 and FB-111 bombers and on various support and command post aircraft.

Radio telescope funds

Proponents of the National Science Foundation's very-large-array radio telescope are lobbying hard in the Senate, hoping for a reversal of a House decision to delete the $10-million requested by the foundation to start construction of the facility. Several million dollars have already been spent for the project, which is estimated to have a total cost of about $80-million.

The installation, which would be near Sorroco, N.M., would consist of 27 dish-shaped radio telescopes, each 82 feet in diameter and each movable along three 13-mile arms of a Y-shaped layout of railroad tracks. The foundation says the project would give insight into the laws of gravity, the nature of gases between the galaxies and the origin of the universe. Selection of an antenna contractor was to have been made this fall.

Data-under-voice communications pressed

American Telephone and Telegraph Co. hopes to put in a digital communication system to link 96 cities across the nation by 1976, as a result of the Federal Communications Commission's approval of its proposal for a "data-under-voice" system. The system will use a now unused portion of the bandwidth on 4 and 6 GHz. The initial segment of the system, which could be operating in less than a year, would connect Boston, New York, Philadelphia, Washington, D.C., and Chicago.

Capital Capsules:

Employment of scientists and engineers in the aerospace industry is expected to drop 4.2% between December, 1972, and December, 1973, the Aerospace Industries Association of America estimates. Total employment for the industry, it says, will decline from 944,000 to 913,000 . . . The Electronic Industries Association's final figure for 1972 show that **the U.S. electronics market reached $29.4-billion**, a 6.8% increase over 1971. Communications and industrial products rose 9.4 percent, federal governments sales 2.8 percent, consumer products 19.8 percent . . . NASA's Goddard Space Flight Center in Greenbelt, Md., is **requesting proposals for design, fabrication and test of a new inertial reference assembly** for the international ultraviolet Explorer spacecraft project. . . The Naval Air Systems Command is **looking for R&D sources to do basic research on the use of thermoelectrics for cooling** semiconductor devices and packages. . . . The Naval Air Development Center, Warminster, Pa., is **looking for contractors to bid on the support contract to integrate systems for the advanced Light Airborne Multi-purpose System (LAMPS) helicopter program.** The contractor will help interface the LAMPS system with shipboard digital and analog systems. . . . The Dept. of Health, Education and Welfare will buy **100 satellite TV receivers** from Westinghouse Electric Corp., Baltimore, to be used for demonstrations with the NASA experimental communications satellite ATS-F. . . . **An alarm system, consisting of pen-sized transmitters that generate an ultrasonic signal,** has been developed from technology developed by Jet Propulsion Laboratory in ultrasonic sterilization of spacecraft exteriors. . . . **The General Accounting Office has asked Congress to empower it to subpoena contractors to get details of negotiated contracts and subcontract records** and to give the Comptroller General authority to make studies of the profits of Government contractors and subcontractors. . . . **The military communications market will remain between $400-million and $500-million during the remainder of the 1970s** but will witness the onset of major technological changes during that period, according to a Frost & Sullivan analysis of hearings by the House Congressional Special Subcommittee on Defense Communications. Because most field tactical communications equipment is obsolete, the emphasis will turn to communications satellites and multimode, multiapplication radios.

“Scotchflex” Flat Cable Connector System makes 50 connections at a time.

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Build assembly cost savings into your electronics package with "Scotchflex" flat cable and connectors. These fast, simple systems make simultaneous multiple connections in seconds without stripping or soldering. Equipment investment is minimal; there's no need for special training. The inexpensive assembly press, shown above, crimps connections tightly, operates easily and assures error free wiring.

Reliability is built in, too, with "Scotchflex" interconnects. Inside of connector bodies, unique U-contacts strip through flat cable insulation, grip each conductor for dependable gas-tight connections.

"Scotchflex" offers you design freedom, with a wide choice of cable and connectors. From off-the-shelf stock you can choose: 14 to 50-conductor cables. Connectors to interface with standard DIP sockets, wrap posts on standard grid patterns, printed circuit boards. Headers for de-pluggable connection between cable jumpers and PCB. Custom assemblies are also available on request.

For more information, write Dept. EAH-1, 3M Center, St. Paul, Minn. 55101.

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INFORMATION RETRIEVAL NUMBER 30

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General Electric's
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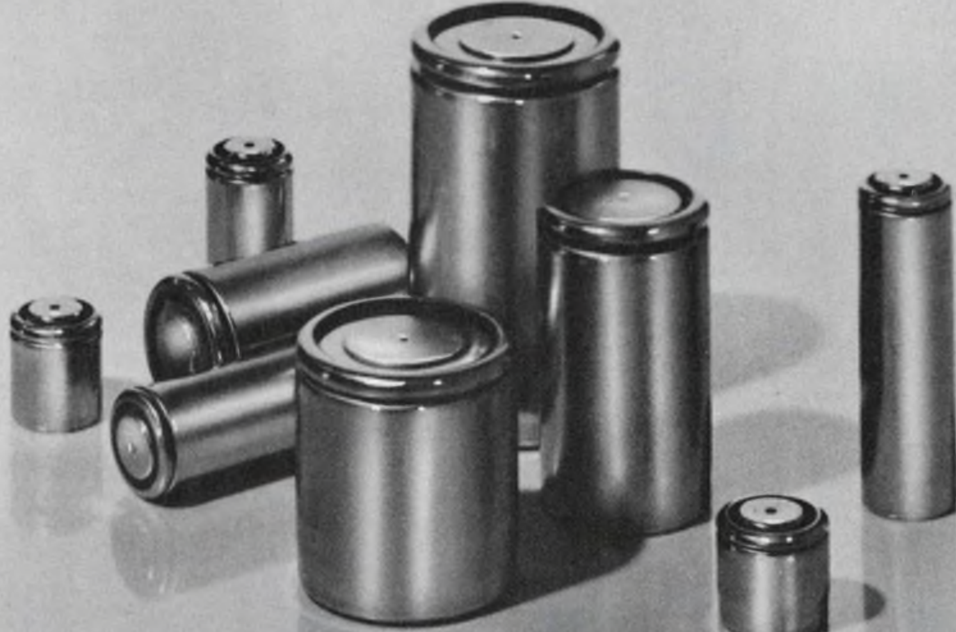

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When charged at room temperature for 15 minutes with an approved charger, General Electric's new PowerUp-15* battery delivers 90 percent of its rated capacity.

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Ideal for portable industrial power tools, photographic equipment, portable communications devices . . . anywhere portable electric power is needed fast.

And you get all the advantages of time-proved GE nickel-cadmium rechargeable batteries.

For more information, write General Electric Company, Section 452-03, Schenectady, N. Y. 12345, or circle reader service card.

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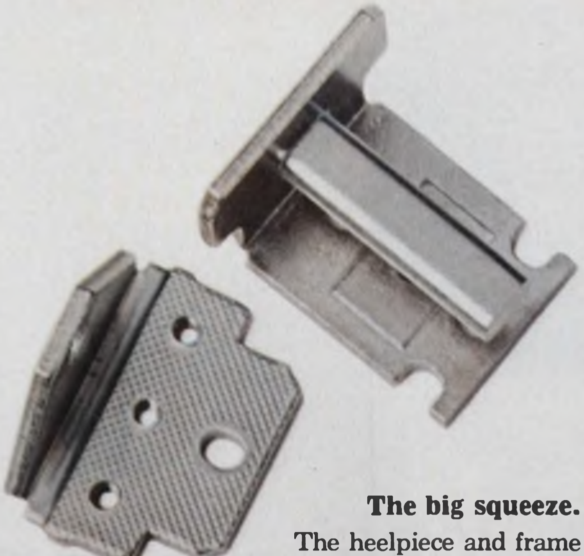
GENERAL ELECTRIC

INFORMATION RETRIEVAL NUMBER 31

Reliability is 756 little dents and one big one.



The big squeeze.

The heelpiece and frame are the backbone of our Class H relay. The slightest squiggle or shimmy out of either and the whole relay is out of whack.

756 tiny dents on the heelpiece, plus one big one on the frame, make sure this'll never happen.

They're the result of planishing, a big squeeze. Planishing is an extra step we go through in forming the pieces to add strength and stability by relieving surface strain. It also makes the parts extra flat.

This takes the biggest press in the industry and the biggest squeeze. Both exclusively ours.

A different kind of coil.

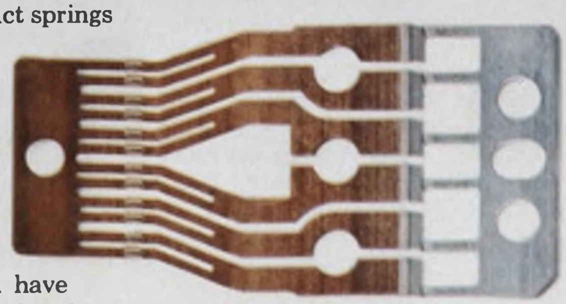
The heart of a relay is the coil. If ours looks different, it's because we build it around a glass-filled nylon bobbin. It costs us more, but you know how most plastic tends to chip and crack.

Also, moisture and humidity have no effect on glass-filled nylon. No effect means no malfunctions for you to worry about. No current leakage, either.

The coil is wound on the bobbin automatically. No chance of human error here.

Springs and other things.

We don't take any chances with our contact assembly, either. Our contact springs are phosphor-bronze. Others use nickel-silver. Our lab gave this stuff a thorough check, but found nickel-silver too prone to stress-corrosion. Atmospheric conditions which cause tarnish and ultimately stress corrosion have almost no effect on phosphor-bronze.



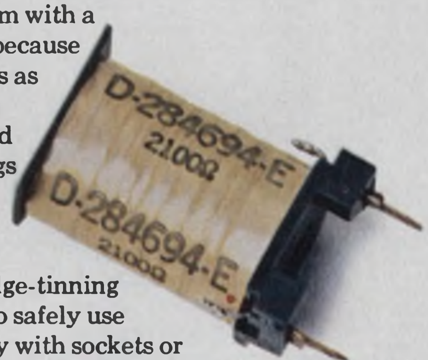
Even things like the pileup insulators (those little black rectangles) get special attention. We precision mold them. Other manufacturers just punch them out.

It makes a lot of difference. They're stronger, for one thing; and because they're molded, there's no chance of the insulators absorbing even a droplet of harmful moisture. Finally, they'll withstand the high temperatures that knock out punched insulators.

Two are better than one.

Our next step was to make sure our contacts give a completed circuit every time. So we bifurcate both the make and break springs.

Each contact works independently to give you a completed circuit every time. Contact material is pure palladium with a gold overlay because no alloy works as well.



Edge-tinned contact springs save you the job of solder tinning them later. Also, edge-tinning enables you to safely use the same relay with sockets or mounted directly to a printed circuit board. A simple thing, but it takes a big chunk out of the inventory you have to stock.

Finally, superior protection.

Out of the dozens of plastics to choose from for our dust cover, we picked a durable polycarbonate. The same material used for plastic windshields and special vehicle bodies. It's strong, resists high temperatures, and is unaffected by most cleaning solvents.

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Etc. Etc. Etc.

There's a lot more to tell about what makes our Class H relay reliable. Now we're waiting to hear from you. GTE Automatic Electric, Industrial Sales Division, Northlake, Illinois 60164.

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INFORMATION RETRIEVAL NUMBER 32

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INFORMATION RETRIEVAL NUMBER 34

Allen-Bradley
Milwaukee, Wisconsin 53204

editorial

Let's not talk our way into a recession

Many years ago I read a science-fiction story about a stock-market operator who had been so successful that he had amassed vast holdings of all the important securities on the stock exchanges. But that wasn't enough to keep him happy. He felt he could invest even more astutely and know true joy if he could predict future stock prices.

So he hired some engineers to develop a time machine. When it was completed, he transported himself into the future, hied himself to a library, then immediately began burrowing through back issues of financial papers. One can picture his shock when he discovered that there had been a staggering collapse in stock prices on the very day he had departed in his time machine.

A man accustomed to quick decisions, he tarried with the papers no longer. He promptly raced his time machine back to the day he left and, without hesitation, called his brokers and sold all his securities. And sure enough, the unprecedented selling wave triggered a market collapse.

His thought was father to the fact. Will ours be the same? Are we thinking and talking ourselves into a recession. During a recent trip abroad I heard many Europeans comment that Americans always talk themselves into a recession. I'm beginning to think it's true. Here we are in the middle of a fabulous business boom, and we seem unwilling to accept it without raising alarms about an impending bust. Many managers, while enjoying record-breaking prosperity, are beginning to moan and wail about what 1974 may hold in store. They're beginning to pull back, reduce investments in people and plant, and prepare for a recession.

Like our science-fiction hero who created a market collapse because he thought there was going to be one, we may be setting the stage for a rotten business year if we keep thinking and talking about how rotten it's going to be.

George Rostky

GEORGE ROSTKY
Editor-in-Chief

What ails electronics management?

Survey shows indecision ranks high among engineer complaints. But working conditions? They appear generally good.

Richard L. Turmail, Management Editor

A good manager has been described as someone who can understand those who are not very good at explaining, and explain it to those who are not very good at understanding. But, according to the latest ELECTRONIC DESIGN survey on management policies, engineering managers often aren't very good at understanding or explaining.

Failure to make decisions and failure to support subordinates are the complaints most often mentioned by both engineers and their immediate managers. Chief engineers and corporate officers, however, think that taking on too many projects is the most troublesome error that management makes. That could help to explain why they're considered to be indecisive and nonsupportive.

Other opinions that the survey uncovered with unmistakable clarity included these:

- There are more managers than necessary to do the job—in fact, the belief is that too many managers spoil the job.
- Management delegates responsibility to engineers but fails to give them the authority to do the job.
- Management is usually too remote from the job to know what procedure is the right one to use.
- More times than not, good engineers do not make good managers; there's a need for more and better management training. Commenting on management training for engineers, one engineering manager quoted Oliver Wendell Holmes: "We need education in the obvious more than investigation of the obscure."

Working conditions no problem

Survey questionnaires were mailed to 1000 randomly selected engineers and managers. A total of 55% responded.

The two least-registered complaints were poor working conditions and an unreachable management. The electronics industry has passed the era of the sweat shop.

But apparently management everywhere listens to engineers' complaints often without doing anything about them. Asked what poor management policies they had experienced before their present position, most respondents listed the same complaints that they had now. Their company's location and size did not alter appreciably the degree or pattern of the complaints.

The survey produced a few surprises, too. One

Put your management to the test

This article reports the findings of a survey conducted in April and May among subscribers to ELECTRONIC DESIGN. A total of 1000 questionnaires were mailed to a randomly distributed domestic sample of the magazine's circulation, and 553 replies (55%) were returned in time for tabulation and analysis. Respondents were requested to reply anonymously.

Here's a chance to rate your company, if you wish. After the first six questions, designed to categorize the response, the survey asked the following:

How does the pay here compare with other companies in the area?

How do you rate your company as a place to work?

How do you feel about your company's concern for its employees?

How do you feel about your company's policies toward and procedures with its customers?

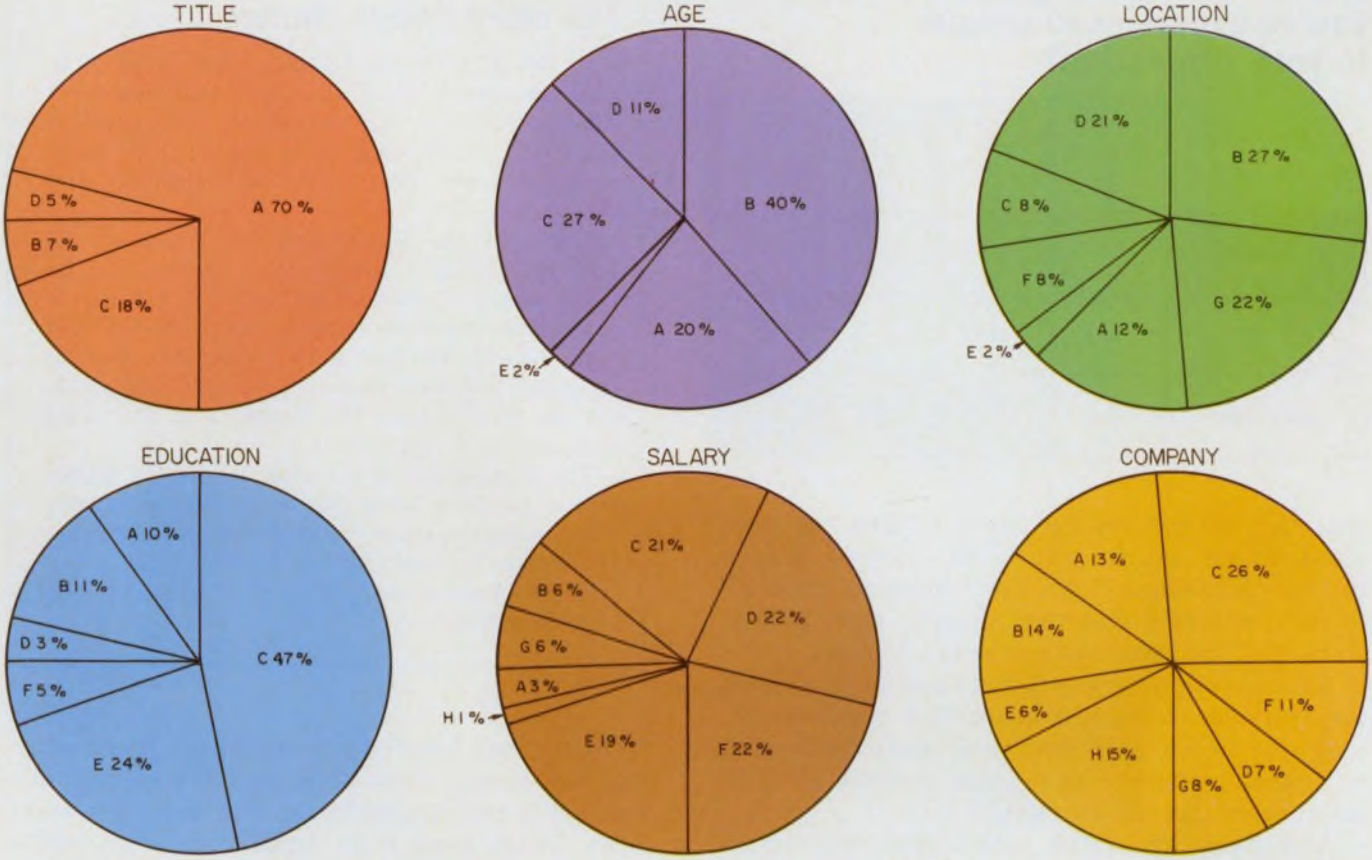
Do you believe that the poor management you've experienced is unique to your profession?

Does your company use layoff as a disciplinary action?

Has your company lost money because of poor management this year?

What is your over-all solution for better engineering management?

Respondents' Profile



TITLE
- A. ENGINEER
- B. CHIEF ENGINEER
- C. MANAGER
- D. CORPORATE OFFICER

AGE
- A. 20s
- B. 30s
- C. 40s
- D. 50s
- E. 60s AND OVER

LOCATION
- A. NEW ENGLAND
- B. MID ATLANTIC
- C. SOUTH
- D. MIDWEST
- E. N. PLAINS
- F. SOUTHWEST
- G. WEST COAST

EDUCATION
- A. NO DEGREE
- B. ASSOCIATE
- C. BACHELOR
- D. PROFESSIONAL
- E. MASTER
- F. DOCTORATE

SALARY
- A. UNDER \$10,000
- B. \$10,000 TO \$12,000
- C. \$12,001 TO \$15,000
- D. \$15,001 TO \$18,000
- E. \$18,001 TO \$20,000
- F. \$20,001 TO \$25,000
- G. \$25,001 TO \$30,000
- H. OVER \$30,000

COMPANY
- A. UNDER \$1 MILLION
- B. \$1 TO \$9.9 MILLION
- C. \$10 TO \$24 MILLION
- D. \$25 TO \$49 MILLION
- E. \$50 TO \$99 MILLION
- F. \$100 TO \$499 MILLION
- G. \$500 TO \$1 BILLION
- H. OVER \$1 BILLION

Salaries by Title

	ENGINEERS	CHIEF	MANAGER	CORPORATE
UNDER \$10,000	4 %	5 %	4 %	3 %
\$10,000 TO \$12,000	8 %	5 %	5 %	—
\$12,001 TO \$15,000	27 %	5 %	12 %	6 %
\$15,001 TO \$18,000	25 %	22 %	22 %	12 %
\$18,001 TO \$20,000	14 %	9 %	10 %	16 %
\$20,001 TO \$25,000	20 %	36 %	30 %	30 %
\$25,001 TO \$30,000	2 %	15 %	12 %	30 %
OVER \$30,000	—	3 %	5 %	3 %

Where the companies are

	NEW ENGLAND	MID ATLANTIC	SOUTH	MIDWEST	N PLAINS	SOUTHWEST	WEST COAST
UNDER \$1 MILLION	12 %	15 %	25 %	13 %	—	15 %	22 %
\$1 TO 9.9	25 %	19 %	14 %	11 %	20 %	18 %	20 %
\$10 TO \$24	14 %	7 %	20 %	5 %	—	15 %	8 %
\$25 TO \$49	16 %	7 %	3 %	6 %	—	7 %	9 %
\$50 TO \$99	5 %	6 %	3 %	9 %	—	5 %	4 %
\$100 TO \$499	12 %	15 %	3 %	18 %	—	22 %	20 %
\$500 TO \$1 BILLION	5 %	11 %	3 %	19 %	40 %	5 %	8 %
OVER \$1 BILLION	11 %	20 %	29 %	19 %	40 %	13 %	9 %

Are the poor management policies you've experienced unique to your profession?

	ENGINEER	CHIEF	MANAGER	CORPORATE
YES	9%	6%	3%	23%
NO	64%	80%	71%	50%
DON'T KNOW	27%	14%	26%	27%

was the answers to the query: "Are the poor management policies you've experienced unique to your profession?" An overwhelming majority of 66% reported that they thought most professions had the same management problems.

Another surprise was that no matter how much the respondents carped about bad management, only one in six said that they were dissatisfied with their company as a place to work or with its concern for its employees.

And those who think that large corporations are stifling places in which to work are in for a shock. According to the poll, a higher percentage of satisfaction was reported from those who work for large companies than from those who work for small ones. Perhaps, in these unstable times, employees of small companies are worried about how long their employer will stay solvent.

Respondents are mainly young

Who are the respondents to the survey?

Seven out of 10 are engineers. Most are young, with three in five less than 40 years old—but not quite as young as the respondents to last year's ELECTRONIC DESIGN survey, when two thirds were less than 40.

What's their salary? Three of five engineers earn $15,000 a year or better—about the same as reported in last year's survey. Engineers in their 20s complain their salary is lower than that paid by other companies in the area. Half of the chief engineers earn $20,000 or more. Half of the managers earn $18,000 or more. And three of five corporate officers get $20,000 or more. Three of four respondents in those three categories report that their salary is comparable to that of other companies in their area.

They're pretty well educated, too. Three of 10 respondents have a master's degree or better. Over two-thirds live in one of three regions: Mid-Atlantic, 27%, Midwest, 21% and West Coast, 22%.

The more things change . . .

In the ELECTRONIC DESIGN issue of Nov. 8, 1969, the majority of engineers and managers alike in response to a survey on "management sins" in engineering complained that their managers were most guilty of indecision and nonsupport.

Later, in the ELECTRONIC DESIGN issue of April 27, 1972, respondents to another survey were saying: "Management inhibits inventive approaches to solving engineering problems" and "It's difficult to deal with young engineering managers who have no experience and judgment, but one must because the mentality of the times is geared to 'being young'."

The complaints most often logged in ELECTRONIC DESIGN's latest poll on management policies are that managers are guilty of indecision and failure to support their subordinates.

As the French say: "Plus ça change, plus ca reste le meme."

One in four respondents works for a company that has annual sales of $10-million to $24-million, with the remainder of the response scattered. There were more small companies ($10-million or less) reporting from the West Coast, and more large companies ($1-billion and more) reporting from the South.

To test the state of the job market, the survey asked if engineering jobs were available where the respondents work. Only 44, or 8%, reported that no jobs were available in their area. A total of 238 (43%) said that there were jobs, 227 (41%) said that jobs were occasionally available and 44 (8%) said that they didn't know if jobs were open.

Taking the gripes one by one

What type of respondent is most satisfied with his company as a place to work? The survey shows, as you would probably guess, that it's a corporate officer in his 50s who helps to control a company in New England with sales of more than $1-billion a year. The least satisfied respondent? An engineer, naturally; he's in his 20s and works for a $500-million-to-$1-billion company in the Southwest. He cites poor morale and poor organization as the reasons for his dissatisfaction. Perhaps this response only confirms what you've already suspected: that the higher up the management ladder you go, the more likely you are to be a company man.

What about management's concern for its employees? According to the response, the most satisfied man is a corporate officer in his 60s who works for an under-$1-million company on the

	Engineers	Managers	Chiefs	Corporates						New England	Mid Atlantic	South	Midwest	Northern Plains	Southwest	West Coast									
Too much paperwork	17%	15	20	18	19%	16	20	18	10	20%	17	15	21	–	20	18	15%	12	14	19	16	25	18	21	–
Unreachable	6%	9	8	5	8%	7	8	10	25	9%	8	10	8	10	9	6	8%	9	10	10	7	7	4	8	12
Other, i.e. Questionable ethics Lack of contracts Too many managers Too much politics Too decentralized	5%	3	3	–	5%	4	4	3	25	6%	6	5	2	–	5	5	4%	7	4	3	4	3	3	6	13

The trouble with management...

	By title				By age					By location							By company size								
					Twenties	Thirties	Forties	Fifties	Sixties +								Under $1 million	1 to 9.9 million	10 to 24 million	25 to 49 million	50 to 99 million	100 to 499 million	500 to 1 billion	Over 1 billion	Government
Indecisiveness	23%	25	16	23	25%	27	26	21	20	20%	25	26	28	27	25	25	25%	24	27	26	24	22	30	23	50
Lack of support	32%	23	20	13	21%	21	22	24	10	18%	23	22	23	27	22	24	17%	21	28	28	21	21	23	25	–
Poor working conditions	7%	3	10	5	10%	8	6	11	10	8%	7	8	6	18	8	5	8%	7	4	–	7	8	10	7	–
Too many projects	10%	22	23	36	12%	17	14	13	–	19%	14	14	12	18	11	17	23%	20	13	14	21	14	12	10	25

Has your employer lost money because of poor management this past year?

	NEW ENGLAND	MID ATLANTIC	SOUTH	MIDWEST	N. PLAINS	SOUTHWEST	WEST COAST	UNDER $1 MILLION	$1 TO $99 MILLION	$10 TO $24 MILLION	$25 TO $49 MILLION	$50 TO $99 MILLION	$100 TO $499 MILLION	$500 TO $1 BILLION	OVER $1 BILLION
YES	20%	38%	31%	22%	14%	34%	43%	36%	41%	32%	36%	17%	33%	31%	25%
NO	42%	37%	21%	36%	43%	23%	32%	49%	36%	24%	33%	43%	27%	24%	28%
DON'T KNOW	38%	25%	48%	42%	43%	43%	25%	15%	23%	44%	31%	40%	40%	45%	47%

The table above is listed by location and company size.

West Coast. But how many of these corporate types are there? Few, of course. Far greater is the number of dissatisfied engineers in their 20s who work for a $10-million-to-$24-million company in New England.

Many of the dissatisfied respondents work for the $10-million-to-$24-million company, and the reasons for their discontent are varied. Companies around the $20-million mark are usually on the threshold of a major management realignment. Whereas engineering personnel reported directly to department managers and the founders of the company when the business was small, now they report to a new middle management, which has been installed to help carry the work load. In its early stages, middle management tends to hamper the lines of company communications.

One young engineer working for a large company in the Mid-Atlantic region says: "Upper management is too remote from its employees and has too little concern for them, and lower management is unable to plow through the bureaucracy to make changes."

Another engineer in his 30s, with a large company in the Midwest, complains: "Our management gives only what it has to, and if it wasn't for the factory union, our benefits would be next to nothing. We're part of management when it comes to giving to the Community Chest or asked to work overtime; otherwise when profit-sharing and bonuses are handed out, they're for managers only, and we're suddenly relegated to the working force."

And this from a young southern manager of a small company: "My boss knows little about my job, but he still tries to do it for me."

Engineers who work for under-$1-million companies are most satisfied with their employer's policies toward customers. Small-company engineers may be the most satisfied, because they have more contact with the customer than engineers in large companies.

Nothing unique about management errors

Explaining why engineering management errors are not unique to the engineering profession, a manager in his 40s, working for a small company on the Eastern Seaboard, speaks for many of the respondents when he says:

"Management errors are characteristic of people, not jobs. An incompetent man rises to the top and then spends most of his time hiding from exposure, hoping that lower levels will make the decisions for him and still allow him to take credit."

Four of five chief engineers, who've usually been around for awhile, agree that there's nothing unique about engineering management problems.

On the other hand, a corporate officer from the Mid-Atlantic region thinks that engineering management errors are unique to engineering because "high technology creates unforseeable management problems."

One conclusion that can be drawn from these opinions is that if you are working on the frontier of the state of the art, situations may arise that create management errors that are unique to engineering. The question is can we learn anything from everyday engineering management errors in preparation for that day?

What about layoffs and losing money?

While half of the engineers responding think that their company uses layoff as a disciplinary action, an average of four out of five managers, chiefs and corporate officers naturally think not.

How the respondent rates his company

	A	B	C	D	A	B	C	D	E	A	B	C	D	E	F	G	A	B	C	D	E	F	G	H
How does the pay compare with other companies?																								
Lower	52%	13	18	6	28%	14	15	11	22	16%	15	17	19	–	17	15	22%	23	22	8	17	15	17	10
Comparable	21%	80	70	71	63%	76	73	79	66	79%	74	67	76	71	60	77	64%	68	76	89	77	78	72	75
Higher	27%	7	12	23	9%	10	12	10	12	5%	11	16	5	29	23	8	14%	9	2	3	6	7	11	15
How do you rate your company as a place to work?																								
Excellent	19%	24	37	50	22%	26	18	25	50	28%	21	22	24	24	17	26	36%	23	13	16	23	18	11	25
Good	50%	57	43	38	45%	48	52	59	50	53%	51	56	45	38	43	52	39%	43	50	57	50	48	51	51
Neutral	27%	13	17	9	26%	22	25	13	–	13%	22	12	28	38	37	17	17%	27	28	27	23	31	32	21
Poor	4%	6	–	–	6%	3	5	3	–	6%	4	10	3	–	3	4	6%	7	9	–	4	3	6	3
Bad	–	–	3	3	1%	1	–	–	–	–	2	–	–	–	–	1	2%	–	–	–	–	–	–	–
How do you feel about your management's concern for its employees?																								
Very Satisfied	11%	14	18	35	14%	13	11	10	30	14%	14	18	7	–	4	16	36%	12	2	11	13	3	10	7
Satisfied	42%	49	55	48	33%	39	41	59	50	33%	34	35	42	50	46	49	35%	35	35	31	42	48	32	46
Neutral	29%	22	18	11	29%	33	34	28	10	36%	37	30	36	50	38	19	20%	35	49	43	39	31	32	28
Dissatisfied	14%	11	6	3	14%	11	12	3	10	13%	11	10	10	–	8	12	5%	14	12	11	3	15	20	12
Very Dissatisfied	4%	4	3	3	10%	4	2	–	–	4%	4	7	5	–	4	4	4%	4	2	4	3	3	6	7
How do you feel about your company's policies toward its customers?																								
Very Satisfied	13%	20	18	38	20%	18	13	16	60	21%	15	30	15	–	11	16	41%	14	14	18	16	13	13	13
Satisfied	53%	50	60	50	46%	49	59	60	30	42%	53	33	55	63	62	54	38%	49	42	41	61	63	60	54
Neutral	27%	23	18	9	30%	25	22	22	10	32%	23	33	27	37	22	21	16%	25	37	35	13	16	23	31
Dissatisfied	7%	7	4	3	4%	8	6	2	–	5%	9	4	3	–	5	9	5%	12	7	6	10	8	4	2

By title
- **A** Engineers
- **B** Chiefs
- **C** Managers
- **D** Corporates

By age
- **A** 20s
- **B** 30s
- **C** 40s
- **D** 50s
- **E** 60s +

By location
- **A** New England
- **B** Mid Atlantic
- **C** South
- **D** Midwest
- **E** Northern Plains
- **F** Southwest
- **G** West Coast

By company
- **A** Under $1 million
- **B** $1 to $9.9 million
- **C** $10 to $24 million
- **D** $25 to $49 million
- **E** $50 to $99 million
- **F** $100 to $499 million
- **G** $500 to $1 billion
- **H** Over 1 billion

Are engineering jobs available in your area?

	NEW ENGLAND	MID ATLANTIC	SOUTH	MIDWEST	N PLAINS	SOUTHWEST	WEST COAST
YES	46%	46%	43%	50%	10%	40%	65%
NO	10%	4%	5%	7%	20%	6%	4%
OCCASIONALLY	35%	36%	45%	39%	70%	38%	27%
DON'T KNOW	9%	14%	7%	4%	—	16%	4%

Over half of all respondents thought not, regardless of the size of the company they worked for or where it was located.

Most respondents thought that their company had lost money because of bad management, poor planning and poor communication between departments. They cited the following among the bad managerial practices:

- Too many engineers doing paperwork, with not enough quality technical help.
- Failure to take advantage of the newest advances in analytical instrumentation to support production.
- Complete lack of project planning, resulting in widespread interdivision politics and the wrong people making the decisions.
- Unwillingness to expand support functions (procurement and manufacturing) to meet contract requirements, thereby causing delivery problems.
- Waste resulting from Government budget practices that force unnecessary spending at the end of each fiscal year to use up unspent funds.
- Failure to make decisions in time to capture the market.

Cures for what ails management?

Finally, the engineers and their managers were asked if they had any suggestions for better engineering management. This was a typical reply: Decentralize maximum-authority management and delegate responsibility to the lowest levels possible.

Winston Churchill once said, "There is nothing wrong with change, if it is in the right direction." Respondents offered the following ideas to change engineering management for the better:

- In time managers become technically obsolete or burdened with past ways of doing things. The solution is to motivate those under them to carry on with improvements.
- Use company men for upper-management positions rather than import them on a temporary basis from the parent company.
- Base the selection of engineering management on the man's hardware capabilities rather than on his optimism about the future.
- Encourage more engineers to quit and form their own companies. If they succeed, they're grateful to you. If they fail, you can always hire them back.
- Give design engineers a percentage of the gross of the product they design that stays sold. Deduct for failures. Also give percentages for effective cost reduction.
- Overload all engineers with work by 10% at least; give them a reasonable goal and budget; monitor to make sure that an acceptable pace is being followed, and judge on the basis of results. If the results are poor, remove the engineer from his position of responsibility and use him as a delegative worker. If he's still no good, suggest departure. ■■

Much obliged, respondents!

To the more than 500 subscribers who took the time to complete our questionnaire, thank you. Your effort has been of service to electronics engineers and engineering managers nationwide.

Many thanks also to Sharon Blau and Christine Krempa, Editorial Assistants at ELECTRONIC DESIGN whose tabulating and typing of the survey response helped to make the report possible.

Drop us a line . . .

We realize that there may be legitimate reasons for those actions of engineering management that breed complaints from engineers and that many engineers, and even their managers, may not always know what the offensive actions are.

With that thought, we invite engineering and corporate managers everywhere in the electronics industry to respond to this report. Are the complaints justified? If not, why not? Are there other managerial migraines that haven't even been mentioned? What are they, and what is the cure for them?

Given enough information, we'll write another article based on the response.

Write to: Hayden Publishing Co., 50 Essex St., Rochelle Park, N.J. 07662. Att: Management Editor, ELECTRONIC DESIGN.

Protected:

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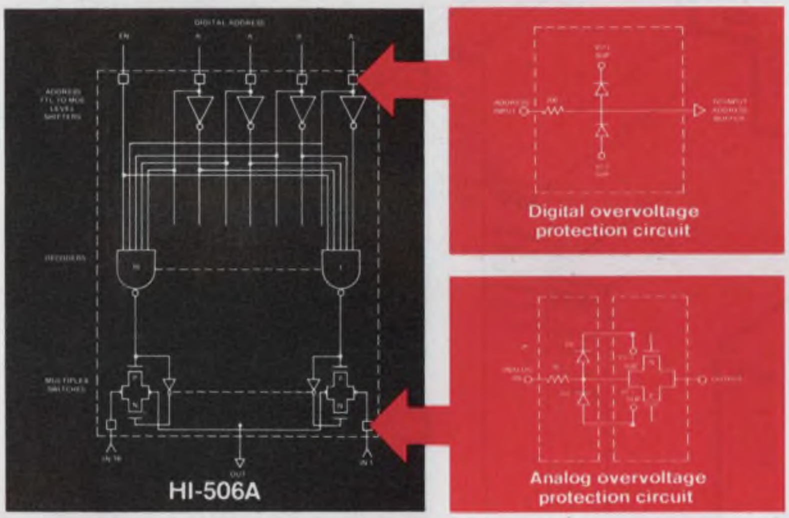
Designated the HI-506A, this new Harris 16-channel multiplexer combines DI/CMOS (dielectric isolation) processing and unique circuit design to provide on-board protection against analog input overvoltage. Therefore, in the event of overvoltage in one channel, there is no output error when other channels are being addressed. This same protection circuit eliminates latch-up as well as unpredictable operational characteristics that could result from transient voltages originating in either the signal or supply. A second similar protection circuit provides the device with the necessary safeguards against static charges. In addition, break-before-make switching eliminates undesirable channel interaction.

Applications include data acquisition, telemetry systems, process control and general analog switching. The device is available in volume now for off-the-shelf delivery. For details see your Harris distributor or representative.



Features:

Internal overvoltage protection, both analog and digital

No channel interaction with power loss

Break-before-make switching

DTL/TTL and CMOS compatibility

Supply current	**4mA at 1 MHz toggle rate**
Power requirement	**7.5 mW disabled**
Power requirement	**7.5 mW enabled**
Access time	**500 ns**
Power supply	**±15V**
Signal range	**±15Vdc**

Supplied 28-pin DIP

	100-999 units
HI1-506A-5 0°C to +75°C	**$28.60**
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INFORMATION RETRIEVAL NUMBER 37

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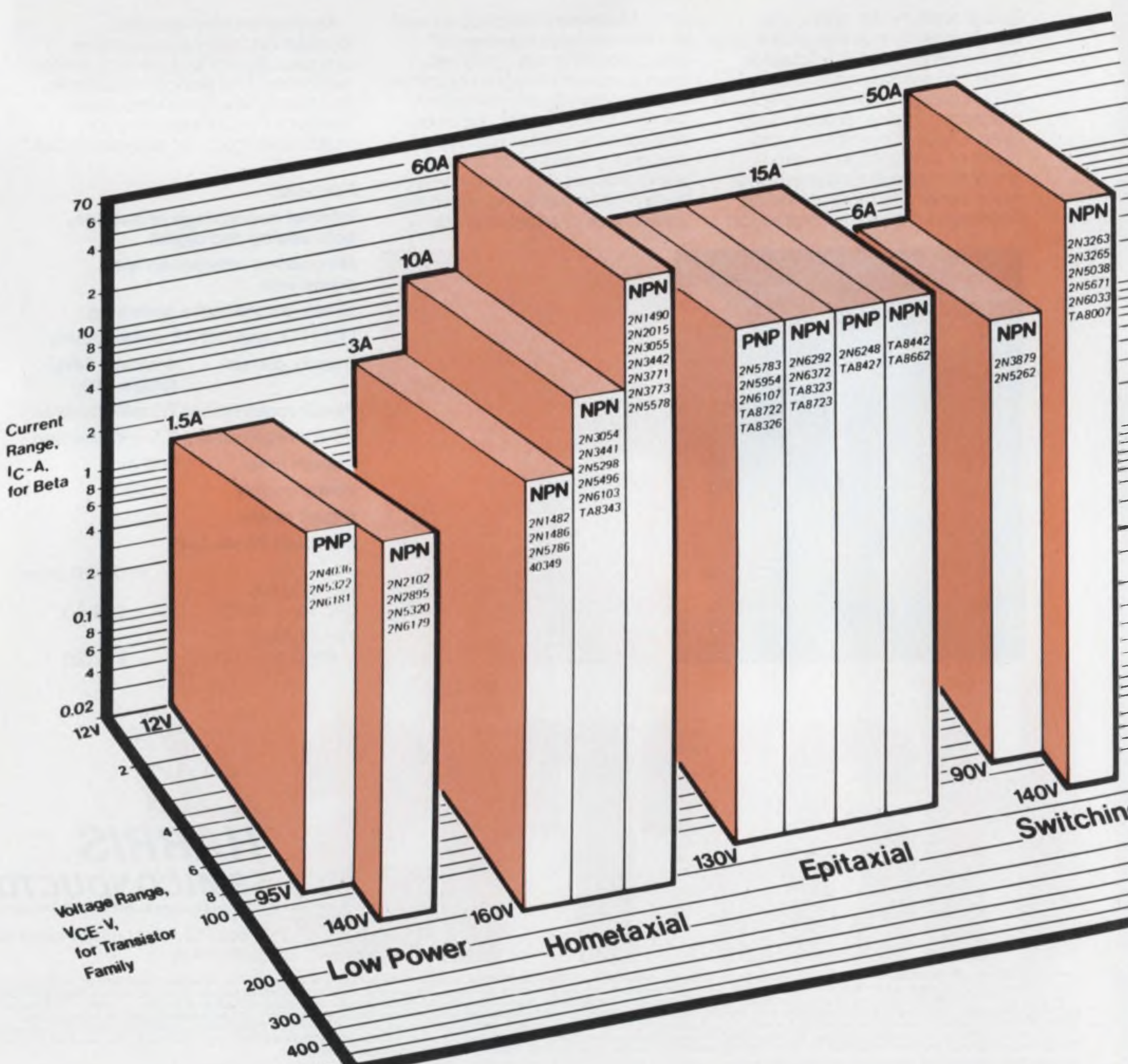


INFORMATION RETRIEVAL NUMBER 38

Improve avalanche-photodiode designs

with a careful analysis of device characteristics. You can evaluate noise sources and obtain the optimum S/N ratio.

The avalanche photodiode (APD) has been commercially available for many years, yet its use is limited to a relatively few sophisticated systems because of a lack of common understanding about operation and optimization.

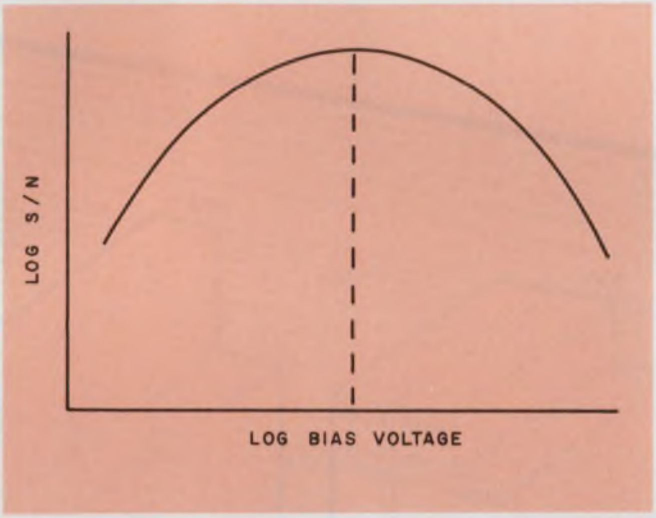
The major difficulty in using an APD in a system is determining its optimal bias point. As shown in Fig. 1, the signal-to-noise (S/N) ratio is degraded above or below the optimal bias point.

Many detector manufacturers specify the noise produced by the detector as noise equivalent power (NEP). This can be confusing when the detector is used in a system with an amplifier: Because of amplifier noise, there may be a considerable reduction in the performance outlined in the manufacturer's specifications. Hence the total system performance should be considered. Analysis of system performance reveals detector gain to be a desirable attribute.

If amplifiers were noise-free, there would be no need for gain in the detector, since unlimited gain could be achieved without a disproportionate increase in noise. But, because amplifiers generate noise, any gain in the detector will improve the system S/N—provided the amplifier noise reduction is greater than the detector noise increase. The amplifier then needs less gain to produce equal signal response for the system.

The APD is a solid-state photodetector that uses carrier multiplication in the semiconductor bulk to produce gain in a manner similar to that in a photomultiplier tube. The photomultiplier tube forms the principal competitor for APDs. Although there are benefits resulting from the use of both types of photodetectors, the APD has distinct advantages when the application requires low cost and operation at the long end of the visible spectrum and near infrared. When the APD is compared with the p-i-n photodiode, approximately one to three decades of improvement in signal-to-noise ratio can be expected for the system.

Anthony E. Barelli, Research Associate, School of Medicine, Dept. of Surgery, Case Western Reserve University, Cleveland, Ohio 44106.



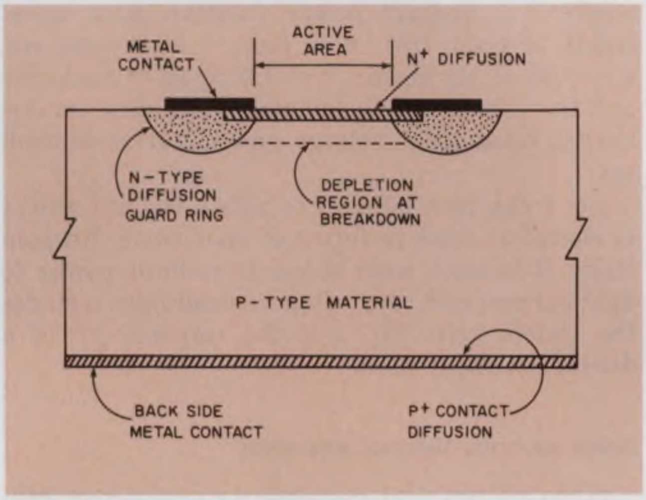
1. **Obtaining the optimal bias potential** represents one of the major design problems with APDs.

The APD is basically a reverse-biased diode with a structural design that allows breakdown to occur uniformly at the pn-junction rather than at the junction edge. The major device design goal then is one of allowing uniform avalanche multiplication to occur while minimizing leakage current. These goals are achieved by two commercially available structures: the graded guard-ring type introduced by Texas Instruments and the exposed-junction version introduced by General Electric.

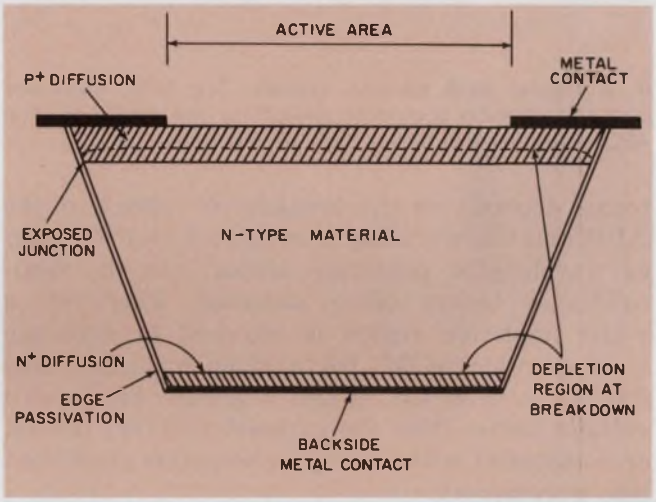
In the graded guard-ring structure (Fig. 2), used in silicon and germanium APDs, the guard ring and active area are in electrical contact. The guard ring eliminates breakdown at the junction edge, allowing the avalanche effect to occur uniformly in the active area of the pn junction and not in the high electric field regions at the junction's curvature. This uniform avalanching is accomplished by tailoring the guard-ring concentration and curvature so that the electric fields in the depletion region produced by the guard ring are lower than those produced at the edge of the active area.

In the exposed-junction structure (Fig. 3), used in silicon APDs, the interface between n and p type of material is exposed by etching the diffused substrate below the point where the depletion region extends. This procedure avoids the problem of junction edge breakdown by removing the curved pn-junction, which would break down first in the high electric fields necessary for gain. The exposed junction is then passivated to minimize surface leakage current—a process sometimes referred to as contouring.

Exposing the pn-junction enables the device to have breakdown voltages approaching 2000 V and improved quantum efficiency at longer wavelengths. At the same time a low junction capacitance can be maintained. The disadvantage of this approach is the complexity of fabrication.



2. **The graded guard-ring structure** is used for silicon and germanium APDs. Junction-edge breakdown is eliminated by the guard-ring concentration and curvature.



3. **The exposed junction structure** is used in silicon APDs. Here breakdown problems are eliminated by removal of the curved portion of the pn-junction.

In both structures the depletion region contains high-density electric fields. Carriers generated in this region are accelerated to the avalanche region at high drift velocities, thus yielding good frequency response and gain characteristics—typically an 8-GHz gain-bandwidth product. Gain occurs because the high-velocity electrons have sufficient energy to dislodge other electrons from the crystal lattice, thus causing avalanche multiplication and an enhanced signal.

Two leakage currents to spec APDs

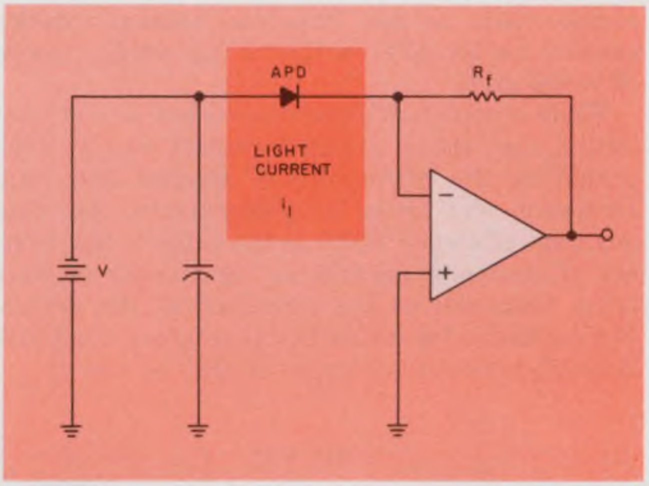
Data sheets for p-i-n diodes specify dark current. This spec alone can provide a good indication of the noise in the detector. Before the system designer can determine the detector noise with an APD, he needs specifications for two types of leakage current plus the gain. The two leakage terms are the diode surface term, I_{DS}, and the diode bulk term, I_{DB}. These same components are present in the p-i-n diode but can be separated in the APD because of its gain properties. Specifically the bulk leakage is multiplied by the avalanche gain process, whereas the surface term is not. The total leakage (dark) current for an APD is $I_{dark} = I_{DS} + MI_{DB}$, where M is the gain.

When a photon of light is absorbed in a crystal lattice, the lattice energy increases locally, thus enhancing the probability of electron-hole pair formation and hence of photocurrent. Absolute quantum efficiency (QE) is the ratio of the number of incoming photons to the number of electrons measured at the terminals of the device. Furthermore, for an APD the designer must distinguish between two types of QE: ac and dc.

In the case where the semiconductor is semitransparent to the incident light, some light may pass through the depletion region without being absorbed. This is particularly true at longer wavelengths —about 1 μm for silicon and 1.6 μm for germanium. P-i-n photodiodes also exhibit this double QE phenomenon, but it is more pronounced in the APD because of its gain. The ac QE arises only from those electron hole pairs generated in the depletion region, since only these carriers can be quickly accelerated and recognized as photocurrent.

The dc QE term is either equal to or greater than the ac term because it arises not only from those electron hole pairs generated in the depletion region (the ac QE) but also from those carriers generated within a diffusion length. When this length is long, light that enters the zero-field region can generate carriers that consequently have long diffusion transit times. As a result, at higher frequencies and longer wavelengths, the slowly diffusing carriers can contribute to the noise current while adding nothing to the signal.

For most guard-ring structured APDs, the ac and dc QEs are roughly equal to 100 kHz. Above this frequency the difference between the two



4. **A typical APD op-amp system.** The APD, capacitor and supply form a current source for the amplifier. The APD generally exhibits a high source resistance.

terms depends on the breakdown voltage of the APD and the wavelength of light detected. Longer wavelengths penetrate deeper into the semiconductor before being absorbed. Therefore a wider depletion region is required to maintain a comparable ac QE for a given material. This implies a need for either a higher breakdown voltage device, like the exposed junction device, or a material with a larger absorption coefficient like germanium.

A difficulty with devices having wide depletion regions is that their QE at the shorter wavelengths is less than that achieved with narrower depletion devices. This arises because the pn-junction tends to be deeper, making it difficult for electron hole pairs absorbed near the surface to be swept into the high field region. The following serve as useful rules of thumb for increasing the APD's QE at longer wavelengths:

- Increase the depletion width by using higher breakdown devices.
- Add antireflective coating to the APD's active area surface.
- Use a reflective back metal contact and reduce the width of the back junction undepleted bulk.

A comparison of QE specifications also requires a recognition of the difference between absolute and relative QE. The above discussion applies to absolute QE. Relative QE is an absolute value that has been renormalized so that the peak of the detector's response corresponds to a QE of 100%. This tends to make the devices look better than they are. Moreover, it makes comparison between device types difficult.

The designer can compare them by noting the device's responsivity at a particular wavelength and renormalizing the entire curve, using Eq. 1. APD and p-i-n diodes compare very favorably with the QE of photomultiplier tubes. At red and infrared wavelengths the solid-state devices can have many decades more of absolute QE than their photomultiplier-tube counterparts.

Since light flux absorbed in the APD produces electron flow or current, the photons themselves can be thought of as light current measured in amperes. This concept is important in understanding optical system noise, because in many cases the shot noise resulting from the light current determines the system's sensitivity limit. This is termed simply the shot-noise-limited case. The following equation relates the radiant power of the light to its current in amperes:

$$I_l = \frac{P\lambda Qq}{hc}, \tag{1}$$

where P = radiant power (watts), λ = wavelength of light (m), $h = 6.62 \times 10^{-34}$ joule-sec, $c = 3.00 \times 10^8$ m/sec, $q = 1.6 \times 10^{-19}$ coulombs and Q = the absolute quantum efficiency (wavelength, breakdown voltage and material dependent).

Eq. 1 can now be used to relate radiant power to electrical noise in terms of shot noise. Responsivity R is often used to relate radiant power to light current and very often misleadingly includes the system gain. Eq. 1 is the responsivity of a detector without gain.

Noise sources: thermal and shot

Since all physical components experience random fluctuations in their physical parameters, the problem of optimizing the design of a total system in terms of signal-to-noise ratio is based on choosing the components to minimize noise in the system and to maximize the signal processed by it. This requires characterizing electrical noise accurately. Two general sources of noise are thermal and shot:

Thermal noise is a phenomenon associated with the Brownian motion of electrons in a conductor. The Norton equivalent for a thermal noise source (rms current) in resistor R is

$$i_{thermal} = \left[\frac{4KT\Delta f}{R}\right]^{1/2}, \tag{2}$$

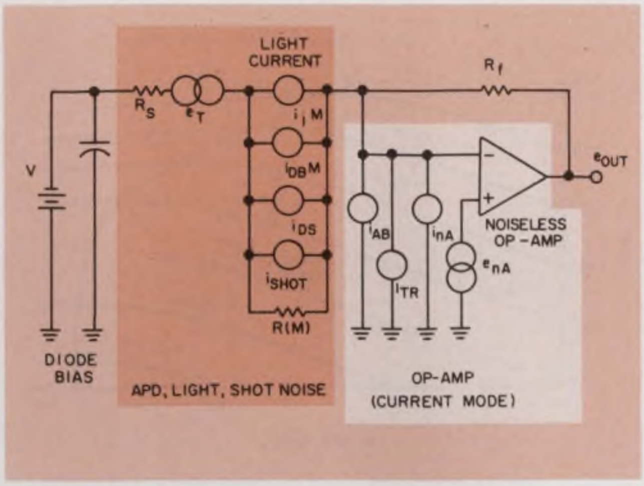
where K = Boltzmann's constant, or 1.38×10^{-23} joule/°K, Δf = bandwidth (Hz), R = resistance (ohms) and T = the absolute temperature of the resistor noise source (°K).

Shot noise is caused by the discrete nature of electron flow. The Norton equivalent for the shot noise (rms current) produced by an average current flow I is

$$i_n = [2qI\Delta f]^{1/2}, \tag{3}$$

where I = average direct current and $q = 1.6 \times 10^{-19}$ coulombs.

The circuit for which the APD system is modeled is shown in Fig. 4. In it the op amp is configured in a current-amplifier mode, where the APD, capacitor and battery are the current source. The gain (input current to output volt-



5. **The equivalent circuit** for the APD op-amp system. Separation of all noise and signal sources permits the calculation of their individual effects on output voltage.

age) of a current amplifier is $-R_f$. The capacitor, which shunts the signal around the battery while maintaining a reversed dc bias on the APD, is neglected in the analysis.

A current amplifier is used, since the APD is usually a very good current source because of its high source resistance. The APD thus transforms light current to electrical current with current gain. Many p-i-n photodiode application notes recommend an op amp in a voltage configuration with a large value of input resistance. Both approaches are essentially the same until the RC frequency roll-off of the circuit is considered. The APD capacitance and series resistance determine the roll-off frequency of the current amplifier circuit.

In the voltage amplifier configuration the device capacitance and the input resistor essentially determine the roll-off frequency. Thus, for higher frequency applications, the current amplifier has a distinct advantage.

For the detection of subnanosecond pulses, the device capacitance is the limiting parameter of frequency response. To achieve rise times that are better than 100 ps, some users have electrically insulated the APD chips from their packages, thereby eliminating much stray capacitance.

Minimize high temperature effects

Where temperature variations may be significant, the battery is replaced by a voltage regulator, which controls its output to compensate for thermal changes. Since the APD's temperature coefficient at breakdown can be higher than 100 mV/°C, temperature-compensating biasing circuits should be used to ensure that the APD is operated at optimal gain.

Sometimes a second APD is required, with comparable breakdown, to act as a temperature sensor. It controls the voltage regulator for the first APD that is used as a photodetector. With thermal changes compensated for in this way, variations in the APD gain, as a function of temperature, are avoided. In the case of extreme temperature change, thermal runaway can cause the device's destruction.

If the system is not subject to significant temperature changes, the bias voltage can be controlled manually. Some systems use the change in system noise with temperature to control the bias-compensating circuitry. This approach is useful when the total shot noise of the system is less than the total thermal-noise component.

To optimize an APD amplifier system, the following effects must be considered:

- Shot noise created by the incident light current and by the leakage current of the APD.
- Added noise created by the APD's gain.
- Noise current and voltage of the op amp.
- Junction and series resistance of the APD.
- Thermal noise of the APD and feedback resistor.
- Gain of the op amp and the absolute maximum gain of the APD.

An equivalent circuit to that described in Fig. 4 is shown in Fig. 5. Here all voltage, current, noise and signal sources are separated so their effect on the system can be analyzed in terms of their contribution to the total output voltage. Thus the model is constructed in terms of the op amp's output, both signal and noise. Since the op amp's output is in volts, S/N can be conveniently defined in terms of a voltage.

In Fig. 5, the following definitions apply: V = bias potential, R_s = series contact resistance, e_T = thermal noise voltage source of APD, i_l = light current (both ac and dc components) and M = current gain of APD.

In addition i_{DB} = APD bulk leakage current, i_{DS} = APD surface leakage current, i_{shot} = shot noise due to total dc in circuit and $R_J(M)$ = APD junction resistance (a function of M).

Finally i_{AB} = amplifier bias current, i_{TR} = thermal noise of feedback resistor R_f, R_f = feedback resistor of the op amp, i_{nA} = op-amp rms noise current per $\sqrt{\text{Hz}}$ and e_{nA} = op-amp rms noise voltage per $\sqrt{\text{Hz}}$.

The individual output sources of noise signal include the output noise voltage due to the op-amp input noise:

$$e_A^2 = \left[e_{nA} \left(1 + \frac{R_f}{R_j + R_s}\right) \right]^2 \Delta f + i_{nA}^2 (-R_f)^2 \Delta f. \tag{4}$$

These current and voltage terms are added like vectors or electrical power, since they are uncorrelated noise sources. Because e_{nA} and i_{nA} are expressed in voltage and current per square root Hertz, Δf is required for normalization. In addition, since a current amplifier is considered, an op amp with an i_{nA} value as low as possible should be chosen.

The output noise voltage due to the thermal noise of the feedback resistor is

$$e_{TR} = \left[\frac{4KT\Delta f}{R_f}\right]^{1/2} (-R_f) = -[4KT\Delta f R_f]^{1/2}. \quad (5)$$

In general, this term is not neglected since R_f and Δf are usually large enough to make a contribution. If $\Delta f R_f > 10^6$ Ω-Hz, then e_{TR} could contribute to the system noise.

The output noise voltage due to the thermal noise of the APD is

$$e_{TAPD} = [4KT\Delta f R_s]^{1/2} \frac{(-R_f)}{R_J + R_s}. \quad (6)$$

Note that R_J does not contribute to the noise voltage in Eq. 6 because the term does not represent a real resistance. It does, however, affect the voltage gain of the op amp. In general, at room temperature and below, particularly in the shot-noise-limited case, this term can be neglected. Series resistance R_s is usually less than 50 Ω, making e_{TAPD} about two orders below the other noise terms. Voltage e_{TAPD} will contribute when either T or R_s is large or when R_J is small.

The shot-noise contribution to total noise is the most difficult term to formulate, because the sum of all dc currents in the circuit must be carefully defined. The dc terms in this circuit arise from three sources: the light current, the bias current of the op amp, and the leakage current of the APD. Because of the possibility that part of the light current may be background, total light current is written as

$$I_l = I_s + I_{DC}, \quad (7)$$

where I_s = signal current and I_{DC} is the dc background component.

If the background light is the same wavelength as the signal or some finite number of monochromatic wavelengths, Eq. 1 can be easily used. Current I_{DC} as a spectrum is difficult to calculate, because the spectral power $P(\lambda)$, λ and $Q(\lambda)$ must be integrated with Eq. 1 over the background spectrum limits.

The total dc current in the circuit is

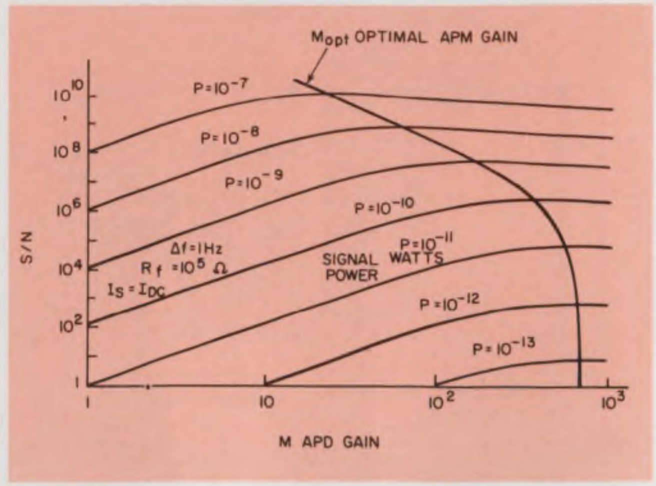
$$M[I_{DC} + i_{DB}] + i_{DS} + i_{AB}. \quad (8)$$

Because avalanche gain is a noisy process, current that is multiplied in the avalanche process produces more shot noise. Therefore Eq. 8 is modified by a correction factor, d, which accounts for the added noise encountered because of avalanche gain. This d factor is said by some to be wavelength-dependent. In any event, a very good empirical value for d in silicon is 2.3 and in germanium 3.0; it has not been reported to vary more than 0.1 from these values.

The effective shot-noise current is now

$$I_T = M^d [I_{DC} + i_{DB}] + i_{DS} + i_{AB}. \quad (9)$$

The output noise voltage resulting from the shot noise of the total dc current flowing in the circuit now becomes



6. **The variation of S/N vs APD gain** at different light power levels for the TIXL 56 at λ = 632.8 nm. Since M is a highly nonlinear function of bias voltage, these curves are altered from the curve in Fig. 1.

$$e_s = [2q\Delta f I_T]^{1/2}(-R_f). \quad (10)$$

Eq. 10 generally yields the predominant noise term, unless there is little background light.

The total noise at the output due to thermal noise (Eqs. 5 and 6), amplifier noise (Eq. 4) and shot noise (Eq. 10) must be added as the sum of the squares, since they are uncorrelated electrical power-noise sources. Thus

$$e^2_{noise} = e^2_T + e^2_s + e^2_A + e^2_{TR} \quad (11)$$

The output signal voltage is

$$e_{sig} = M I_s (-R_f). \quad (12)$$

The signal-to-noise ratio is definied as

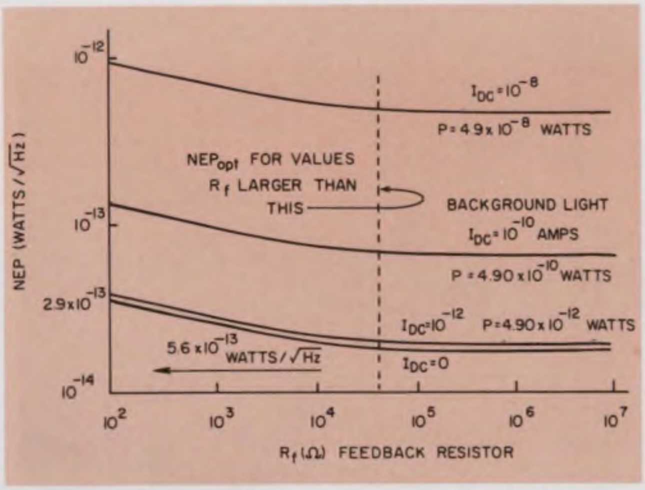
$$S/N = e_{sig}/e_{noise}. \quad (13)$$

At this point the terms can be solved explicitly, but a look at the relative size of the physical parameter dictated by the situation can save much time if an approximation is made. Resistance R_J is usually much larger than R_s and R_f. This knowledge alone can greatly simplify the calculations.

Resistor R_J in the equivalent circuit is the junction resistance of the APD, or the slope of the V/I curve for the diodes. At a gain of unity this can be greater than 500 MΩ typically, but at high gains and for leaky diodes this resistance can approach 1 MΩ or less. The junction resistance is important only when R_f and R_J are within two orders of magnitude of each other. If this occurs, R_J must be treated as a function of APD gain (M) in the optimization procedure, and the solution of optimal gain must then be found by computer techniques.

Resistor R_J can best be found by measuring it in the circuit under actual conditions. The following equation for R_J is derived for modeling purposes and can be used for a good approximation:

$$R_J = \frac{V_B}{n\, I_l} \frac{(M-1)^{1/n}}{M^{1/n} + 2}. \quad (14)$$



7. **Feedback resistance vs NEP variation** for different background light levels. In general, the value of R_f doesn't depend on the background light. The NEP improves with larger R_f values up to a value of $5 \times 10^4\ \Omega$.

Here n is the Miller equation correction factor (silicon, $n = 0.6$; germanium, $n = 2.6$) and V_B is the APD breakdown voltage. Resistor R_J depends on I_l as well as APD gain and bias. Thus to some extent, where R_J is small and I_l large, the total light current affects the noise gain of the circuit. Since signal current is also shunted through R_J, particularly in the case where the input resistance of the op amp is significantly high, the gain of the APD is diminished when R_J becomes small.

In practice the signal level commonly decreases when background light, I_{DC}, greatly increases. This is referred to as the "debiasing effect," because the APD gain M appears to decrease. In actuality R_J decreases as I_l increases. Therefore when I_{DC} greatly increases, the gain appears smaller, because more signal current is shunted through R_J. The "debiasing effect" is rarely significant in system designs but can cause annoying difficulties with signal-intensity calibrations when the background levels change markedly.

Voltage noise terms can be simplified

Since $R_J >> R_f$ and R_s in almost all cases, the voltage-noise terms e_{nA} and e_T in Fig. 3 can be simplified. Hence Eq. 4 becomes

$$e^2_A \simeq e^2_{nA}\,\Delta f + i^2_{nA}\,R^2_f\Delta f \qquad (15)$$

and Eq. 6 becomes

$$e_T \simeq 0. \qquad (16)$$

Of course, when R_J becomes smaller, the APD starts to act less like a current source and more like a voltage source. The voltage terms become more appreciable, since the current amplifier now acts more like a voltage amplifier, with R_J as the input resistance.

The S/N ratio can be expressed more simply by using Eqs. 5, 10 through 13, 15 and 16:

$$S/N = \frac{M^2 I^2_s R^2_f}{\Delta f\,[R^2_f(2qI_T + i^2_{nA}) + R_f 4KT + e^2_{nA}]}, \qquad (17)$$

where $I_T = I_T(M) = M^d(I_{DC} + i_{DB}) + i_{DS} + i_{AB}$. Note that S/N is normalized by Δf.

To obtain the optimal bias point or gain of Fig. 1, set the derivative $d(S/N)/dM = 0$ and solve for M_{max}. The optimal gain for the system then becomes

$$M_{opt} = \left[\frac{2c}{(d-2)\,b}\right]^{1/d}, \qquad (18)$$

where $c = 2qR^2_f\,(i_{DS} + i_{AB}) + e^2_{nA} + i^2_{nA}R^2_f + 4KTR_f$, $b = 2qR^2_f\,(I_{DC} + I_{DB})$ and d = noise correction factor defined in Eq. 9. The terms $i_{DS} + i_{AB}$ and e^2_{nA} can usually be neglected. By substituting M_{opt} into Eq. 17, we can find S/N_{opt}. This is the best S/N the system can achieve with a given set of conditions. Note the following features of M_{opt}:

- Total independence of the signal light current, I_s, and S/N.
- Inverse variation with the background light I_{DC} and the bulk leakage i_{DB}.
- Direct variation with the amplifier noise and APD surface-leakage term.

The noise equivalent power (NEP) of a photodetection system is the light's signal power per $\sqrt{Hz}$ necessary for a $S/N = 1$ at the output of the system. The NEP approach to describing minimal signal-detection capabilities is the standard of comparison for APDs and many other detectors. This approach has the advantage of an implicit double normalization ($S/N = 1$ and $\Delta f = 1$) that reduces the qualification necessary to specify sensitivity. With the definition of NEP and Eqs. 1 and 17, an explicit relation for the system NEP results:

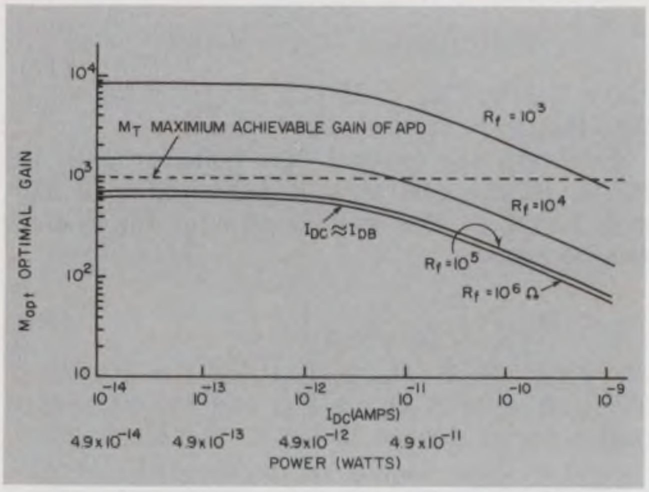
$$NEP = \frac{hc}{\lambda Q q R_f M_{opt}}\sqrt{R_f^2(2qI_T + i^2_{nA}) + R_f 4KT + e^2_{nA}}, \qquad (19)$$

where $I_T = I_T(M_{opt})$ and $M_{opt} = M_{opt}\,(I_{DC}, R_f)$.

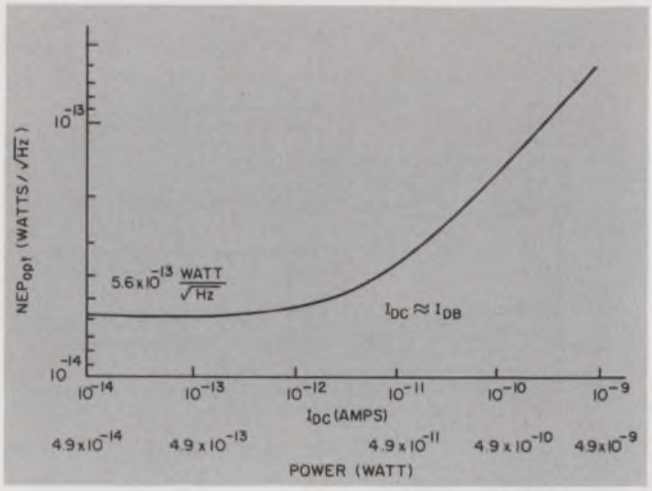
Here M_{opt} replaces M to obtain the optimal case. In some cases M_{opt} may not be achieved either because of technological or economical limitations. If M is restrained below M_{opt}, then the highest M practical should be used and appropriately substituted into Eq. 19.

This equation shows that once the op amp and APD are chosen, both R_f and I_{DC} can alter the system NEP. In most cases I_{DC} is determined by the application. Therefore one engineering problem besides that of optimizing gain is to choose R_f to maximize the system sensitivity. When the system is optimally sensitive for a given condition, NEP_{opt} has been achieved.

There is no simple procedure for choosing R_f to obtain NEP_{opt}. The NEP improves with higher resistance values at a rate of 5 to 8 dB/decade of resistance up to the point where the feedback-



8. **Optimal system gain exceeds the maximum achievable** gain for certain values of feedback resistance. Above M_T, the APD becomes excessively noisy.



9. **The optimal NEP has a minimum** at low background light currents. The feedback resistance was determined from Fig. 7.

resistor thermal noise is significant. Larger values of feedback resistance do not improve the NEP. A computer approximation is probably the most precise approach, but choosing a sufficiently large R_f commensurate with system bandwidth is the most practical. The use of a smaller-than-optimal R_f reduces the system's sensitivity only slightly, since NEP does not change much with R_f.

The NEP and S/N approaches are essentially the same. For example, if a system's NEP is 10^{-13} W/$\sqrt{\text{Hz}}$ and an S/N = 8 is desired, the minimum light power necessary in a 1-Hz bandwidth is 8×10^{-13} W/$\sqrt{\text{Hz}}$. A comparison of Eqs. 17, 18 and 19 with experimental results is very good and in most cases better than 10%.

The above system analysis can be applied to p-i-n photodiode systems by making two adjustments in Eqs. 17 and 19:

1. Let $M_{opt} = M = 1$.
2. Let $I_{DB} + I_{DS} = I_{PIN}$ (dark current)

The APD system is most commonly used in the 30-to-50-MHz frequency range for comunication and ranging systems. Since many APD systems that are already optimal at high frequencies are commercially available in modular form, a system using a low-frequency op amp is considered here. The results, however, are representative of most APD systems at any frequency.

Let's look at the system shown in Fig. 3. Assume that $T = 300°K$, $\lambda = 6328$ Å (He-Ne laser) and I_{DC} varies from 0 to 10^{-8} A. We arbitrarily set $I_s = I_{DC}$.

The APD is Texas Instruments' TIXL 56, which has an active area with a diameter of 10 mils. The following specs apply to the APD: $V_B = 160$ V, $i_{DB} = 5 \times 10^{-12}$ A, $i_{DS} = 3.5 \times 10^{-9}$ A, $R_s = 50\ \Omega$, $M_T = 1000$, $d = 2.3$ and $n = 0.6$.

The op amp—a Teledyne Philbrick 100301—has an i_{AB} of 5×10^{-12} A and an e_{nA} of 1.6×10^{-8} V/$\sqrt{\text{Hz}}$. In addition $i_{nA} = 8 \times 10^{-13}$ A/$\sqrt{\text{Hz}}$, $A = 10^6$ and gain-bandwidth product = 2 MHz.

From these specifications, Figs. 7 through 9 can be plotted. With Eq. 17, the changes in S/N vs APD gain are shown for different signal-power levels in Fig. 6. Note how optimal gain passes through the peak of the S/N curve; once the light power becomes larger than the APD bulk leakage, the optimal gain drops.

Remember that $I_{DC} = I_s$ was arbitrarily chosen for this example. If $I_s > I_{DC}$, the NEP would improve. Also Fig. 6 does not look exactly like Fig. 1 since M varies very nonlinearly with bias voltage. Additional changes in curve forms result from the use of gain rather than bias voltage as one of the axes.

From Eq. 19, the variation of NEP with R_f is plotted in Fig. 7 for different background light levels. The NEP improves up to $R_f = 5 \times 10^4\ \Omega$ and then levels off with no improvement with larger values. NEP is referred to as NEP_{opt} above this level. Note that NEP increases only about 20% per decade for this example at less than optimal values of R_f. For practical purposes, the optimal choice of R_f is independent of background light level.

Fig. 8 is based on Eq. 18 and shows optimal gain vs background light current at different values of feedback resistor. Notice that M_{opt} is affected more by changes in R_f than is the NEP in the previous figure. Also, when $I_{DC} \simeq I_{DB}$, the optimal gain decreases as in Fig. 6. For some values of feedback resistor, the optimal gain cannot be achieved because it is above the maximum gain, M_T, at which the APD can operate before becoming excessively noisy.

Finally Fig. 9 shows NEP_{opt} vs background light current for an optimal value of R_f—5×10^4 Ω, from Fig. 7. The best NEP for this system is 5.6×10^{-13} W/$\sqrt{\text{Hz}}$. ■■

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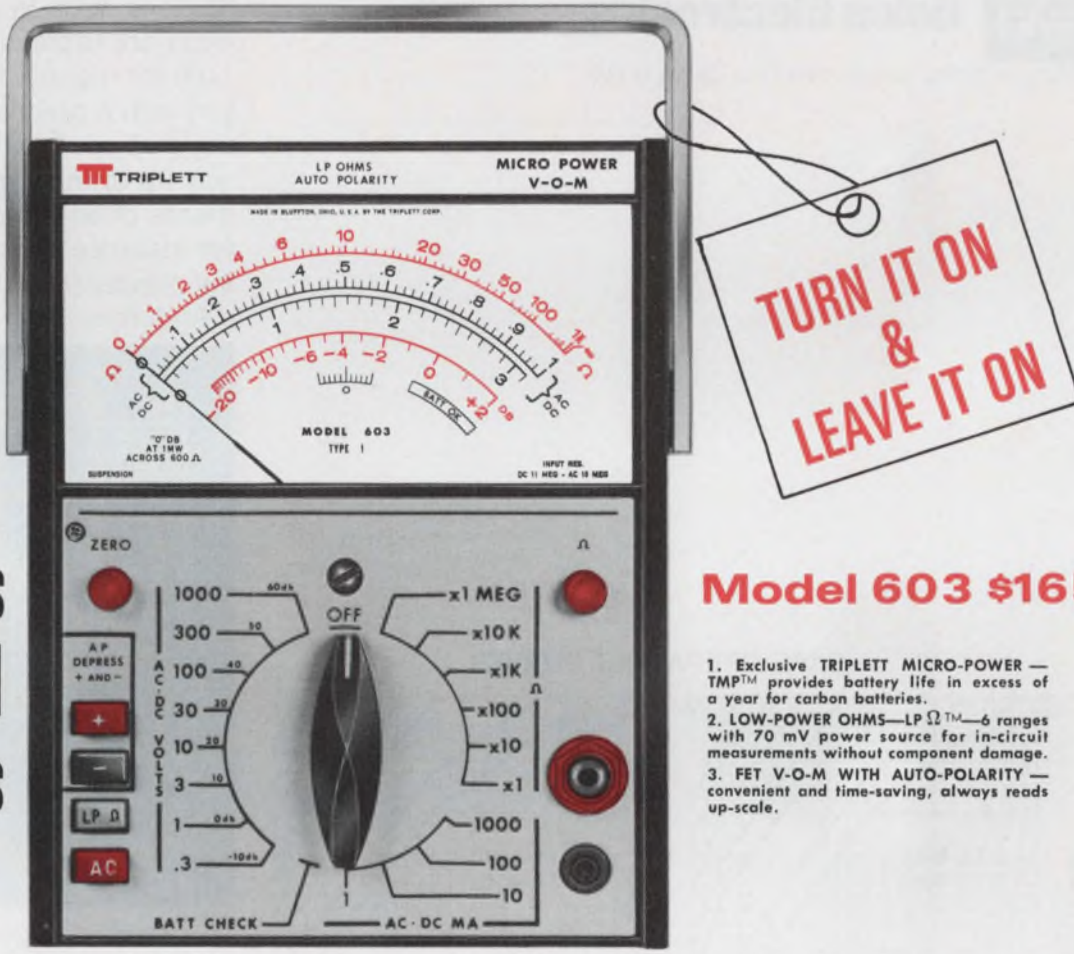

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INFORMATION RETRIEVAL NUMBER 129

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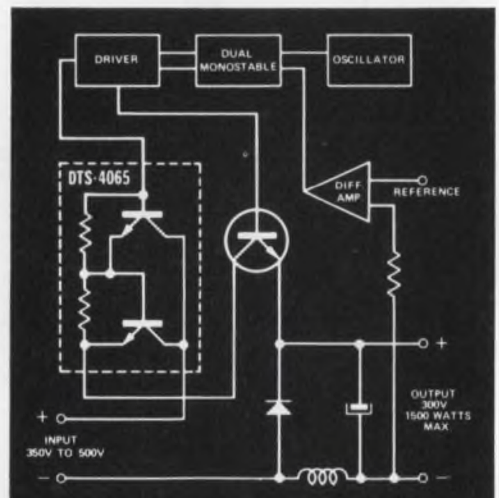

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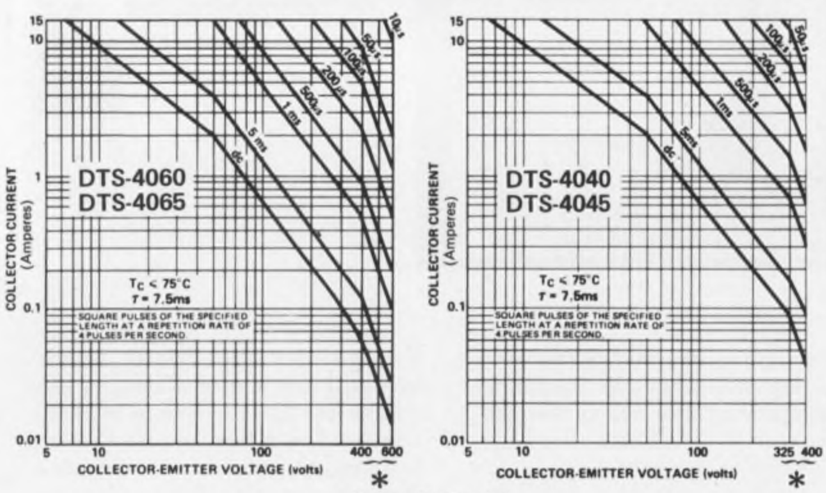

*Reverse Bias Required

TYPE	V_{CEO}	I_C (Cont.)	V_{EBO} (Max.)	$V_{CEO(sus)}$	h_{FE} @ I_C	t_f (com. base)	P_D(max.)
DTS-4040	400V	15A	20V	325V	250/3A	0.25μs	100W
DTS-4045	400V	15A	20V	325V	500/3A	0.25μs	100W
DTS-4060	600V	15A	20V	400V	250/3A	0.25μs	100W
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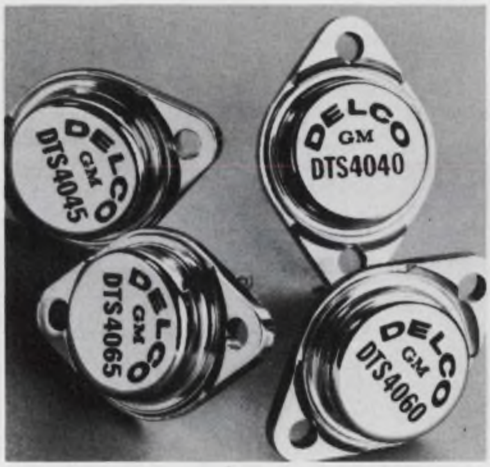

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INFORMATION RETRIEVAL NUMBER 40

Minimize the effects of time delay with a predictive network. Conventional delay lines and op amps synthesize the required characteristic.

Conventional sampling and PCM encoding of speech signals waste channel bandwidth because of redundant information in the input signal. Predictive encoding techniques conserve bandwidth by encoding only the difference between the current and predicted values of the signal. But prediction of speech signals usually requires extensive digital processing, involving such algorithms as the Fast Fourier Transform. On the other hand, conventional analog delay networks can perform the same operation—often with considerable savings in hardware and software.

All electrical networks take time to respond to an incident signal change, just as mechanical systems take time to respond to an accelerating force. This delaying effect of a network is expressed in three ways:

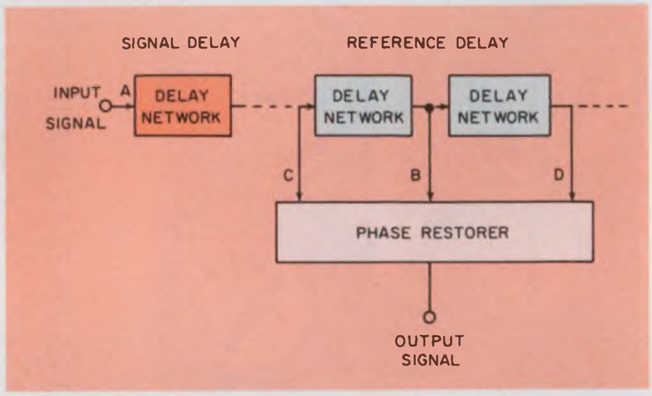
1. Phase shift—the difference in phase between signals entering and leaving the network.
2. Phase delay—the phase shift at a specific frequency divided by the frequency.
3. Envelope delay—the time taken by a signal to pass through a network.

Predictive delay networks use conventional delay elements but do not comply with the rule that associates envelope delay and phase shift with frequency. They achieve envelope delay without phase shift by arithmetically comparing a group of delayed reference signals. From these, the circuit reconstructs a close approximation to the amplitude and phase of the original signal. In this way a fundamental electrical law is conveniently circumvented.

Compensating for signal phase shifts

The networks are intended for speech signal processing, predictive encoding and noise reduction. They can be incorporated in amplifier and servomechanism feedback loops to improve high frequency and transient responses by compensating for open-loop phase shift.

Lewis Illingworth, Chief Engineer, Radio Engineering Products, P.O. Box 460, Montreal 248, Canada.

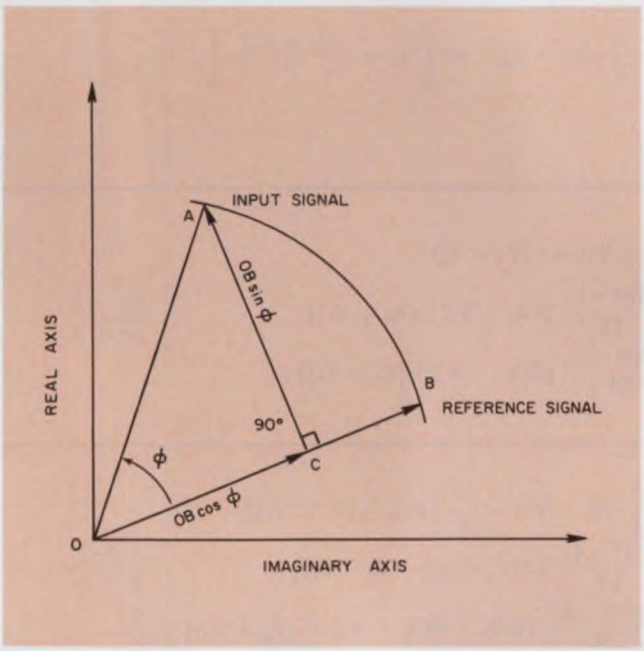


1. **A predictive delay network** preserves the input signal's envelope delay while restoring the original phase. A linear combination of delayed reference signals compensates for the phase shift of the signal delay section.

A predictive delay network has three basic parts: a signal delay, reference delay and phase restorer (Fig. 1). The signal delay is the principal delay network of the system, and it imparts both phase shift and envelope delay to the input signal. The reference delay has a number of sections, each of which delays and phase-shifts the signal by some fixed fraction of the total signal delay. The various delayed signals are compared in the phase restorer and linearly processed to generate an approximation to the input signal.

The closeness of the approximation, and the range of phase shift for which the phase control can maintain zero phase angle, depends principally on the number of signals from the reference delay available for processing by the phase restorer. This number is called the order of the network. The approximation depends, to a much smaller extent, on the ratio between the phase shift of the signal delay and the total phase shift of the signal and reference delays. This is called the delay ratio of the network.

Although the networks are intended to produce envelope delay, the operation of the restorer function depends only on the phase shift of the delay elements. Therefore we shall express all time delay values by their phase shift. For most delay lines, the envelope delay is approximately



2. **Orthogonal phasors** derived from the delayed reference signals serve to reconstruct the input signal. One of the phasors is parallel to the phasor representing the signal input to the reference network.

the phase shift divided by the frequency. Hence the use of the phase shift (the delay multiplied by the frequency) effectively normalizes the network functions.

Generating the restoring signals

The phasor diagram (Fig. 2) shows how the original signal (with delayed envelope) is reconstructed. Two orthogonal signals, OC and CA, are derived from the delayed signal OB. Phasor OC is parallel to OB, and phasor CA is normal to OB. Their vector sum approximates input signal OA, which requires that

$$|OC| = |OA| \cos \phi$$

and

$$|CA| = |OA| \sin \phi$$

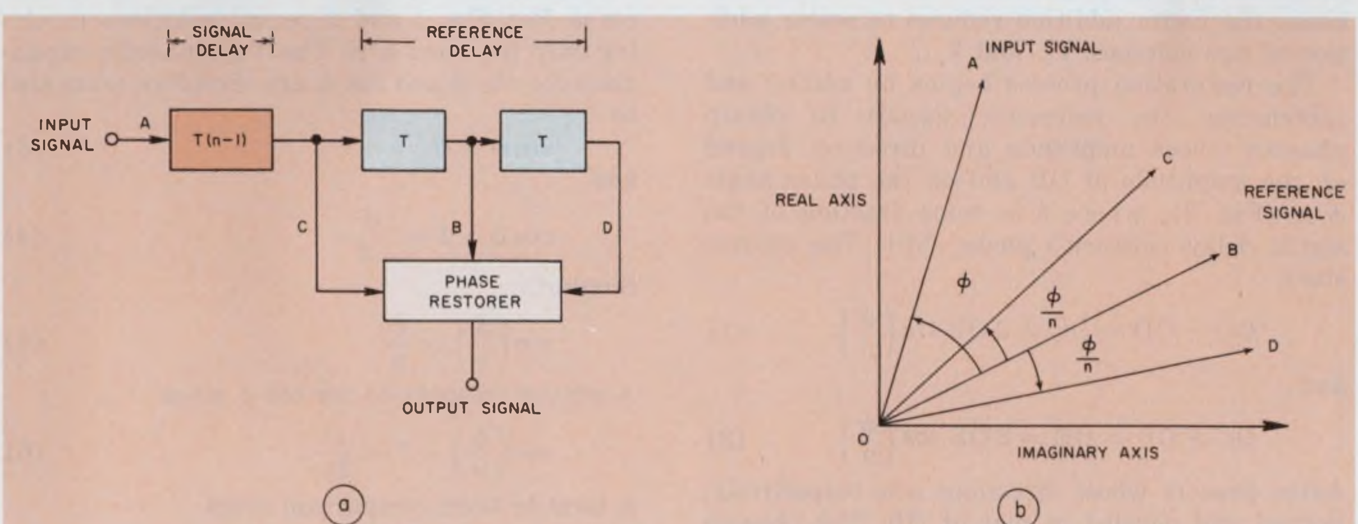
Since the magnitude of the phasor OB equals that of phasor OC, these expressions can be written as

$$|OC| = |OB| \cos \phi$$

and

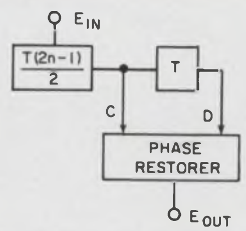
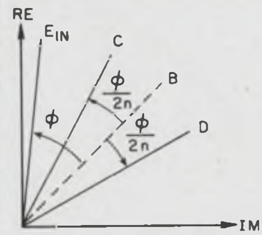
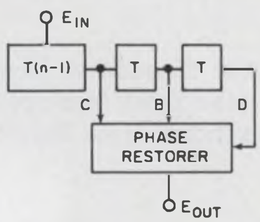
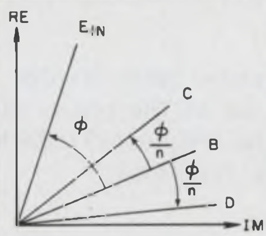
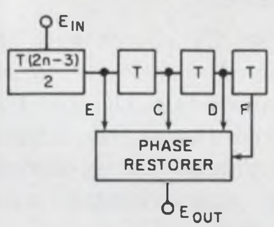
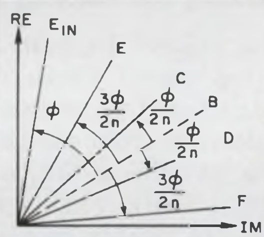
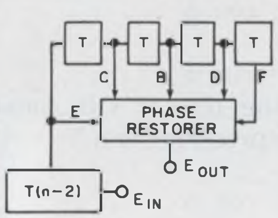
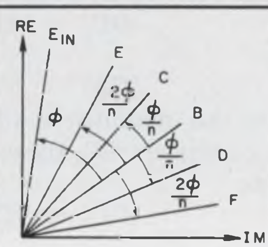
$$|CA| = |OB| \sin \phi$$

However, the imaginary axis is merely a



3. **A third order filter (a)** provides three reference signals. The phasor diagram (b) shows that the angle ϕ/n may be used to reconstitute the input. Linear addition and subtraction in the restorer section generates the orthogonal restoring vectors. Angle ϕ equals the phase shift of the signal delay section.

Table 1. Filter transfer functions

Filter	Phasor Diagram	Transfer Function	Delay Ratio
		$\frac{1}{2}(V_C + V_D) + n(V_C - V_D)$	$\frac{2n-1}{2n+1}$
		$V_B + \frac{n}{2}(V_C - V_D) - n^2\left[V_B - \frac{(V_C + V_D)}{2}\right]$	$\frac{n-1}{n+1}$
		$\frac{1}{2}(V_C + V_D) + n(V_C - V_D)$ $- \frac{(4n^2-1)}{16}[(V_C + V_D) - (V_E + V_F)]$ $- \frac{n(4n^2-1)}{24}[3(V_C - V_D) - (V_E - V_F)]$	$\frac{2n-3}{2n+3}$
		$V_B + \frac{n}{2}(V_C - V_D) - \frac{n^2}{2}[2V_B - (V_C + V_D)]$ $- \frac{n(n^2-1)}{12}[2(V_C - V_D) - (V_E - V_F)]$ $+ \frac{n^2(n^2-1)}{24}[6V_B - 4(V_C + V_D) + (V_E + V_F)]$	$\frac{n-2}{n+2}$

mathematical convenience. The two signals are available only as projections onto the real axis; hence the vector addition reduces to scalar addition of two voltages, V_{OC} and V_{CA}.

The restoration process begins by adding and subtracting the reference signals to obtain phasors whose amplitude and direction depend on the amplitude of OB and on the phase angle ϕ/n (Fig. 3), where n is some fraction of the signal delay network's phase shift. The expressions

$$OC - OD = DC = 2\,OB \sin\left(\frac{\phi}{n}\right) \qquad (1)$$

and

$$OC + OD = OE = 2\,OB \cos\left(\frac{\phi}{n}\right) \qquad (2)$$

define phasors whose directions are, respectively, normal and parallel to that of OB. The phasors (Eqs. 1 and 2) have the proper direction for use in the synthesis of the input waveform.

Construction of orthogonal phasors with the correct magnitude requires that $\sin(\phi/n)$ and $\cos(\phi/n)$ be expressed in terms of $\sin\phi$ and $\cos\phi$. But Eqs. 1 and 2 permit solutions involving only the term ϕ/n. The Taylor-series expansions for $\sin\phi$ and $\cos\phi$ are therefore truncated to

$$\sin\phi \simeq \phi \qquad (3)$$

and

$$\cos\phi \simeq 1 - \frac{\phi^2}{2}. \qquad (4)$$

Similarly

$$\sin\left(\frac{\phi}{n}\right) \simeq \frac{\phi}{n} \qquad (5)$$

A similar comparison for $\cos\phi$ gives

$$\cos\left(\frac{\phi}{n}\right) \simeq 1 - \frac{\phi^2}{2n}. \qquad (6)$$

A term-by-term comparison gives

$$\sin\phi \simeq n \sin\left(\frac{\phi}{n}\right) \qquad (7)$$

A similar comparison for $\cos\phi$ gives

Table 2. Filter performance vs phase shift (f_oT)

Insertion loss and phase response for second order networks.

Signal	Insertion loss, dB				Phase shift, °				
Delay	0.5	0.66	0.8	0.9	0.5	0.66	0.8	0.9	Delay Ratio
(deg.)	1.5	2.5	4.5	9.5	1.5	2.5	4.5	9.5	n
5	−0.0293	−0.0316	−0.0325	−0.0329	0.0112	0.0121	0.0125	0.0126	
10	−0.1159	−0.1251	−0.1287	−0.1300	0.0888	0.0958	0.0985	0.0995	
15	−0.2562	−0.2765	−0.2844	−0.2871	0.2935	0.3164	0.3253	0.3284	
20	−0.4447	−0.4797	−0.4933	−0.4980	0.6768	0.7286	0.7487	0.7556	
25	−0.6746	−0.7273	−0.7478	−0.7548	1.2776	1.3734	1.4103	1.4231	
30	−0.9385	−1.0114	−1.0396	−1.0494	2.1220	2.2771	2.3369	2.3575	
35	−1.2291	−1.3240	−1.3608	−1.3735	3.2239	3.4532	3.5415	3.5719	

Insertion loss and phase response for third order networks

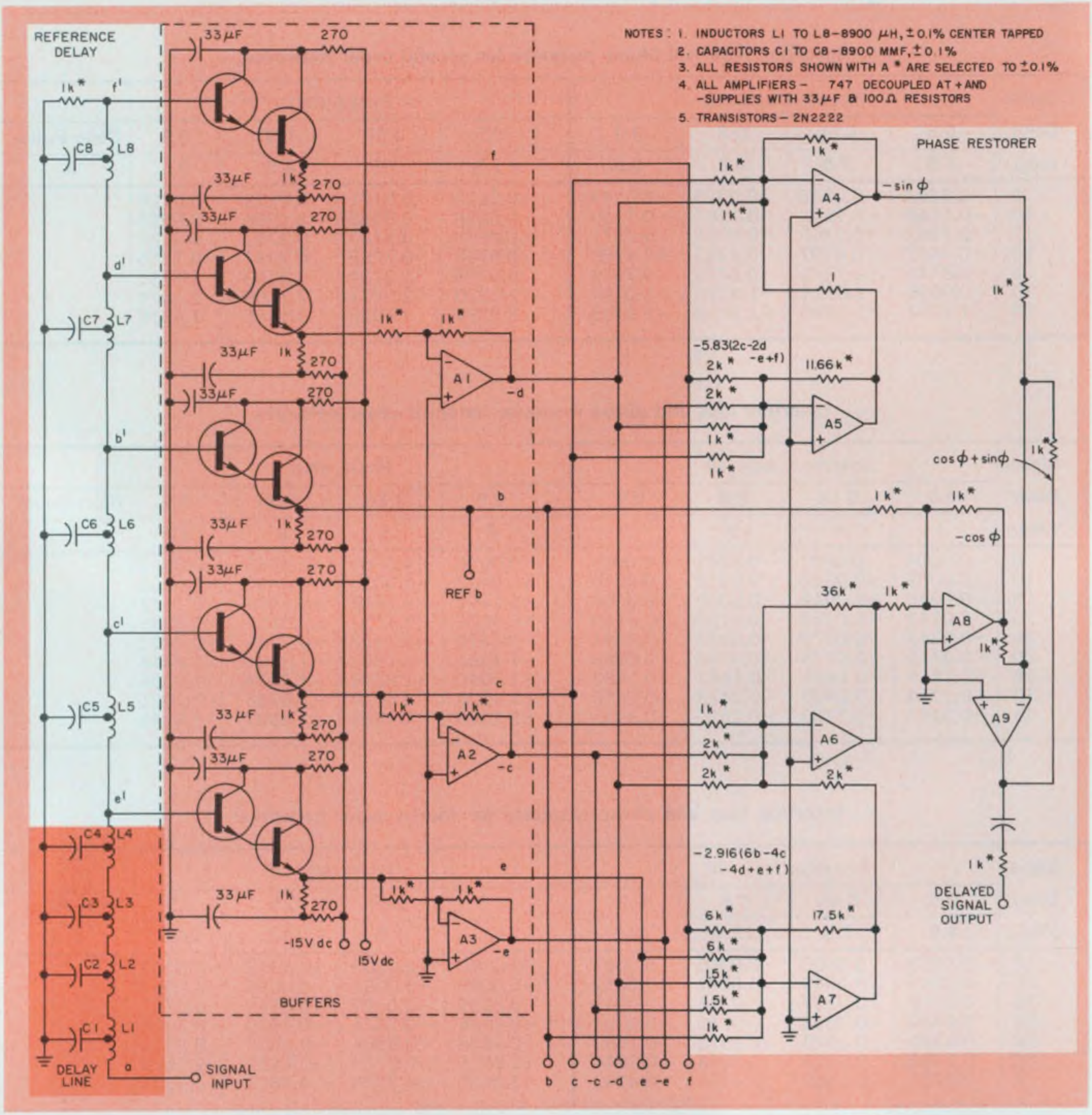
Signal	Insertion loss, dB				Phase shift, °				
Delay	0.5	0.66	0.8	0.9	0.5	0.66	0.8	0.9	Delay Ratio
(deg.)	3	5	9	19	3	5	9	19	n
5	−0.0001	−0.0001	−0.0001	−0.0001	−0.0056	−0.0061	−0.0063	−0.0063	
10	−0.0009	−0.0010	−0.0010	−0.0010	−0.0447	−0.0483	−0.0497	−0.0502	
15	−0.0045	−0.0049	−0.0050	−0.0050	−0.1491	−0.1610	−0.1657	−0.1673	
20	−0.0143	−0.0154	−0.0159	−0.0160	−0.3471	−0.3750	−0.3850	−0.3896	
25	−0.0347	−0.0376	−0.0387	−0.0391	−0.6620	−0.7152	−0.7359	−0.7431	
30	−0.0716	−0.0775	−0.0798	−0.0806	−1.1091	−1.1982	−1.2328	−1.2448	
35	−0.1315	−0.1424	−0.1467	−0.1482	−1.6940	−1.8296	−1.8824	−1.9006	
40	−0.2214	−0.2400	−0.2473	−0.2498	−2.4100	−2.6018	−2.6763	−2.7021	
43	−0.3487	−0.3780	−0.3895	−0.3935	−3.2369	−3.4918	−3.5907	−3.6249	

Insertion loss and phase response for fourth order networks

Signal	Insertion loss, dB				Phase shift, °				
Delay,	0.5	0.66	0.8	0.9	0.5	0.66	0.8	0.9	Delay Ratio
(deg.)	4.5	7.5	13.5	28.5	4.5	7.5	13.5	28.5	n
10	0.0003	0.0003	0.0003	0.0003	−0.0003	−0.0003	−0.0003	−0.0003	
20	0.0045	0.0049	0.0051	0.0051	−0.0086	−0.0093	−0.0096	−0.0097	
30	0.0217	0.0237	0.0244	0.0247	−0.0639	−0.0697	−0.0719	−0.0727	
40	0.0636	0.0693	0.0716	0.0724	−0.2636	−0.2875	−0.2970	−0.3003	
50	0.1396	0.1523	0.1573	0.1590	−0.7838	−0.8564	−0.8850	−0.8950	
60	0.2496	0.2723	0.2813	0.2844	−1.8925	−2.0720	−2.1431	−2.1679	
70	0.3733	0.4065	0.4195	0.4240	−3.9430	−4.3275	−4.4801	−4.5333	

Insertion loss and phase response for fifth order networks

Signal	Insertion loss, dB				Phase shift, °				
Delay,	0.5	0.66	0.8	0.9	0.5	0.66	0.8	0.9	Delay Ratio
(deg.)	6	10	18	38	6	10	18	38	n
10	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	
20	0.0001	0.0001	0.0001	0.0001	0.0020	0.0022	0.0023	0.0024	
30	0.0010	0.0011	0.0012	0.0012	0.0147	0.0161	0.0167	0.0174	
40	0.0057	0.0062	0.0065	0.0066	0.0568	0.0626	0.0648	0.0656	
50	0.0208	0.0230	0.0238	0.0241	0.1548	0.1705	0.1768	0.1785	
60	0.0596	0.0657	0.0681	0.0689	0.3313	0.3654	0.3790	0.3838	
70	0.1429	0.1577	0.1636	0.1657	0.5870	0.6485	0.6731	0.6816	
80	0.3014	0.3334	0.3461	0.3506	0.8729	0.9669	1.0047	1.0170	
90	0.5769	0.6400	0.6652	0.6742	1.0502	1.1680	1.2156	1.2301	



4. **Practical fifth-order network** maintains the output phase to within − 2 to +3 degrees of the input signal. The signal delay is 40 µs and the over-all delay is 80 µs. Op amps perform the requisite linear additions.

$$\cos\phi \simeq 1 - n^2 (1 - \cos\frac{\phi}{n}). \qquad (8)$$

Eqs. 1 and 2 define sin ϕ/n and cos ϕ/n in terms of phasors OC and OD. Substitution of these terms in Eqs. 7 and 8 provides the two orthogonal phasors needed to reconstruct the input signal:

$$OB \sin\phi \simeq \frac{n}{2}(OC - OD), \qquad (9)$$

and

$$OB \cos\phi \simeq OB - n^2 [OB - \frac{1}{2}(OC + OD)]. \qquad (10)$$

The sum of the two phasors, or the corresponding voltages, gives the desired output, expressed in the form

$$V_{out} = V_B - n^2 [V_B - \frac{1}{2}(V_C + V_D)] + \frac{n}{2}(V_C - V_D). \qquad (11)$$

Higher-order networks, with more reference signals, allow use of more terms in the Taylor expansion. The approximations are then closer and permit correction for larger signal-phase shifts. The method of analysis is similar to that of the third-order network, though the equations contain more terms. The additional terms occur because extra angles are defined by the additional phasors. A summary of the filter configurations up to order five is given in Table 1. Table 2 lists the corresponding performance.

Error sources in practical networks

Predictive delay networks may employ either digital or analog techniques or a combination of both. The principal sources of system error are magnitude errors in the reference-delay signals caused by digital quantizing, approximations and analog component tolerances. The multiplications of small differences between reference signals by large constants in the phase restorers greatly amplifies the errors. Delayed reference-signal accuracy is limited to ±0.1% in analog systems by the practical limitations of the components. A digital system with a 12-bit analog-to-digital converter achieves accuracy of ±0.025%. With these figures, the maximum value of any multiplier in a phase-restorer transfer function that will cause an output signal amplitude error of less than 0.5 dB is 50 for an analog system and 200 for a 12-bit digital system.

The figures, however, must be treated with caution. The analog error represents a variation of signal amplitude and phase, whereas the digital error represents noise. The maximum permissible value of a multiplier limits the maximum delay ratio that can be employed before gross errors occur. These are listed in Table 3.

Other major factors influencing the accuracy of an analog system are addition and subtraction errors in the manipulation of the delayed reference signals. The effect of such errors on system accuracy is comparable to a magnitude error in a reference signal. It is not encountered in digital networks that leave accurate addition and subtraction circuits.

Multiplication errors have a smaller influence on the over-all accuracy. This is because the effect is direct—a 1% gain error produces a 1% amplitude error, whereas a 1% error in a reference signal amplitude can produce a 50% error in the output amplitude.

Design example—fifth-order network

A fifth-order analog predictive delay network with a 0.5 delay ratio demonstrates the feasibility of the design technique (Fig. 4). This particular network was chosen for its complexity—it has probably the highest order that can be achieved with a normally obtainable component accuracy. It employs an eight-section delay line with a signal delay of 40 μs and total delay of 80 μs. The five reference signals are tapped from the four-section delay line L_5 through L_8. All additions and subtractions are made by summing currents at the virtual ground in the input circuits of operational amplifiers, and multiplication is by operational amplifiers. All resistor, inductor and capacitor values are adjusted to better than 0.1%. The network is designed to operate over a 0-to-3-kHz frequency range with an amplitude error of −0, +0.06 dB and phase error of −0, +0.4°. The measured performance shows an amplitude error of ±0.35 dB and a phase error of −2, +3°, which substantiates accuracy predictions.

The circuit arrangement allows adjustment of the various terms in the phase-restorer transfer function. All adjustments make use of a phasemeter and VTVM with point b as the reference for both phase and amplitude. An accurate adjustment of each stage is required to ensure correct operation of the network, just as every tuned circuit in a wave filter must be adjusted to a resonant frequency for correct amplitude and phase response.

First, adjust the delay network sections and the gains of amplifiers A_1, A_2 and A_3 to obtain a set of equal-amplitude signals, +b, +c, −c, −d, +e, −e and +f, with accurate phase differences. Next, disconnect amplifiers A_6 and A_7 and adjust the gain of A_8 for an amplitude of −6. Reconnect A_6 and adjust the resistors for an output equal to 18 (2b −c −d).

Adjustment is simplified by setting the various components at different frequencies. Start by removing the resistor corresponding to 2b. The output signal becomes −18 (c + d) and is equal to 18 at frequencies below 100 Hz when the cosine of the phase angle approaches 1. Reconnect the resistor corresponding to 2b. At frequencies below 100 Hz, 2b = c + d; so the signal should be zero. Methodically adjust each stage for the correct function at high frequencies and for zero signal at low frequencies. Two major checks are the sine signal at the output of A_4 (90° out of phase with the signal at b) and the cosine signal at the output of A_8 (180° out of phase with A_6's output). With these correct, the output of the final summing amplifier, A_9, provides the required approximation to the input. ■■

Table 3. Allowable delay ratio for 0.5 dB amplitude error

Network order	2	3	4	5	Network Type
Delay ratio for 0.5 dB error	0.98	0.75	0.63	0.49	Analog
	0.99	0.87	0.75	0.61	12-bit a/d

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BCD logic- Part 3

BCD division: the inverse of multiplication but more complex in execution. Successive subtractions and additions can do it, but ROMs help speed results.

This is the third of a series of articles on binary-coded-decimal logic. The first article discussed BCD addition and subtraction ("BCD: Logic of Many Uses," ED No. 13, p. 90). The second article considered multiplication ("BCD Multiplication, ED No. 14, p. 62).

Binary coded decimal (BCD) division, like any division, is the inverse of multiplication. In multiplication a product can be formed by adding the multiplicand to itself. The number of times this is done is equal to the multiplier. In division a quotient can be formed by repeatedly subtracting the divisor from the dividend. The number of times this can be done is the quotient. However, note the phrase "can be done." After successive subtractions, should the remainder be smaller than the divisor, the subtraction operation must cease. Another operation must then intervene before subtraction can be resumed.

BCD division therefore may involve a trial-and-error process, since at some point one operation depends upon the result of a previous operation. This is illustrated in the so-called "restoring" technique of BCD division (Table 1). Each time a subtraction is made, the polarity of the remainder must be checked. A negative remainder indicates that the quotient has become too large; the previous remainder and quotient must be restored. This is done by adding the divisor to the negative remainder and reducing the quotient by a unit increment, as shown.

Note that the process starts with a unit increment, ΔQ, of the most-significant quotient digit. When the remainder becomes negative—and after the remainder is restored—the divisor is moved one digit to the right (divided by 10). Then subtraction can resume. Now, however, with each subtraction the quotient's second most-significant digit increases by a unit quantity. This sequence of operations repeats for succeeding quotient digits until the remainder becomes zero or the quotient has the degree of accuracy desired.

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Eliminating the restoring operation

But the restoring technique is slow. It requires an average of 5.5 subtractions and one restoration for each quotient digit. The process can be speeded somewhat by the elimination of the restoring operation (Table 2). Instead of a restoring routine after the remainder becomes negative, the divisor is shifted one digit to the right, and then the divisor is added repeatedly until the remainder becomes positive again. Next, the divisor is shifted one more digit to the right and repeatedly subtracted from the remainder until it becomes negative. In this way the subtract and add processes are alternated until the desired quotient accuracy is obtained.

When a calculator starts a nonrestoring process, it checks the dividend's left-most digit for the presence of zero. If a zero is present, the machine shifts the dividend to the left until the most-significant digit is detected. Then it tests the polarity of the dividend. If the polarity is positive, the calculator subtracts the divisor from it; if the polarity is negative, the machine adds to it. And each time a subtract operation is performed, the circuit increases the corresponding quotient digit by a unit quantity. For an addition, the quotient digit is decreased.

Speed division with divisor multiples

By a technique similar to adding multiples of the multiplicand, BCD division can be speeded by use of multiples of the divisor. Like paper-and-pencil division methods, the multiple-divisor technique uses an "estimate" quotient to multiply the divisor before the subtraction/addition process takes place. However, to simplify the estimating process (Table 3), the quotient is restricted to the five values 1, 2, 5, 0.5, 0.2. These are multiplied by appropriate powers of 10 as the process proceeds. In a calculator the fractional values of 0.2 and 0.5 can be produced by a shift of a 2 or 5

Table 1. Restoring technique 184,659 ÷ 789 = 234 + R33

	ΔQ	Quotient
+ 184659-Dividend		
− 78900-Divisor		
+ 105759	+ 100	1 0 0
− 78900		
+ 26859	+ 100	2 0 0
− 78900		
− 52041-negative remainder	+ 100	3 0 0
1st Restoring operation		
+ 78900		
26859	− 100	2 0 0
− 7890		
+ 18969	+ 10	2 1 0
− 7890		
+ 11079	+ 10	2 2 0
− 7890		
+ 3189	+ 10	2 3 0
− 7890		
− 4701-negative remainder	+ 10	2 4 0
2nd Restoring operation		
+ 789		
+ 3189	− 10	2 3 0
− 789		
+ 2400	+ 1	2 3 1
− 789		
+ 1611	+ 1	2 3 2
− 789		
+ 822	+ 1	2 3 3
− 789		
+ 33-final remainder	+ 1	2 3 4

Table 2. Nonrestoring technique 184,659 ÷ 789 = 234 + R33

	ΔQ	Quotient
+ 184659-Dividend		
− 78900-Divisor		
+ 105759	+ 100	+ 100
− 78900		
+ 26859	+ 100	+ 200
− 78900		
− 52041-negative remainder	+ 100	+ 300
+ 7890		
− 44151	− 10	+ 290
+ 7890		
− 36261	− 10	+ 280
+ 7890		
− 28371	− 10	+ 270
+ 7890		
− 20481	− 10	+ 260
+ 7890		
− 12591	− 10	+ 250
+ 7890		
− 4701	− 10	+ 240
+ 7890		
+ 3189-positive remainder	− 10	+ 230
− 789		
− 2400	+ 1	+ 231
+ 789		
− 1611	+ 1	+ 232
+ 789		
− 822	+ 1	+ 233
+ 789		
33-Final remainder	+ 1	+ 234

Table 3. Estimating schedule

	Left most dividend digit: 1	2	3	4	5	6	7	8	9
Divisor digit 1	1	2	2	2	5	5	5	5	5
2	.5	1	1	2	2	2	2	2	5
3	.5	.5	1	1	2	2	2	2	2
4	.2	.5	1	1	1	1	2	2	2
5	.2	.5	.5	1	1	1	1	2	2
6	.2	.5	.5	.5	1	1	1	1	1
7	.2	.2	.5	.5	.5	1	1	1	1
8	.2	.2	.5	.5	.5	1	1	1	1
9	.2	.2	.5	.5	.5	.5	1	1	1

Estimated quotient digit

Table 4. Division by using the estimating schedule

184,659 ÷ 789 = 234 + R33
Dividend ÷ divisor = Quotient

Dividend or remainders	Most-significant digit of divisor	Estimated multiplier	Quotient
+ 184659-dividend	7	-0.2×10^3	200
− 157800*			
+ 26859-positive remainder	7	-0.2×10^2	220
− 15780			
+ 11079	7	-0.2×10^2	240
− 15780			
− 4701-negative remainder	7	$+0.5\times10^1$	235
+ 3945			
− 756	7	$+1.0\times10^0$	234
+ 789			
+ 33			

* $789 \times 0.2 \times 10^3 = 157{,}800$

one-digit to the right. The positive powers of 10 are also produced by shifts, but to the left. Table 3, which can be programmed on a ROM, shows the distribution of the estimated multiplying quotients.

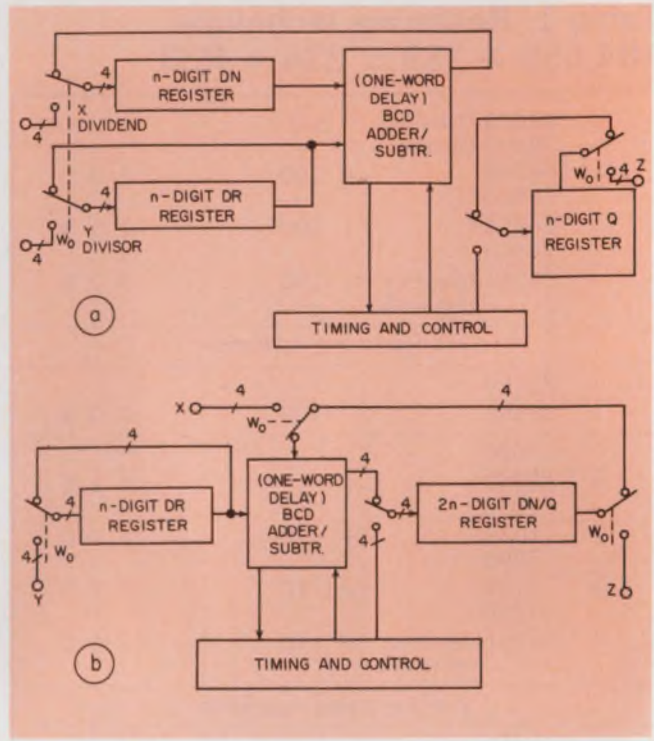
Table 4 repeats the example used in Tables 1 and 2, but with considerably fewer operations. However, the price of the added speed is a substantial increase in hardware.

Other techniques are possible, but the greater amounts of hardware needed do not justify their use in calculators.

How are practical dividers organized? As shown in Fig. 1a, the general configuration of an n-digit divider includes three n-digit registers, an adder/subtractor and the timing and control logic. The three registers store divisor Y in register DR, dividend X in register DN and quotient Q in register Q. Where n is the number of digits in the divisor or dividend, the timing periods are partitioned into n-digit intervals and n + 1 word intervals, and the contents of each register are circulated once every n-digit intervals. The circuit requires one word interval to generate each quotient digit, but the number of circulation periods, T_c, per word interval will vary with the details of a specific technique.

Frequently Q and DN registers are combined to form a double-length accumulator (Fig. 1b). Thus a 2n-digit dividend can be handled. As dividend digits shift to the left during division, the Q digits enter the emptied register stages. The operation of such a double-precision divider, however, requires that each T_c period be 2(n + 1) digit-intervals long.

Dividers can be designed for bit-serial or bit-parallel operation. In a bit-serial circuit, each register in Figs. 1a and 1b becomes four times as long, and the circulation period is 4n clock periods. In a bit-parallel circuit, four parallel, n-stage registers are used, and each signal line and each control switch represents four items in parallel.



1. **The general organization** of a single-precision divider (a) can be converted to a double-precision divider (b) if the functions of the dividend register, DR, are combined with the Q register to form a DN/Q double-length register to hold both quotient and dividend.

Bit serial: slow and simple

Bit-serial circuits are slower but simpler than bit-parallel. Therefore let's first examine two versions of bit-serial dividers—single and double-precision configurations. A single-precision divider for two 16-digit numbers requires an average of $5.5 \times 64 \times 16 = 5632$ clock periods (Fig. 2). Compared to single precision, a double-precision divider requires twice as many periods, or an average of 11,264 (Fig. 3), but it can handle a 32-digit dividend. The reason for this is that the combined DN/Q register requires 128 clock periods for one circulation.

Both double and single-precision systems require the same four-bit intervals, B_0 to B_3, per digit interval in their timing circuits. Then for a 16-digit circuit there are 16-digit intervals, D_0 to D_{15}, in each circulation period. And during each of the 16 word times, W_1 to W_{16}, one quotient digit is generated. Interval W_0 is reserved for loading and unloading the divider circuit. The registers' contents may have to be circulated up to 10 times during one word interval.

Since the single-precision restoring circuit is somewhat simpler than the double-precision configuration, let's concentrate on it first (Fig. 2).

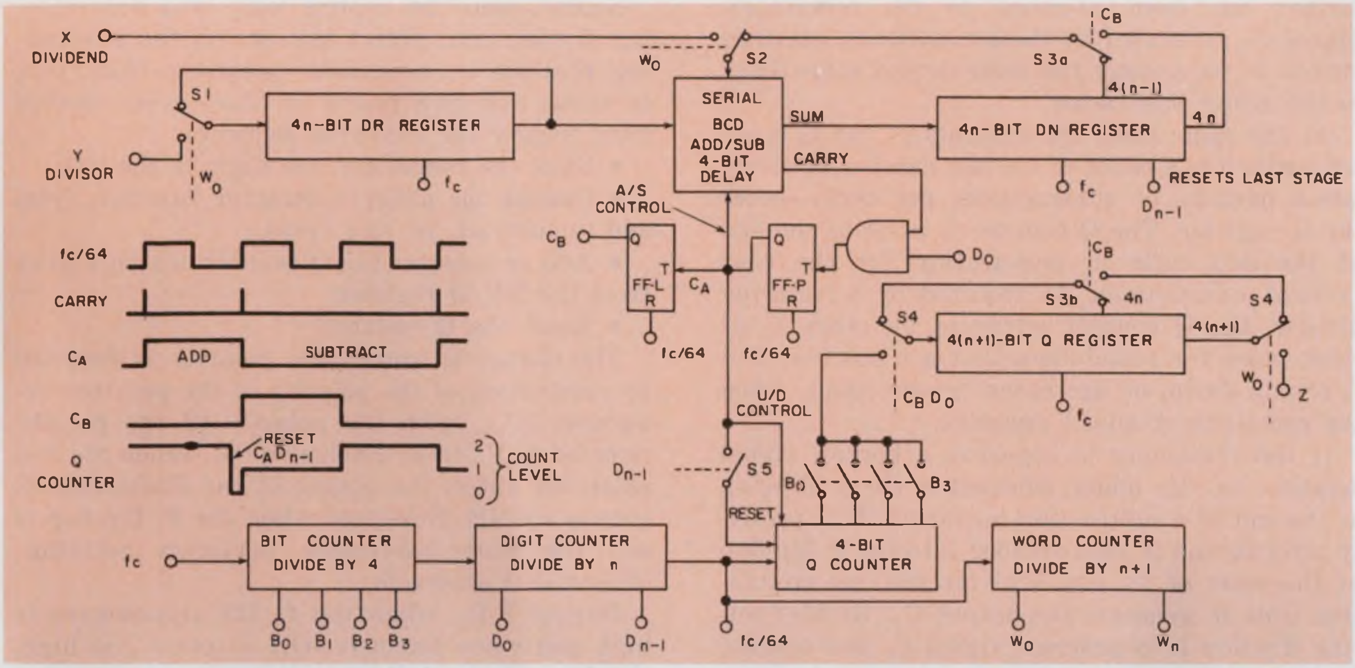
In general, a divider has two main operational modes: input/output and execution. In the input/output mode, which occurs during W_0, the dividend and divisor enter the DN and DR registers. At the same time the quotient, or answer, leaves the Q register. Interval W_0 needs only one circulation period to do this. The execution mode starts with interval W_1 and continues to W_n.

In the restoring algorithm of Table 1, which is used in Fig. 2, the divisor is successively subtracted from the dividend until the remainder becomes negative. Then the divisor is added back to the remainder, followed by a one-digit shift of the DN register's contents to the left. The contents of the Q counter transfer into the Q register, and the counter resets. The process then repeats to generate the second quotient digit during W_2, and so on, for intervals W_3 to W_n.

All three registers—DR, DN and Q—operate at the clock frequency f_c. When n = 16 digits, the DN register has an auxiliary output from stage $4(n-1)$ or 60. The $4(n-1)$ stage output provides the computational circulation into the adder/subtractor. And since the serial adder/subtractor has a built-in, four-bit delay, the total circulation has the required 64 stages.

Thus the output of stage n, or 64, is used only when the contents of DN must be shifted one digit to the left. After one feedback circulation from this output, the four left-most stages contain the next most-significant digit. This is equivalent to a one-digit shift to the left, and the total loop delay is now 68 bits.

The dividend undergoes such a shift after a



2. **In this bit-serial, single-precision, restoring divider,** the contents of the DN register shift one digit to the left when they are recirculated for 4n clock pulses through a 4(n+1) bit delay via actuated switch S_{3a}.

Step-by-step example—0256 ÷ 016—for system in Fig. 2

Time W_i D_i	DA Register digit stage 1 2 3 4		Carry	DN Register digit stage A/S 1 2 3 4	Q counter	Q Register stage 1 2 3 4 5		Operations
0 0	Load*			Load*		clear		New data
· ·								
0 3	1 6 0 0		0	2 5 6 0 0	0	0 0 0 0 0		
1 0	0 1 6 0	↑	0	0 2 5 6 0	1	0 0 0 0 X		↑
1 1	0 0 1 6	one	0	6 0 2 5 X	1	0 0 0 0 X		
1 2	6 0 0 1	circulation	1	9 6 0 2 X	1	0 0 0 0 X	256	
1 3	1 6 0 0	period ↓	0	0 9 6 0 X	1	0 0 0 0 X	−160	
2 0	0 1 6 0		0	0 0 9 6 0	2	0 0 0 0 0	096	
2 1	0 0 1 6		0	6 0 0 9 X	2	0 0 0 0 X		Subtract
2 2	6 0 0 1		0	3 6 0 0 X	2	0 0 0 0 X	096	
2 3	1 6 0 0		1	9 3 6 0 X	2	0 0 0 0 X	−160	↓
3 0	0 1 6 0		1	9 9 3 6 0	1	0 0 0 0 0	936	↑
3 1	0 0 1 6	C_B high	0	6 9 9 3 X	1	1 0 0 0 X	Xfer end of D_0	Add
3 2	6 0 0 1		0	9 6 9 9 X	1	0 1 0 0 X	936	
3 3	1 6 0 0		1	0 9 6 9 X	0	0 0 1 0 X	+160	↓
4 0	0 1 6 0		1	0 0 9 6 0	1	0 0 0 1 0	096	↑
4 1	0 0 1 6		0	0 0 0 9 6	1	0 0 0 0 1		Left Shift & Subtract
4 2	6 0 0 1		0	0 0 0 0 9	1	1 0 0 0 0	960	
4 3	1 6 0 0		0	8 0 0 0 0	1	0 1 0 0 0	−160	↓
5 0	0 1 6 0		0	0 8 0 0 0	2	0 0 1 0 0	800	↑
5 1	0 0 1 6		0	0 0 8 0 X	2	0 0 0 1 X		Subtract
9 3	1 6 0 0		0		6			
10 0	0 1 6 0		0	0 0 0 0 0	7	0 0 1 0 0		↓
10 1	0 0 1 6		0	0 0 0 0 X	7	0 0 0 1 X		
10 2	6 0 0 1		1	4 0 0 0 X	7	1 0 0 0 X		
10 3	1 6 0 0		1	8 4 0 0 X	7	0 1 0 0 X		↓
11 0	0 1 6 0		1	0 8 4 0 0	6	0 0 1 0 0		↑
11 1	0 0 1 6	C_B high	0	0 0 8 4 X	6	6 0 0 1 X		Add
11 2	6 0 0 1		1	0 0 0 8 X	6	1 6 0 0 X		
11 3	1 6 0 0		1	0 0 0 0 X	0	0 1 6 0 X		↓
0 0	0 1 6 0		1	0 0 0 0 0	0	0 0 1 6		Output

X—don't care *—details of locating decimal point not shown divisor has been re-added to the remainder. Signal C_B generated by these conditions, operates switch S_3 to connect the 64th output stage back to the adder/subtractor.

At the same time, the contents of the Q counter—which is a count of the net number of circulation periods, or subtractions, per cycle—enter the Q register. The Q counter is reset at the end of the add cycle in preparation for the next cycle of subtractions. As required by a restoring divider, the Q counter advances on every $f_c/64$ clock pulse for remainders that are positive. But it counts down, or decreases by one count, when the remainder becomes negative.

If the remainder is negative, a borrow signal remains in the adder/subtractor carry flip-flop at the end of a subtraction operation. This polarity information is then strobed into the P flip-flop at the start of D_0 and held for the one circulation time to generate the output C_A. Besides setting flip-flop L to generate signal C_B and operate S_3, signal C_A also switches the adder/subtractor to the add mode, sets the Q counter to the countdown mode and transfers the S_4 contact to enter the contents of the Q counter into the Q register.

Double precision with little extra hardware

The divider configuration in Fig. 3 for a 16-digit divisor and 32-digit dividend provides a double-precision capability, but the dividing time becomes about twice that of a single-precision circuit. However, this is somewhat offset by use of the slightly faster nonrestoring algorithm of Table 2. Only a small increase in hardware over the single-precision circuit of Fig. 2 is required.

Note that a single flip-flop is inserted in the timing chain after the first divide-by-16-counter to double the circulation time. Thus a circulation period is divided into two 64 clock-period frames: the first, F_0, when the $f_c/128$ squarewave is high, the second, F_1, when $f_c/128$ is low.

The 16-digit divisor and the double-length, 32-digit dividend enter the DR and DN/Q registers during period W_0. When in each word interval, W_1, the dividend shifts one digit to the left, via the recirculation process previously explained, one quotient digit is directed into the space thus vacated. After 16 word times, the remainder occupies the 16 left-most positions of the register. The complete quotient occupies the 16 right-most positions.

The control logic for the nonrestoring algorithm differs from that of the restoring in two ways.

First, the DR register's contents circulate twice for each DN/Q circulation. However, the DR output is connected to the BCD adder/subtractor only during the second circulation period —when $f_c/128$ is low, or F_1—via switch S_2.

Second, since the control logic of a nonrestoring divider must detect and act on the alternating changes in remainder polarity—from plus to minus and then minus to plus—every change must trigger the following sequence:

- Shift the remainder one digit to the left.
- Change the adder/subtractor function from add to subtract, or vice versa.
- Add or subtract the Q counter contents to or from the DN/Q register.
- Reset the Q counter.

The change in remainder polarity is detected by comparison of the polarity of the previous remainder, P_{i-1}, with the polarity of the present remainder, P_i, in an Exclusive-OR. When the two polarities differ, the output of the Exclusive-OR gate is a ONE. Note that when the P_i flip-flop is set, the adder/subtractor performs addition; otherwise it subtracts.

During F_1D_0, when the $f_c/128$ squarewave is high and when Exclusive-OR output C_B is high, the Q counter's contents are added or subtracted to or from the DN/Q register when switch S_2 is placed in its lowest position. Otherwise the circuit operates on the remainder with S_2 in top-position. For input loading, S_3 is set to its left position by W_0. And after the Q counter has delivered its contents, the Q counter is reset to a count of one at the end of $B_3D_0F_1$ via S_6.

Bit-parallel: fast but complex

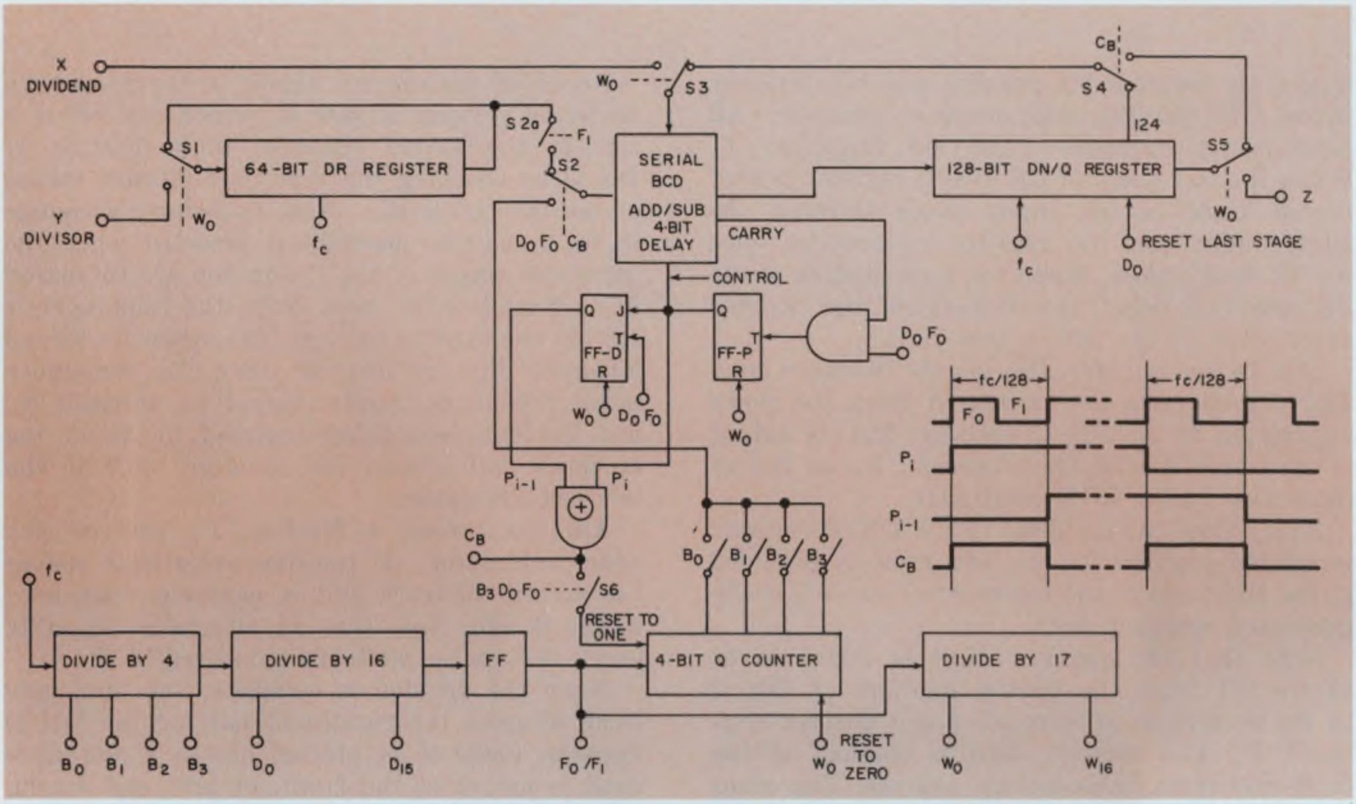
The bit-parallel configuration (Fig. 4) increases computation speed by an order of magnitude over the previously described circuits. A good portion of the increase results from the use of the quotient-approximation technique, described in Tables 3 and 4, and a table look-up digit multiplier. But, of course, considerably more hardware is needed.

The quotient digit is "estimated" from Table 3, and the routine outlined in Table 4 follows. Register DN/Q then sequences as described previously for the double-precision divider.

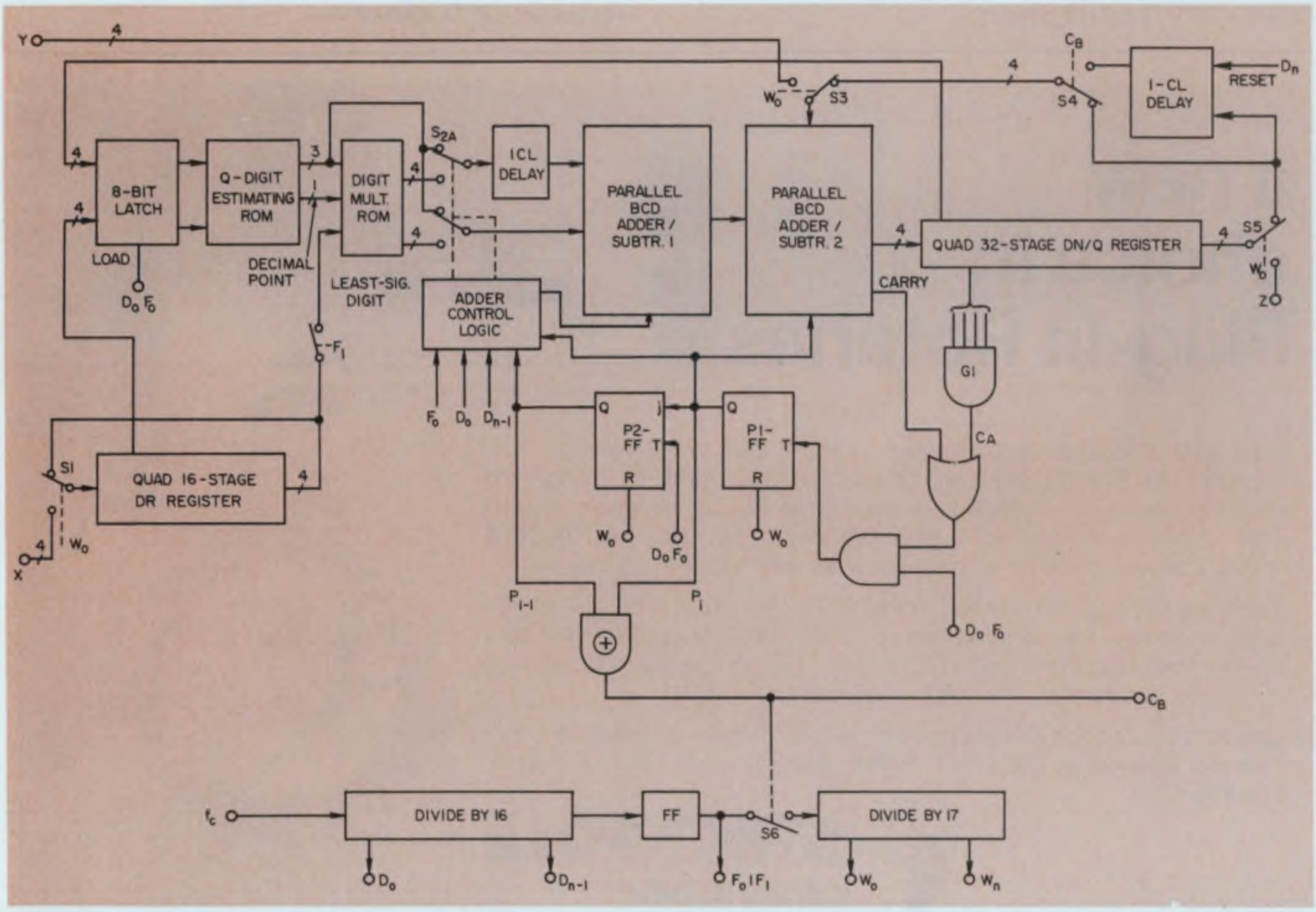
The timing chain is very similar to those used in the bit-serial dividers, but, of course, the bit counter is left out. Now, however, each word interval contains only one or two circulation periods of 32-digit intervals each. Again, a frame flip-flop splits the first 16-digit intervals from the second to form two frames of operation—F_0 and F_1.

During each of the 16-word intervals, a quotient digit is generated and added to or subtracted from the partial quotient. The quotient digit comes from the 100 × 4-bit "estimating" ROM. During D_0F_0 the ROM's inputs are stored in an eight-bit buffer where they are held constant for the complete word interval.

The quad 32-stage DN/Q register in combina-



3. **A circuit for double precision,** and a nonrestoring routine, requires little more hardware than the single-precision, restoring circuit. The DN and Q registers are combined into a single double-length register.



4. **Table look-up methods** and a bit-parallel configuration provide an order-of-magnitude increase in speed in this double-precision divider. One ROM stores the estimating digits, and the other provides digit multiplication.

tion with the four-bit parallel adder/subtractor forms a bit-parallel, digit-serial accumulator. All registers are operated at the clock frequency, f_c. When the last stage of the DN/Q register is connected back to the input stage through the adder/subtractor, the register recirculates once for 32 clock pulses. When the recirculation is via the one-clock delay, the contents of the register are shifted to the left by one digit.

The divisor register, DR, is only 16-stages long. Thus its contents are circulated twice for every circulation of the DN/Q register. But its output is used only during frame period, F_1, as one of the inputs to the ROM multiplier.

Every time the dividend in the DN/Q register is shifted one digit to the left, room is provided at the right end of the register to receive a newly generated quotient digit.

Note that the quotient digit is added to or subtracted from the partial quotient in DN/Q by the movement of S_2 to the upper position during D_0F_0. The quotient digit is one-half of the digit-multiplier, table-lookup address. The other half comes from the DR output.

With S_2 in the lower position, the digit-multiplier output combines with the DN/Q remainder content via the BCD adder/subtractor-2 to generate a new partial product.

An added feature not shown in the previously described systems is gate G_1 which can detect a zero in the second left-most digit location of DN/Q by checking the first four parallel stages of the DN/Q register. And, as before, a change in the remainder polarity is detected when the input and output of the P_2 flip-flop are compared in an Exclusive-OR gate. Now, the remainder is shifted one digit to the left both when its second left-most digit is zero or when the remainder polarity changes. Again, signal C_B actuates S_4, and the one-clock delay inserted by S_1 in the feedback path causes the one-digit shift to the left per circulation.

Also, as before, a flip-flop, P_1, controls the adder/subtractor. A positive remainder makes the circuit subtract and a negative remainder makes it add. Note that P_1 alternates its state every D_0F_0 pulse, while P_2 is steered by P_1.

When the division is complete, the final quotient occupies the righthand half of the DN/Q register, ready to be shifted out as a new dividend is loaded at the front, or left, end during the next W_0. ■■

The fourth article will discuss fixed and floating-point BCD operation.

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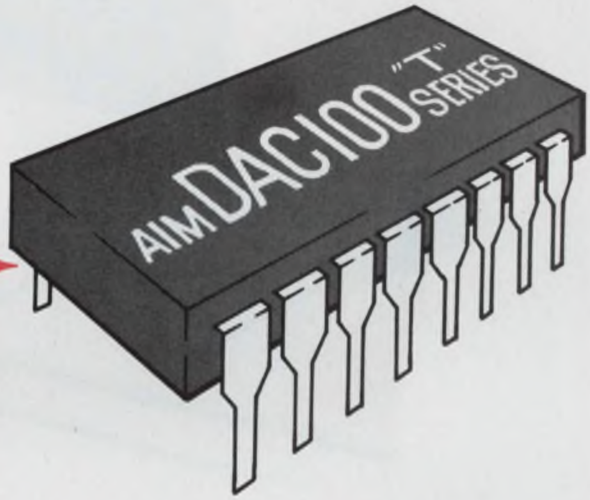

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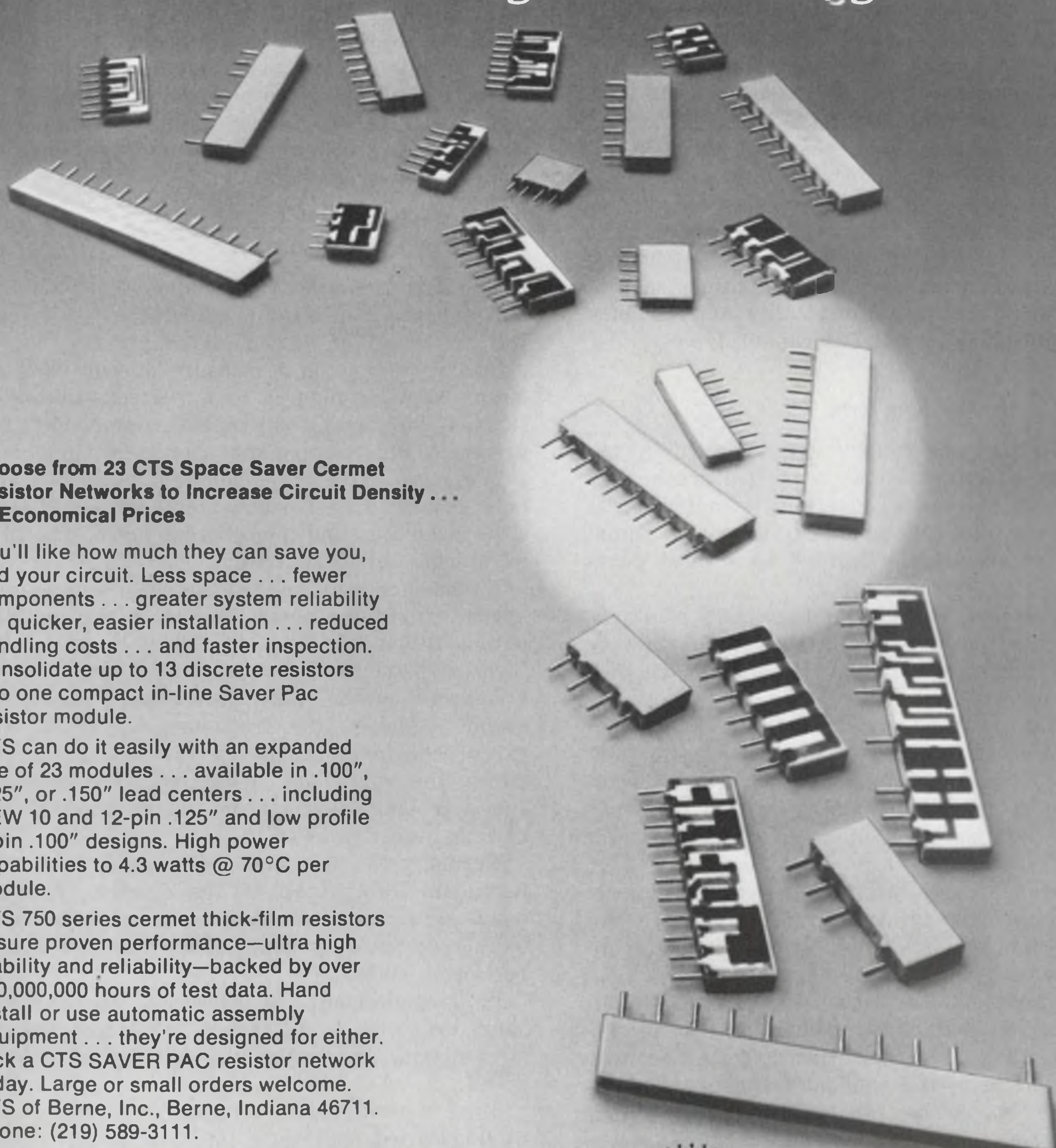

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INFORMATION RETRIEVAL NUMBER 45

Hung up on synthesizer specs? There are only four of major concern in most applications. Here's a basic discussion to help clear the obstacles.

Selecting a frequency synthesizer bugs many engineers. The instrument is still comparatively new to them. And some of the specs—like phase noise and switching speed—are not used with other instruments.

You can ease the confusion by recognizing that there are only four specs that are of basic importance in most frequency-synthesizer applications. They are stability, spurious content, residual phase noise and switching speed. The application will determine the relative importance of other specs, such as output amplitude, search-sweep capability, programmability of frequency and amplitude, and AM-FM capability.

Stability is usually long-term

Synthesizers are usually characterized by excellent long-term stability. A typical synthesizer can provide a frequency stability of a few parts in 10^{10} per day. By contrast, standard signal generators are usually limited to several parts in 10^5.

The long-term stability and accuracy of a synthesizer's output is directly related to stability and accuracy of the standard frequency, whether internal or external.

Internal standards are usually derived from crystal oscillators operated at either room temperature or in an oven. Room-temperature oscillators have a typical stability of 1×10^{-6} per month, while the oven units give improved stability of 1×10^{-9} per month.

For even greater stability, external standards offer variations ranging from a few parts in 10^{11} per day for an ultra-stable crystal oscillator to a few parts in 10^{14} for a hydrogen maser.

Short-term stability refers to the time-domain effects of inherent phase modulation on the output frequency. For short measurement times—of 1 ms or less—the random frequency fluctuations are caused by the synthesizer's residual phase noise.

Robert L. Moynihan, Assistant Product Manager, General Radio, Bolton, Mass. 01740.

Short-term stability can be specified in terms of $\Delta f/f$, where Δf is the rms frequency deviation about the average carrier frequency. In applications involving fast switching and short dwell times, it's important to consider the tradeoff of dwell time vs short-term stability. With long dwell times, stability usually improves because errors are averaged out.

2 types of signal distortion

The next two specs to consider—spurious content and phase noise—indicate the over-all spectral purity of the output signal.

Spectral purity is a measure of how well an output signal compares to a perfect sinusoid—that is, how many unwanted components are present. These components can be divided into two general categories: coherent, spurious signals generated in various nonlinear operations, such as mixing, and noncoherent noise, traceable to internal circuit sources.

Nonharmonically related spurious signals can appear anywhere above or below the selected output frequency (Fig. 1). They can take the form of fixed pairs symmetrically placed about the carrier, or they may move rapidly across the output signal as the frequency is varied. The exact behavior depends on the mechanism by which the spurs are generated. The movable spurs generally arise from mixer products of various higher orders.

Normally the spurious spec should define the maximum level of all of the discrete, nonharmonic signals in the output range, as referenced to the carrier. Any qualifications to this should be clearly stated.

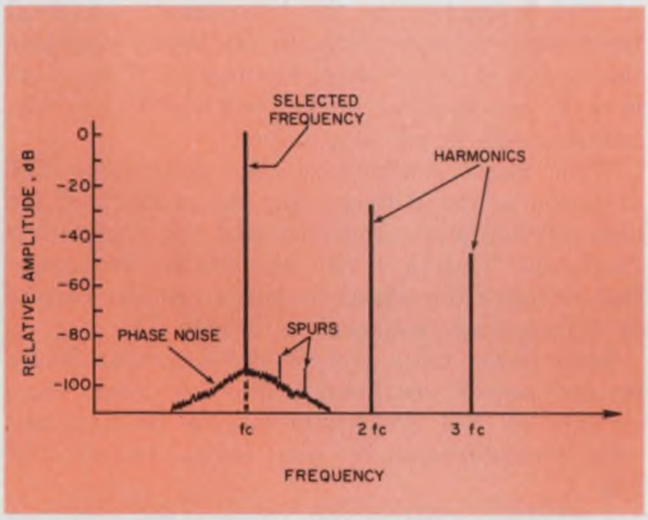
In a high-quality synthesizer, nonharmonic spurs are between 80 and 90 dB below the desired signal, and harmonics are typically down 25 dB.

Since a synthesizer's output is normally amplitude-leveled, and since internal signal processing usually involves limiting, the primary component of output noise is phase rather than amplitude.

The concept of phase noise is perhaps best explained with an example: Suppose white noise is used to modulate an FM signal generator. For a low modulation index, the carrier exhibits a continuous, symmetrical, sideband-noise spectrum that decays by 20 dB per decade of increasing offset frequency.

In a similar way the flicker noise of any pn junction imparts a PM noise spectrum on an rf signal transmitted through the junction.

It has been demonstrated that this intrinsic



1. **A synthesizer's output contains unwanted components** in addition to the carrier. The unwanted signals can be separated into harmonics and spurious components, with phase noise often dominating close to the carrier.

phase modulation has a 1/f power-spectral density, decaying at 10 dB per decade.[1] It is this phenomenon that, to a large degree, determines the inherent phase-noise characteristics of any synthesizer signal.

Phase noise is often specified as the maximum noise power in a 30-kHz bandwidth centered on and excluding the carrier. This broad bandwidth measurement is a summation of all the random phase-modulation products generated internally.

A more explicit way of specifying phase noise is to plot the single-sideband phase-noise ratio in a 1-Hz bandwidth as a function of the frequency offset from the carrier. The term "residual phase noise" is then used to emphasize that the specification refers to the limitation imposed by the synthesizer.

Given a residual noise spec, the user can evaluate the over-all instrument performance when using an external standard. For example, a typical phase-noise spec for a frequency standard is −126 dB at 100-Hz offset from a 5-MHz carrier. With a perfect synthesizer—one having no residual—the standard would produce a 500-MHz output signal, with noise of −126 +40 dB, or −86 dB relative to the carrier. The 40-dB term arises from the frequency (and phase) multiplication factor of 100.

Provided the synthesizer's residual phase noise is less than that of the standard, the output frequency spectrum is related to the input from the standard by a multiplication factor, and the synthesizer circuitry is not the limiting factor.

When comparing the spectral distribution phase-noise curve of a high-quality synthesizer with that of a signal generator, it can be observed that the two curves intersect at an offset frequency of about 10 kHz (Fig. 2). The noise content at this point can be, say, −125 dB/Hz.

At frequencies closer to the carrier, the signal generator's noise rises at about 30 dB/decade, while the typical synthesizer's noise rises at 10 dB/decade. Thus, at 100-Hz offset, the synthesizer's noise is 40 dB less than that of the sig gen.

Defining switching speed

Switching speed describes the time elapsing between a command to a new frequency and the point at which the new output becomes useful. Even when the signal attains the new frequency, its phase can still be changing, similarly to any rapidly decaying transient. It's this change of phase with time that results in a temporary frequency error. Thus an accepted definition for switching speed is the time interval until the new frequency falls within 0.1 radian of its final phase.

This definition avoids possible confusion caused by specifying time intervals much shorter than a period of the final frequency. But the definition must be used cautiously; to be meaningful, the amplitude leveling must respond as fast as the frequency programming in many applications.

One may ask, how close is the frequency to its programmed value after the specified switching time? Since this depends on the digit being switched, a worst-case frequency error should be defined that gives the maximum frequency error when switching between any two frequencies. Although no standards exist, most rf synthesizers are characterized by less than 100-Hz error after the specified switching time.

The continuity of phase of the output signal during rapid frequency changes is important in some applications, such as chirp radar. Often a synthesizer exhibits phase continuity if proper care is taken in the programming so a command for zero-frequency output (dc) doesn't occur.

Some manufacturers specify switching speed for the basic instrument so that, if higher resolution is subsequently ordered, the added digits decrease switching speed. It's advisable to ask what happens when extra digits are added.

Note that switching speed is normally given as the maximum time to switch between any two frequencies. Thus a spec of 100 μs means that there will be an over-all settling time of 100 μs or better—not 500 μs—when five digits are programmed simultaneously.

Other important synthesizer characteristics include resolution, programmability, search-sweep capability, range and modulation properties.

Synthesizer resolution refers to the minimum frequency difference between any two adjacent output frequencies. The choice of resolution should be compatible with the chosen frequency standard. For example, a standard with a stability of one part in 10^6 per month can drift 100 Hz per month at 100 MHz. In this case it doesn't make sense to specify a resolution—0.1 Hz, for example—that is significantly less than this drift.

Almost all modern synthesizers offer external control of frequencies by dc levels. The logic most often used for this is TTL-compatible BCD. Such remote control allows commands that are faster and more reliable than those of older synthesizers that were controlled by electromechanical switches.

Many synthesizers allow amplitude to be remotely controlled. This control is usually accomplished via the output leveling loop by use of an external control voltage. A well-designed leveling loop allows some amplitude modulation.

Often a synthesizer's output frequency can be swept over a limited range. One way of doing this is to provide a continuously adjustable decade that can be substituted for any of the lower-resolution, stepwise-tunable decades.

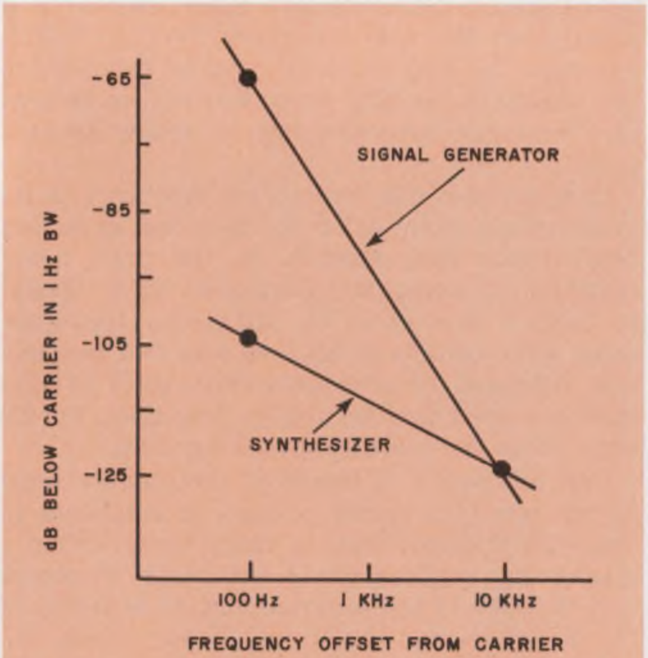
This capability enables the user to investigate the frequency response of narrowband networks with a continuous presentation. Also, with search, the user can control the synthesizer's output frequency in a phase-locked loop by employing a dc signal that's proportional to phase. This, for example, enables tracking of a crystal's resonant frequency during final adjustment.

The search feature also allows the carrier to be frequency-modulated. However, the amount of FM is limited by the instrument's internal bandwidth. A better way to frequency-modulate the carrier is to use phase modulation. When this is done, the spectral purity and stability of the unmodulated output is retained.

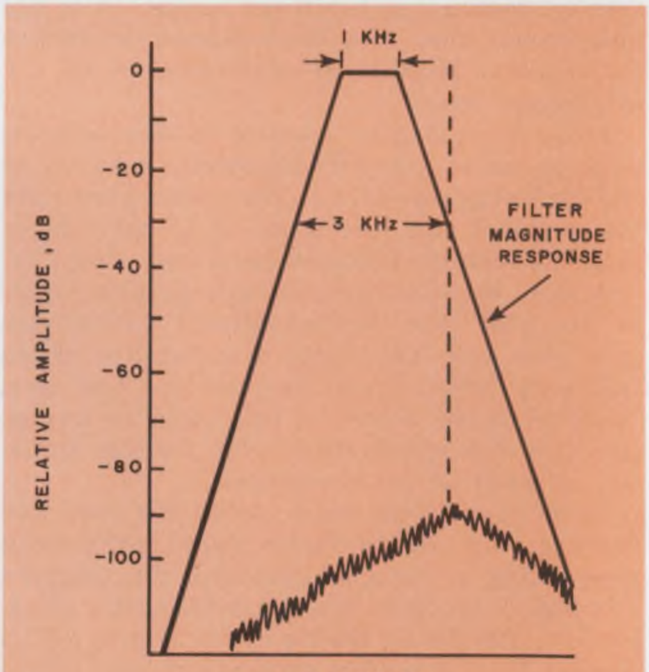
With phase modulation, the equivalent FM deviation is found by taking the product of the phase deviation (in radians) and the modulating frequency. Thus a 1-kHz modulating frequency that deviates the phase by three radians results in a frequency deviation of 3 kHz.

Some newer units provide two summing inputs to the search oscillator, allowing such components as FM discriminators to be analyzed with a combination of slow carrier sweep and FM.

Available synthesizers cover the various ranges from dc to microwaves, so that one instrument can replace many high-performance oscillators. For instance, a 500-MHz synthesizer with 0.1-Hz resolution can generate a staggering



2. **A comparison of a synthesizer** with a standard signal generator reveals that the sig gen's close-in noise can be much greater.



3. **Measurement of crystal filter response** demonstrates the limitations imposed by sideband noise.

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Applications determine requirements

In many applications the synthesizer can be viewed as a sophisticated local oscillator generating precise frequencies upon programmed command. Here the most important spec is spectral purity or switching speed.

In this regard, phase-noise sidebands are particularly important—since they can limit both accuracy and dynamic range in measurement and communication systems.

When attenuation is measured in the stop band of receivers or filters, synthesizer sideband noise is transmitted through the passband with little or no attenuation. At some point the magnitude of the attenuated signal will become less than that of the noise.

In the worst case, a broadband detector will be unable to separate the signal from the noise, and the measurement will be impaired. Just how much depends on the width of the passband and the steepness of the skirts.

As an example, consider a crystal filter response that has a passband (zero attenuation) 1-kHz wide and is 3-kHz wide at the 30-dB-down frequencies (Fig. 3).

When the test signal is at either 30-dB-down point, the single sideband noise—at offset frequencies between 1 and 2 kHz—is transmitted unattenuated through the passband.

Now suppose that an average single sideband phase noise of -100 dB/Hz is specified for the offset range indicated. The signal-to-noise ratio at the output of the filter becomes 40 dB: -100 dB/Hz +30 dB (1-kHz bw) +30 dB (filter attenuation).

Although this result may not appear dramatic, the accuracy of the magnitude measurement is obviously limited under these circumstances.

Sideband noise of synthesizers used as local oscillators in communication receivers can limit the usable dynamic range. Also, unless spurious signals from the synthesizer are minimized, the received signal can contain errors.

Ordinarily, because it exhibits low close-in noise, a synthesizer provides the most attractive solution for recovery of modulation information at rates up to a few kilohertz. ■■

Reference:

1. Halford, Donald; Wainwright, A. E., and Barnes, James A., "Flicker Noise of Phase in RF Amplifiers and Frequency Multipliers: Characterization, Cause and Cure," *Proceedings of the 22nd Annual Symposium on Frequency Control*, 1968, pp. 340-341. National Technical Information Services, Springfield, Va. 22151

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INFORMATION RETRIEVAL NUMBER 48

ideas for design

Program uses convolution technique to compute linear network output

Use of the convolution integral to compute the time responses of linear networks eliminates the need to express the input and network functions as polynomial ratios. The latter restriction often occurs with available Laplace transform programs.

The program calculates the time response from equally spaced discrete time points of the input function X (kT) and the network's impulse response H (kT). Arrays X and H accept up to 100 data points for each of the two functions. A rectangular approximation is used to compute the convolution integral. The input data represent the midpoints of the intervals DT in H (t) and X (t).

With the present program, 20 input points provide accuracies of better than 1% on several classical problems. More points improve computational accuracy.

If additional input data storage is needed, the size of the H and X arrays can be increased. Then the YT array must be increased to equal the product of the H and X array dimensions.

C. L. Stansberry, 20521 Debbie Lane, Saratoga, Calif. 95070.

CHECK NO. 311

```
1 C:INSTRUCTIONS;DIVIDE H(T)&X(T) INTO EQUAL TIME INCREMENTS
OF DT
2 C: ENTER DT,ENTER G, THE # OF DT INCREMENTS IN H(T)
3 C: ENTER F, THE # OF DT INCREMENTS IN X(T)
4 C: ENTER THE MIDPT AMPLITUDES OF DT FOR EACH DT IN H(T)
5 C: ENTER THE MIDPT AMPLITUDES OF DT FOR EACH DT IN X(T)
6 C: H(T) IS THE IMPULSE RESPONSE OF THE SYSTEM
7 C: X(T) IS THE INPUT SIGNAL TIME FUNCTION
8 C: THE PROGRAM OUTPUTS THE TIME RESPONSE OF THE SYSTEM
9 C: THE PROGRAM IS A SOLUTION TO THE CONVOLUTION INTEGRAL
10 DIMENSION H(100),X(100),XT(100),YT(1000)
11 INTEGER G,F
12 ACCEPT DT,G,F,(H(I),I=1,G),(X(I),I=1,F)
13 DISPLAY"TIME         AMPLITUDE"
14 C:REVERSE ORDER OF X(T)
15 Z=F;R=F
16 DO 25 I=1,R
17 XT(I)=X(Z);Z=Z-1
18 25 CONTINUE
19 DO 27 I=1,F
20 X(I)=XT(I)
21 27 CONTINUE
22 N=1
23 DO 10 K=1,G
24 DO 20 I=1,F
25 YT(N)=H(K)*X(F+1-I);N=N+1
26 20 CONTINUE
27 10 CONTINUE
28 Q=F+1;P=2;N=2
29 SUM=YT(1)
30 DISPLAY DT,SUM*DT
31 30SUM=0
32 DO 40 I=P,Q,F-1
33 SUM=SUM+YT(I)
34 40 CONTINUE
35 P=P+1;Q=Q+F
36 DISPLAY N*DT,DT*SUM
37 IF(P .GT.F) GO TO 50
38 N=N+1
39 GO TO 30
40 50 IF( G .LT. F) Q=G*F-1
41  P=2*F
42 60 SUM=0;N=N+1
43 DO 70 I=P,Q,F-1
44 SUM=SUM+YT(I)
45 70 CONTINUE
46 IF(F .LT. G .OR. G .EQ. F) Q=Q+F
47 P=P+F
48 DISPLAY N*DT,DT*SUM
49 IF(P .GT. (G*F-1))GO TO 80
50 GO TO 60
51 80SUM=0;N=N+1
52 SUM=YT(G*F)
53 DISPLAY N*DT,DT*SUM
54 END
```

Time-domain response for the linear network H (t), driven by X (t), is computed by this Fortran program. The program uses a rectangular approximation to the convolution integral.

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Not only does the Micromemory 3000 give you core reliability and low cost, but the compact convenience of a complete memory system—including all required logic, drive and sense circuitry—on a single printed circuit card. Maximum capacity per card is 8K by 18 bits, or 16K by 9. But you can stack the cards to get any size system you need. Or we'll do it for you.

In fact, the unit shown is our standard Micromemory 3000 chassis. It can accommodate up to four individual memory cards plus power supply, self-test or interface cards and other features. Yet it is only 5¼-inches high, and fits a standard 19-inch rack. Other chassis holding up to 16 cards are also available.

With over two years' field experience, the Micromemory 3000 is so popular we are producing them at the rate of 6000 a year. Combine this proven reliability, high performance and low cost in your next memory system. Write or call Mel Zeramby at (213) 644-9881 for all the details.

EMM ELECTRONIC MEMORIES
COMMERCIAL PRODUCTS
A Division of Electronic Memories & Magnetics Corporation
12621 Chadron Ave., Hawthorne, Calif. 90250

INFORMATION RETRIEVAL NUMBER 49

Simple algorithm computes square roots on a four-function calculator

Users of four-function calculators can compute square roots rapidly with a simple approximation routine. Two or three iterations are usually enough for eight-place accuracy.

The equation

$$X_2 = \left(\frac{N}{X_2} + X_1\right)/2$$

derives a second approximation to the square root of the number N, from a first approximation X_1.

For example, to calculate the square root of 85, use the number 9 as a first approximation. Then, with the calculator switched out of the constant mode, perform the keyboard operations (85) (÷) (9) (+) (9) (=) (÷) (2) (=), giving the result 9.22222.

Round the first answer to four places and perform a second iteration

(85) (÷) (9.222) (+) (9.222) (=) (÷) (2) (=).

The result, 9.2195445, is accurate to eight places.

To examine the accuracy of the result, switch to the constant mode and depress the |X| and |=| keys. The result is 85. Depressing the |1| and |=| keys recalls the original answer, 9.2195445.

T. P. Sylvan, Teradyne, Inc., 183 Essex St., Boston, Mass. 02111.

CHECK No. 312

High-frequency clock helps extract vertical sync signal

The availability of a high-frequency clock in many video systems permits extraction of the vertical sync pulse by use of a single shift-right, shift-left IC, such as the 7495.

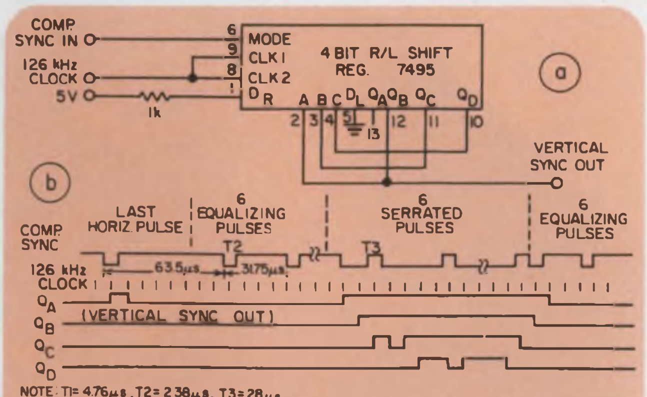
The composite sync waveform is applied to the mode control (MC) input of the shift register (Fig. 1a), and the vertical sync is taken from the Q_B output. When the MC is low, as during the sync pulse period, the register is in the shift-right mode. A logic ONE enters pin 1 and is clocked from Q_A toward Q_D. But the horizontal and equalizing pulses (Fig. 1b) are not wide enough to allow the ONE to reach Q_B through Q_D. Typical durations are 4.76 and 2.38 μs, respectively. Only the wider vertical serrated pulses (normally 28 μsec) that are present during the vertical interval are wide enough to permit Q_B through Q_D to become ONE.

Between sync pulses, the MC is high and the register operates in the shift-left mode. A ZERO from pin 5 will be clocked from Q_D toward Q_A. But the time between the serrated pulses does not permit the ZERO to reach Q_B. Hence Q_B becomes a ONE during the first serrated pulse, and it remains high until the last serrated pulse terminates. The separation delay is considerably less than with comparable analog circuitry.

A four-bit register suffices for the 126-kHz clock used in this example. Q_A may go high, depending upon the phase relationship between the leading edge of the sync pulses and the falling edges of the clock pulses, but that presents no problem. Operation can be extended to higher clock frequencies by cascading of the registers. For example, if a 3.58-MHz clock is available, it can be divided to 358 kHz. Two cascaded registers will provide the sync output at the Q_A output of the second register.

V. R. Godbole, Systems Design Engineer, North Electric Co., 553 S. Market St., Galion, Ohio 44833.

CHECK No. 313



With a shift register connected for sync separation (a), the vertical sync pulse appears shortly after the start of the vertical interval (b). ONEs entering pin 1 and clocked toward Q_D reach Q_B during the long serrated pulse interval. ZEROs from pin 5 are clocked toward Q_A when the composite sync signal is high.

Schmitt trigger provides switch drive and regulation for power supply

A low hysteresis Schmitt-trigger circuit simplifies the design of switching regulators by providing both switching action and output voltage regulation.

Schmitt-trigger action occurs at Q_1 and Q_2. When the potential at the base of Q_1 exceeds the zener voltage by 0.5 V, Q_1 turns on and saturates. This shuts off Q_2 and removes the base drive to switching transistor Q_3.

If the potential at the base of Q_1 drops below the firing voltage, then Q_1 turns off, which in turn causes Q_2 to turn on. The current source and resistor R_3 supply 5 V to drive the base of Q_2. Transistor Q_2 and resistor R_2 form a current source to bias switch Q_3 on. There is a small, but finite hysteresis that equals the zener impedance of 10 Ω times the current difference between 0.5 mA and 1 mA or 5 mV.

Components L and C can be selected according to the equations

$$L \simeq \frac{E}{2\, I_L\, F_S}$$

$$C \simeq \frac{I_L}{E_H\, F_S},$$

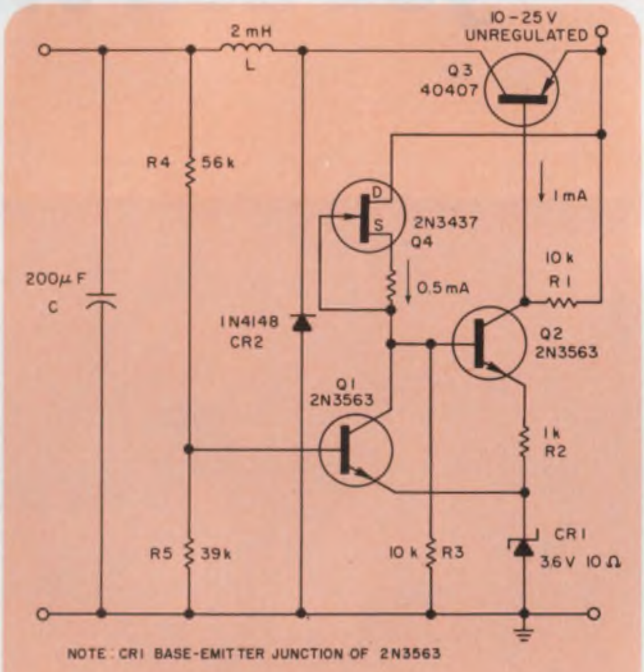
where F_S is the desired switching frequency, I_L the load current, E the voltage switched across the inductor and E_H the trigger's hysteresis voltage.

The small voltage excursions at the collectors of Q_1 and Q_2 ensure rapid Schmitt-trigger action. Current regulator Q_4 provides better line regulation than a simple resistor attached to the unregulated input.

With the components shown, the circuit operates at a switching frequency of 50 kHz, provides 0.5% line regulation and load regulation of 0.5% with 10 to 50 mA of load current. The output ripple is 10 mV.

Eric Burwen, Research Engineer, Center for Space Research, Massachusetts Institute of Technology, Cambridge, Mass. 02139.

CHECK No. 314



Switching regulator uses low-hysteresis Schmitt trigger (Q_1 and Q_2) to drive switch Q_3. Switching action occurs when the voltage across divider R_4 and R_5 goes above or below the trigger point.

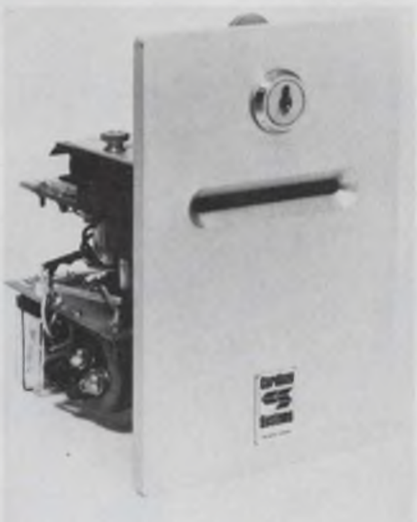
IFD Winner of March 15, 1973
Terry Byers, Lockheed Electronics Co., Houston Aerospace Systems, Station B-11, 16811 El Camino Real, Houston, Tex. 77058. His idea "Wideband circuit fits curves with straight-line segments" has been voted the Most Valuable of Issue Award.

Vote for the Best Idea in this issue by checking the number for your selection on the Information Retrieval Card at the back of this issue.

SEND US YOUR IDEAS FOR DESIGN. You may win a grand total of $1050 (cash)! Here's how. Submit your IFD describing a new or important circuit or design technique, the clever use of a new component or test equipment, packaging tips, cost-saving ideas to our Ideas for Design editor. Ideas can only be considered for publication if they are submitted exclusively to ELECTRONIC DESIGN. You will receive $20 for each published idea, $30 more if it is voted best of issue by our readers. The best-of-issue winners become eligible for the Idea of the Year award of $1000.

new products

Novel card decoder prevents reuse of ID



Cardkey Systems, Inc., 20339 Nordhoff St., Chatsworth, Calif. 91311. (213) 882-8111. From $549; 3 wk.

The CR-112X and CR-116X Card Readers provide an effective one-time-card-use feature. They magnetically decode the entrance code from the card when it is inserted into an access reader. At the same time, the card key is recoded so it will only operate an exit reader. Since the recoded card will only activate an entrance reader one time, card "pass-back" to another person for reuse is effectively foiled. Exit readers reverse the procedure, decoding and recoding the card for entrance use again. The card-reader portion of the system allows information encoded on the user's card to be read out to peripheral equipment. Model CR-112X utilizes a three-digit system with a total card recognition capacity of 999; Model CR-116X is a four-digit system capable of separately identifying 9999 different card keys. The card readers employ readily interchangeable K5RX program matrix cards by which a new reader "lock combination" may be programmed by simply inserting a new matrix card into the rear of the reader housing.

CHECK NO. 255

Recording heads have multiple-channel models

Lipps Inc., 1630 Euclid St., Santa Monica, Calif. 90404. (213) 393-0449. From $4 (8-chan.) and $7 (2-chan.), prod. qty.; 3 to 4 wk.

Eight-channel flying-disc recording-heads use high-density barium-titanate pads to give a pad flatness of 25 μin or better. Heads are suitable for discs of 10 to 14 in. diameter. The dc resistance is 2 Ω for the full-head coil with an inductance of 15 μH for a half coil at a frequency of 140 kHz. Write current is 50 to 70 mA/leg at a 2000 bits/in density. Nominal gap width is 100 μin. A two-channel flying-drum recording head is also available. This version is suitable for 6 to 12-in. diameter drums, at speeds of 1800 and 3600 rev/min. Flying height is 70 to 120 μin., with a track width of 0.01 in. $\pm$0.001 in. and a gap width of 150 μin. The head inductance is 20 μH $\pm$10%/leg at 140 kHz and the write current is 75 mA.

CHECK NO. 256

Matrix printer terminal handles six-part copy

Di-An Controls, Inc., 944 Dorchester Ave., Boston, Mass. 02125. (617) 288-7700. $2895; see text.

Model 9030 teleprinter terminal uses a matrix print head and has operator selectable speeds of 10, 15 and 30 char/s. It offers 132-column print capacity, full ASCII upper and lower case codes and form-feed tractors that adjust from two to sixteeen inches, and can handle six-part copy. The terminal operates in half, full duplex and local modes and has a standard RS232C interface. Model 9030 is shipped ready for use including cabinet, electronics and power supply. The terminal is available in KSR and ASR versions. The KSR version sells for $2895. Delivery ranges from immediate to 90 days depending on model and quantity ordered.

CHECK NO. 257

Magnetic-stripe card reader takes five sec

Conrac Corp., Mill Rock Rd., Old Saybrook, Conn. 06475. (203) 388-3574. $44 (5000); immediate.

Designated Model A31A, this unit is a constant speed, motor-driven device that reads an encoded message from standard magnetic stripe credit cards by means of a tracking magnetic head that travels along an accurate lead screw. The Model A31A is designed for OEM applications and will read formats used by ABA (American Banking Association), IATA (International Air Transportation Association) or NAMSB (National Association of Mutual Savings Banks). The unit handles pre-encoded messages of up to 600 bits or 80 alphanumeric characters. Data density is 210 bits/in. on the IATA and NAMSB track formats. Using the ABA track format, the data density is 75 bits/in. The data read speed is 140 bits/s or 0.66 in/s and total message read time is less than 5 s. The standard Model A31A is available with a single track read head. The standard operating voltage is 115 V, 60 Hz. Planned options include a faster 3.5 in/s model with 12-V-dc or 24-V-ac motor that has multi-track capability.

CHECK NO. 258

Solid state programmer has 10 outputs

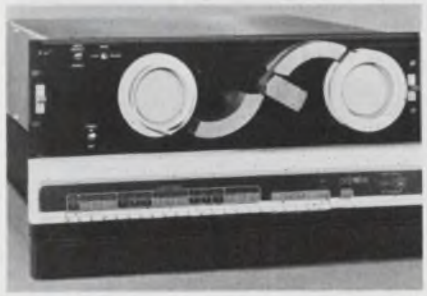
Instrumentation & Control Systems, 129 Laura Dr., Addison, Ill. 60101. (212) 543-6200. $200.

The IPAC 30001 time sequencing system (also referred to as a sequencing programmer or a solid-state stepping switch) provides the functions of time delays, relays, stepping switches and logic in one small unit. One to 10 sequential outputs operate continuously. The unit provides the following timing ranges: for "on" time, 0.05 to 0.5 s, 0.3 to 3 s; and for "off" time, 0.1 to 1 s, 1 to 20 s and 10 to 180 s.

CHECK NO. 259

DATA PROCESSING

Direct access memory uses sectored tape



Computer Operation, Inc., 10774 Tucker St., Beltsville, Md. 20705. (301) 937-5377. From $4500; stock to 45 days.

A plug-compatible direct access mass memory system for the PDP-11 minicomputer, the model CO-500 DA uses reels of presectored tape to create a disc format. The system includes a tape loader, utility software and keyboard executive. Each drive stores up to 335,000 bytes and transfers data at 8400 bytes/s with an average access time of 8.7 s. Up to 15 additional drives may be added to the master unit. The basic CO-500 DA costs $4500; additional drives cost $1700 each.

CHECK NO. 260

Printer/plotter has 100-dot/in. resolution

Gould Data Systems, 20 Ossipee Rd., Newton Upper Falls, Mass. 02164. (617) 969-6510. $7600.

An electrostatic printer/plotter unit designed for interface with minicomputers, the Gould 5000 prints alphanumeric data at a speed of 1200 lines per minute and plots graphic material at a rate of 3-in/s. A nonimpact printer, the unit has an eight-bit data path for input from the minicomputer, and comes with a 64-ASCII character, 7×9-dot matrix font. It generates 132 characters per line with a resolution of 100 dots/in. vertically and horizontally. Printout is on 11-in. wide coated paper which travels through the unit, becomes electrically charged and fluid toned before emerging dry from the machine. The manufacturer can supply printing and plotting software packages and interface hardware packages for most minicomputer systems.

CHECK NO. 261

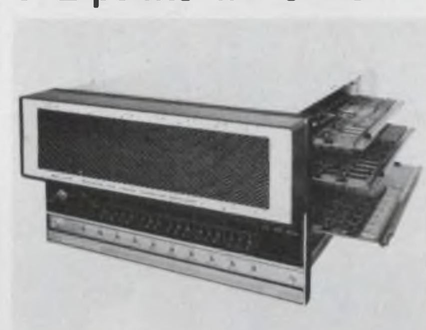
Cartridge drive offers two preset R/W speeds

Applied Data Technology Corp., 169 Bedford St., Burlington, Mass. 01803. (617) 272-4445. From $270.

Available as a complete system (DT-400) or a basic transport (T-400), these units use the 3M DC300A 0.25-in. tape cartridge containing 300 ft. of computer-grade tape. The transport operates in either direction at any of two preset low speeds or at a fast speed of 90 in/s. The user may specify any two read/write speeds between five and 50 in/s. A single dc printed-circuit motor provides the necessary drive. Data can be recorded with densities up to 1600 bits/in. on one, two or four tracks across the tape. The basic configuration sells for $270 and includes the transport, a single-track head, a EOT/BOT sensing, file-protect, and "cartridge-in" sensing.

CHECK NO. 262

FFT processor does 512 points in 9.5 ms

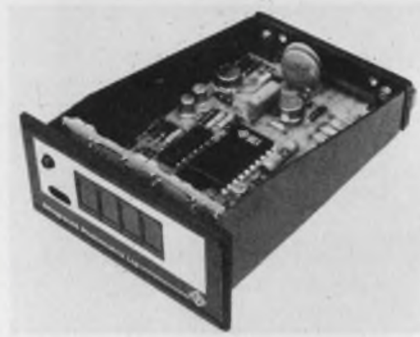


Elystec, 212 Michael Dr., Syosset, N.Y. 11791. (516) 364-0560. $15,200; 70 days.

The 306/HFFT Code 1 FFT processor plugs into the Nova 800 Jumbo computer, or other Data General computers on request. The unit performs a forward or inverse FFT of 16 to 16,384 real points with 16-bit processing accuracy. Typically, the complex Fourier Transform of 512 points takes 9.5 ms when the 306/HFFT Code 1 is used with the NOVA 800 computer. The 306/HFFT consists of three boards which include: Fourier transform processor, point reordering hardware, converter for one real input and the cartesian-to-polar and polar-to-cartesian converter. Software drivers are also supplied.

CHECK NO. 263

DPM kit uses MOS/LSI chip



Teknis/Photomatrix, 93 South St., Plainville, Mass. 02762. (617) 695-3591. $130.

A single MOS/LSI chip, the MC-902, is the heart of a DPM kit. The chip is encapsulated in a 28-lead DIP, and incorporates all the logic required for a four-decade plus one (that is, full-scale count of 19,999) dual-ramp a/d converter. The chip also incorporates automatic overrange and underrange indications, display multiplexing and all the logic for gating the analog functions. In addition to the MC-902 chip the circuitry consists essentially of an integrator, comparator, clock oscillator, input switches, voltage reference and the display.

CHECK NO. 264

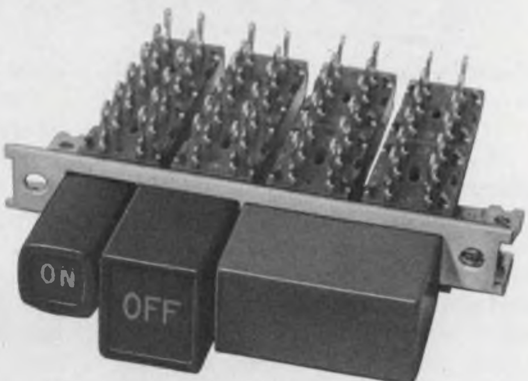
Low-frequency analyzer offers choice of bw

Quan-Tech, Div. of KMS Industries, 43 S. Jefferson Rd., Whippany, N.J. 07981. (201) 887-5508. $2050; 30 days.

Model 2449 Wave and Spectrum Analyzer covers frequency measurements from 10 Hz to 50 kHz in one range, with 1-Hz resolution. Frequency readout is a five-digit LED display. The instrument is electronically tuned and sweep increments of 5 or 50 kHz can be initiated at any starting frequency in the spectral range. Sweep periods of 50 or 500 s are available. Select a 7-Hz bw for high precision frequency measurements; a 1000-Hz bw for high scan capability; or a 100-Hz bw for a middle-of-the-road compromise between resolution and scan speed.

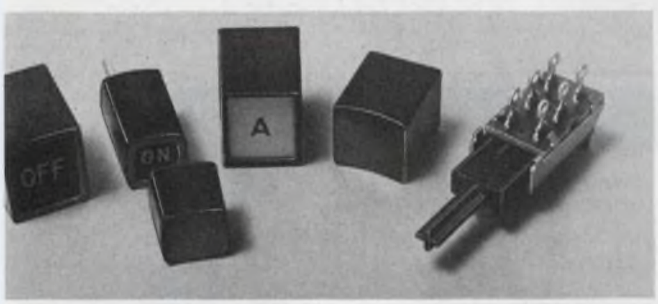
CHECK NO. 265

MORE SWITCH FOR THE MONEY.



NOW YOU CAN SPECIFY PRACTICALLY ANY CUSTOM PUSHBUTTONS ON SWITCHCRAFT'S DW "Multi-Switch®"

There's almost no limit to the variety of pushbuttons you can use on this space-saving, multiple-station pushbutton switch. It has a newly designed "Cross-Rib" actuator located on each module



that makes the switch more versatile than ever.

The "Cross-Rib" actuators conform to industry standards and are furnished 3/4" and 15/16" long to accommodate different size pushbuttons. They solve many operator-machine interface problems when used with Switchcraft non-illuminated "Dual," "Showcase," concave or convex face, rectangular, round or square pushbuttons, or the unique "Glo-Button" that achieves simulated illumination.

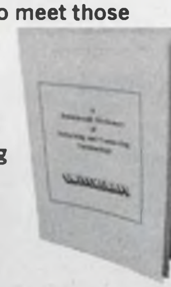
MORE QUALITY FOR THE MONEY.

In a nutshell, the Series 70000, 71000 DW "Multi-Switch®" is an economical 1 to 18 station switch, that offers up to 4 PDT switching per station; Interlock, All-Lock, Non-lock or Push-lock/Push-release functions, plus an almost unlimited variety of electromechanical and electrical accessory options. These switches are adaptations of the Switchcraft Series 65000 DW "Multi-Switch®" switches that are noted for their simplicity, economy and reliability.

DW POWER MODULES FOR HEAVY CURRENT SWITCHING

For "on-off" power switching, motor control and a variety of other high-current applications, specify a DW Power Module —one per station maximum. Turret terminals are brass with tin-lead coating. The snap-action switch is Form 1-C rated at 11 amps, and is U.L. and C.S.A. listed. The mounting brackets and insulating shields are designed to meet those same requirements.

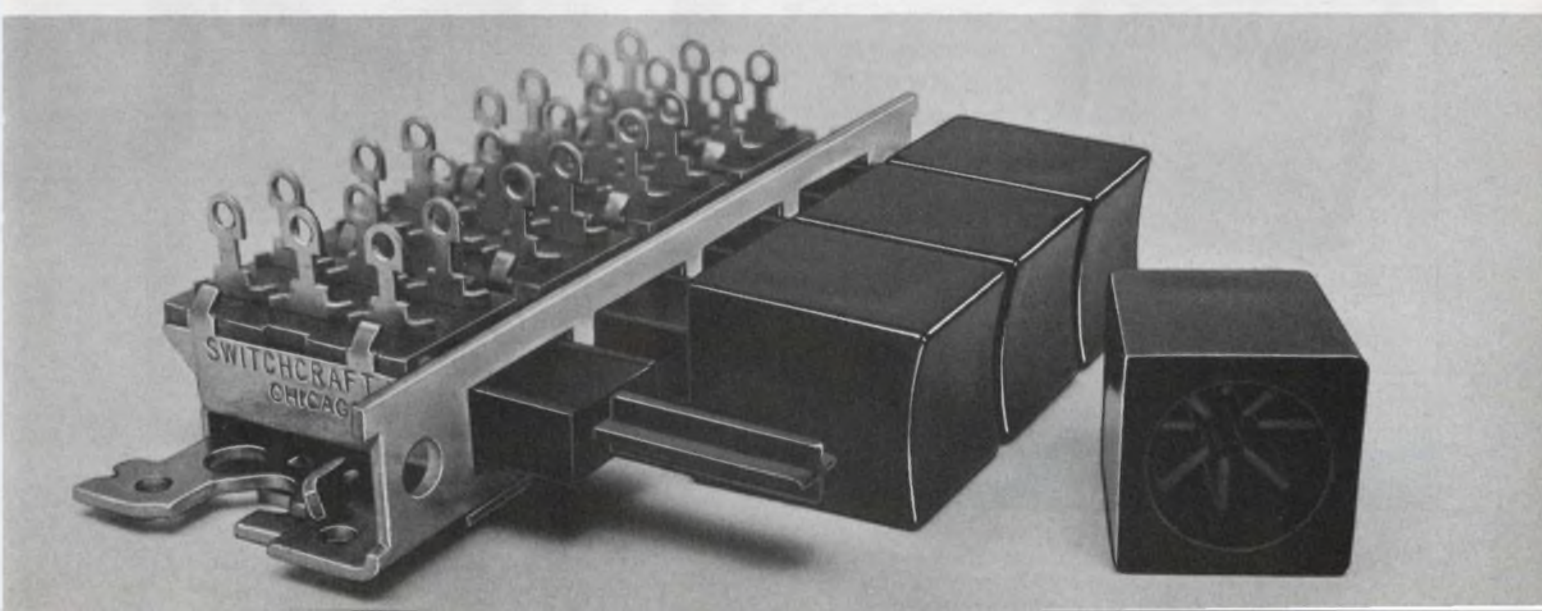
YOUR FREE DICTIONARY



We publish a handy dictionary of switching and connecting terminology. Write us for your free copy and we'll also put you on the list for TECH-TOPICS. Over 12,000 engineers find the application stories in this technical review extremely helpful. SWITCHCRAFT, INC., 5529 N. Elston Avenue, Chicago, Illinois 60630

SWITCHCRAFT® INC.

INFORMATION RETRIEVAL NUMBER 58



INSTRUMENTATION

500-MHz sweep gen sells for $735

Texscan Corp., 2446 N. Shadeland Ave., Indianapolis, Ind. 46219. (317) 357-8781. $735; 30 days.

WB-711 is a solid-state sweep generator that covers the frequency range of 1 to 500 MHz in one band. The unit is simple to operate, having a single center-frequency dial with illuminated indicator and push buttons on all on/off functions. Size is less than one-half rack wide, approximately 4-3/16-in. high and 12-5/8 in. deep. Other specifications are: power output of +10 dBm, sweep rate of 0.5 to 60 Hz and impedance of 50 Ω.

CHECK NO. 266

5-digit DMM costs $995, is fully autoranging

Cimron Instruments, Lear Siegler, 714 N. Brookhurst, Anaheim, Calif. 92803. (714) 774-1010. $995; stock.

DMM-51 five-digit multimeter offers full autoranging, 1-μV sensitivity and 24 total ranges. The unit includes five dc ranges with 1-μV sensitivity, four ac ranges with 10-μV sensitivity, five ranges of dc ratio, four ranges of ac/dc ratio and six resistance ranges from 1 mΩ fs to 12 MΩ fs. Other specs are: Input resistance of 10,000 MΩ, a 20% overrange and a basic accuracy of 0.004%. DMM-51 is protected against 200 V rms or 300 V dc on ohms and 1100 V dc or rms on all other ranges.

CHECK NO. 267

40-MHz counter is priced at $299

Analog Digital Research, 777 Warden Ave., Scarborough, Ontario, Canada. $299; stock to 30 days.

The CM41 counter features a six-digit gas-discharge display, and measures frequencies from 5 Hz to 40 MHz at a sensitivity of better than 35 mV. A pushbutton attenuator and two-pole low-pass filter are included. Besides four decimal-gate times, an rpm position is included, allowing direct display of rpm when counting the output of a revolution sensor. The CM41 also includes a normal totalize mode. The crystal-controlled timebase offers an aging rate of 1 × 10^{-7}/day, and a temperature dependance of less than 1 × 10^{-7}/°C.

CHECK NO. 268

Profits in motion for communications equipment

You can reduce assembly and inventory costs, get reliable total functions in minimum space, and obtain application help when you ask TRW/Globe to build your motion package.

Four builders of communications equipment can affirm this from their experience with the packages on this page.

1. TRW/Globe supplies this complete cassette drive module for a telephone answering system. The customer avoids assembly costs as well as the problem of aligning the two output shafts.

2. This blower was built to fit the space available after most of a military transceiver had been designed. TRW/Globe also helped the customer determine the system's resistance to air flow.

3. TRW/Globe meets all functional requirements in this rotary actuator for switching bands on a military transceiver. The package includes gearing, limit switch, mechanical stop, slip clutch, electro-mechanical brake, and filter.

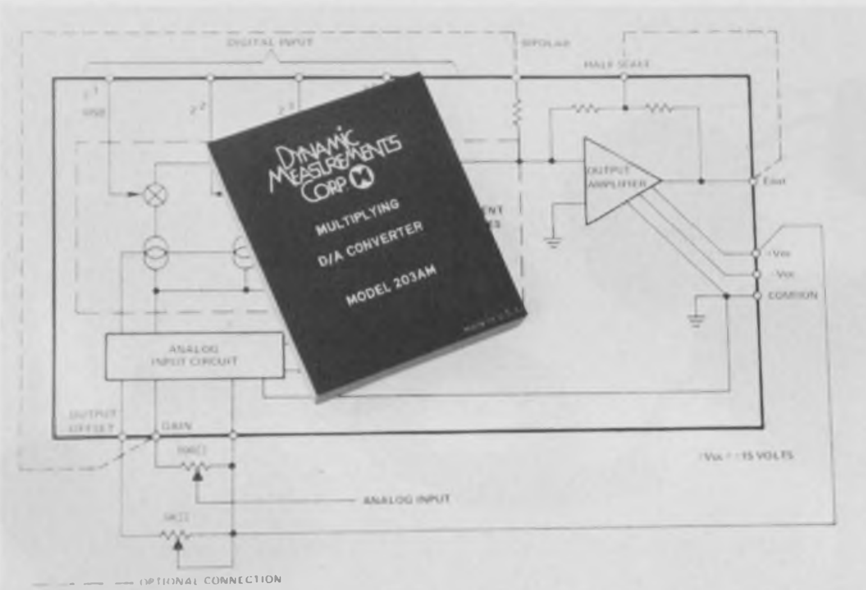
4. This package drives the scanner in a facsimile transceiver. TRW/Globe's experience with hysteresis synchronous motors assures that both the transmitter and recorder will be synced.

To get your profits in motion, call or write: TRW/Globe Motors, an Electronic Components Division of TRW Inc., Dayton, Ohio 45404 (513-228-3171).

TRW® GLOBE MOTORS

INFORMATION RETRIEVAL NUMBER 61

Get up to 40 mA at ±10 V from multiplying DACs



Dynamic Measurements, 6 Lowell Ave., Winchester, Mass. 01890. (617) 729-7870. 1 to 9 pieces: $125 (8-bit); $155 (10-bit); $195 (12-bit); stock.

The Dynamic Measurements 200-AM series of multiplying digital-to-analog converters (MDAC) provides two-quadrant multiplication with very fast response. The units also have a low impedance output that can provide ±10 V at 40 mA.

Three versions are available: the 201AM, an eight-bit MDAC; the 202AM, a 10-bit, and the 203-AM, a 12-bit. All have a minimum slew rate of 25 V/μs. The 12-bit unit has a settling time of 1 μs for a full-scale analog step of 10 V. With an output impedance of 0.1 Ω, the MDAC can directly drive a 75-Ω cable.

Other specifications include stability ranging from 17 ppm/°C for the 12-bit unit to 30 ppm/°C for the eight-bit, an operating temperature range of 0 to 70 C, scale-factor accuracy of 0.005% and a zero offset adjustment that can be trimmed to the same 0.005% tolerance. The linearity error for the worst case is ±0.025% on the 12-bit MDAC.

The 200AM series has a programmable output that is adjustable for 0 to 10, ±5 or ±10 V full-scale. A companion logic module is available to deskew the input digital data and present a synchronized pulse for an analog sample-and-hold.

Two-quadrant MDACs from other manufacturers vary in price from $185 to over $400 for 12-bit units. These compare with $195 for the Dynamic Measurements 12-bit unit. Analogic's MP1012 and DDC's RDAC-12 both deliver output currents of 10 mA but have settling times of 12 μs and 4 μs, respectively. Analog Devices also has the DAC-M12 and Hybrid Systems the DAC390. Both of these units deliver 5 mA, but the Analog Devices unit has a 10-μs settling time, while the figure is 5 μs for the Hybrid Systems model.

Dynamic Measurements **CHECK NO. 250**

Analogic **CHECK NO. 251**

Analog Devices **CHECK NO. 252**

DDC **CHECK NO. 253**

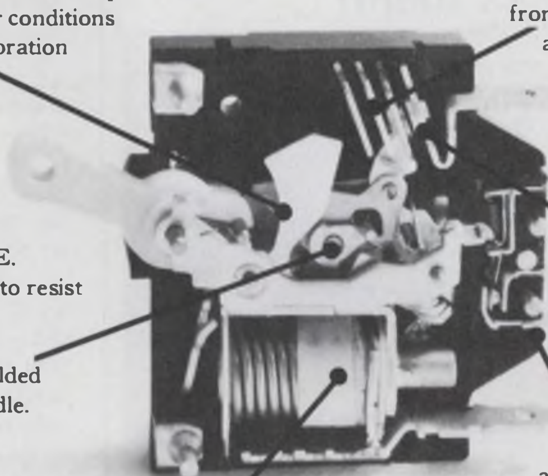
Hybrid Systems **CHECK NO. 254**

INFORMATION RETRIEVAL NUMBER 62

For all that goes into a Heinemann Type J circuit breaker, it's amazing that it sells for so little.

SHOCK- AND VIBRATION-RESISTANT CONSTRUCTION. A counterbalance affixed to the actuating armature serves to prevent mechanical tripping under conditions of shock (100 G's) and vibration (10 to 500 Hz, 10 G's).

HIGH-SPEED ARC QUENCHING. Fragmentation plates and a magnetic blowout are used to attenuate the arc and quench it away from the breaker contacts. This appreciably extends service life and reliability.

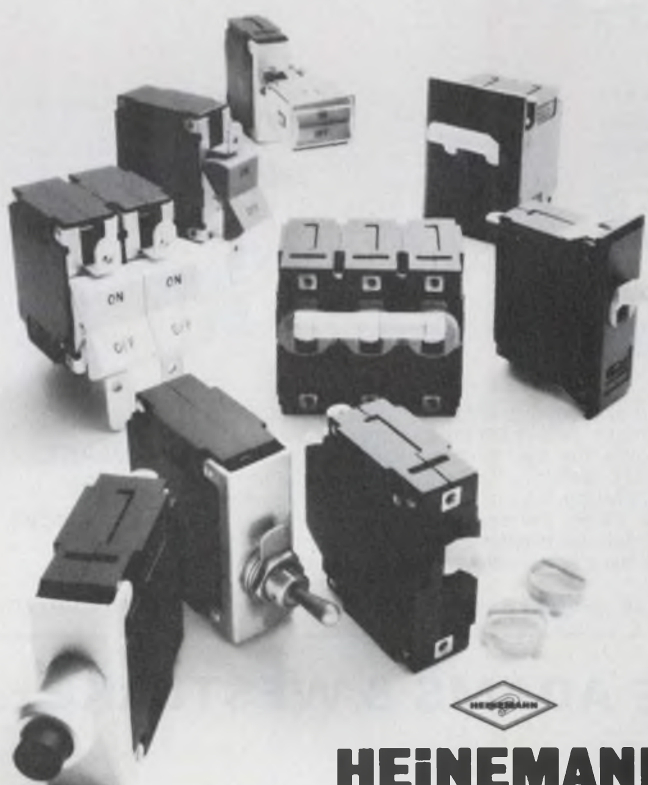


SELF-CLEANING CONTACTS. The contact arm moves on a sliding pivot point, causing a wiping action every time the contacts are opened or closed. Contacts are made of silver alloy.

FUNGUS AND MOISTURE RESISTANCE. All ferrous parts are treated to resist moisture attack, and special inherently fungus-resistant phenolics are used for all molded parts—cases, cover, and handle.

ADAPTABILITY TO SPECIAL FUNCTIONS. The auxiliary switch shown here is one of seven standard internal circuit modifications optionally available. The miniature snap-action SPDT or DPDT switch is rated at up to 10 amp contact capacity, can be used to operate remote indicating or alarm devices.

PRECISION CURRENT SENSING. The Heinemann hydraulic-magnetic sensing element provides closely controlled tripping characteristics with very accurate calibration. Nominal continuous-duty current rating is decimal-point precise, can be supplied in any integral or fractional value from 0.020 to 30 amp.



ATTRACTIVE, FUNCTIONAL PACKAGING. Type J circuit breakers are available with a variety of actuating devices—pushbuttons, rocker handles, and two types of toggle handles. For extra speed and convenience in mounting, there is a snap-in model that can be installed without hardware or tools. Our Bulletin J-3333 gives full details on the entire Type J line. It's yours for the asking. Heinemann Electric Co., 2806 Brunswick Pike, Trenton, N.J. 08602.

HEINEMANN

5533A

INFORMATION RETRIEVAL NUMBER 63

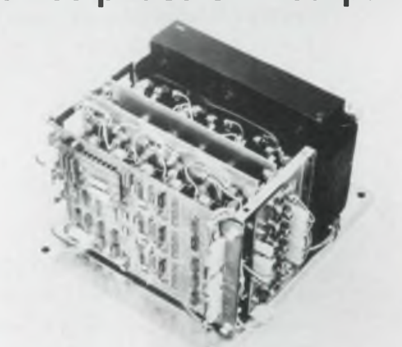
MOS serial delay line stores 20-k bits or more

Melcor Electronics, 1750 New Highway, Farmingdale, N.Y. 11735. (516) 694-5570.

Priced at less than 1/2 cent per bit, the Model 2261 is a solid-state, serial, MOS delay-line with a memory in excess of 20,000 bits in a 4-1/2 × 6 in. package. Data input and output is compatible with DTL/TTL. Unit requires only a single clock and NRZ data. Standard units have either a connector or edge-finger contacts. Clock and data rates can range from 5 kHz to 4 MHz. Special customer requirements can be accommodated.

CHECK NO. 269

Servo-amplifier uses a three-phase SCR output



Westamp Inc., 1542-15th St., Santa Monica, Calif. 90404. (213) 393-0401. Under $900.

The A693 Mini Control provides smooth regenerative control of dc motors. It uses a three-phase, full-wave (6-pulse) SCR output. Standard 90-V-dc motors can be driven at 20 A continuous duty and at up to 100 A for acceleration. The amplifier is complete with power transformer, circuit breaker, and servo compensation for high gain, fast response servo loops.

CHECK NO. 270

relays revisited II

Until we can show you some of the exciting relay ideas submitted to S-D's 50th Anniversary Contest, here are some basic, often overlooked, circuits that offer amazingly versatile, inexpensive switching for present day control applications.

LOCK-UP PROGRESSIVELY, **UN-LOCK** SIMULTANEOUSLY.

In many process control applications a single pilot must lock-up a series of relays in predetermined sequence. The double-throw pilot C1 in Fig. 1 closes and locks an odd number relay each time it touches in the lower position. Even number relays are closed and locked each time C1 touches in the upper position. The sequence starts with R1 and continues until all relays are locked after which C1 has no effect. Interrupting the power or momentarily depressing PB resets all relays simultaneously at any time.

If the pilot is single-throw, have it control the coil of a separate SPDT relay which should be substituted for C1.

No load contacts have been shown because any mixture of relay types can be used in this circuit to meet the power and switching requirements of each load.

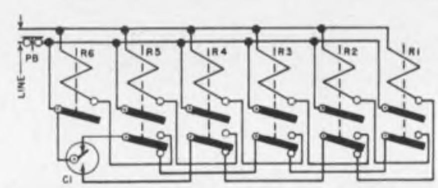
BINARY-DIGITAL CONVERSION, or How to Control Many Loads With Few Relays.

Select any of eight loads with just three relays by using the beautifully simple circuit of Fig. 2. No relay need have more than 4 poles. Letters on the loads indicate the combination of relays that must be energized to connect each load.

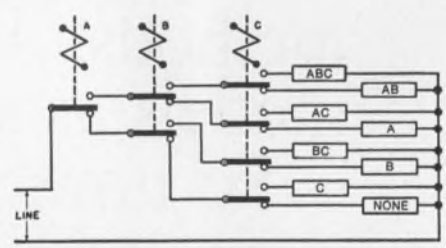
To extend this concept beyond 8 loads, however, entails an unwieldly number of poles on one or more relays as shown in the 16 load variation of Fig. 3. But by "folding" the circuit as in Fig. 4, we still control 16 loads with only four relays. Yet only two of the relays need have as many as five poles.

For dry circuit to 10 VA loads, use reed relays in these circuits and you'll save a bundle over doing the same job with solid state. And you won't lose much space either.

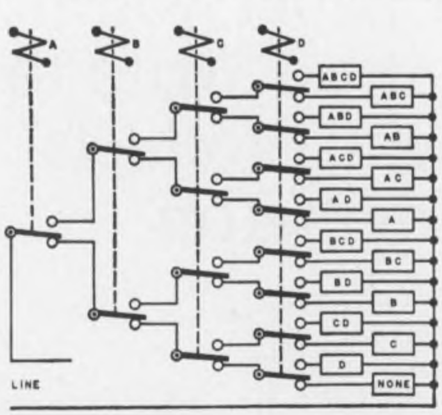
(Fig. 1)



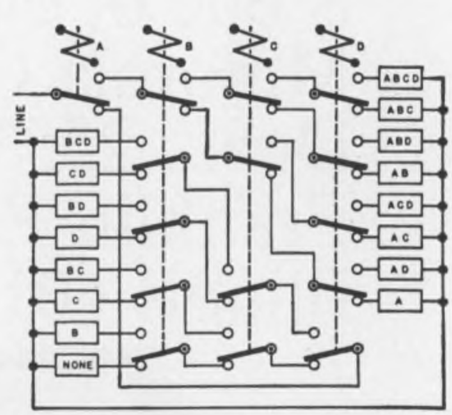
(Fig. 2)



(Fig. 3)



(Fig. 4)



150 PAGES OF RELAYS FOR MOST ANY CIRCUIT. The latest compilation of one of the world's broadest relay lines from the company that has developed an average of 9 new relay designs a month since 1923. Circle reader service card number for your copy.

S-D

STRUTHERS-DUNN, INC.

PITMAN, NEW JERSEY 08071

Canada: Struthers-Dunn Relay Div., Renfrew Electric Co., Ltd.

8S-3105

INFORMATION RETRIEVAL NUMBER 66

MODULES & SUBASSEMBLIES

CMOS clock oscillator draws only 1 mA at 5 V

Vectron, 121 Water St., Norwalk, Conn. 06854. (203) 853-4433. 6 wk.

The CO-236 crystal-controlled clock oscillator generates a high stability CMOS-compatible output at any specified frequency in the 0.01-Hz through 10-MHz range. It operates from a 5 to 15 V dc supply with a current drain typically less than 1 mA at 5 V dc. The oscillator is factory set to within ±0.001% of the specified frequency and stability is ±0.0025% over 0 to 70 C. A tuning adjustment is optionally available for setting frequency to within ±0.0001%. Options include the CO-236-2 which provides a stability better than ±0.005% over the −55 to +125 C temperature range and the CO-236-3 which provides stability of ±0.0003% over 0 to 50 C.

CHECK NO. 271

Keyboard offers 25 keys in space of 20-key units

Controls Research Corp., 2100 S. Fairview, Santa Ana, Calif. 92704. (714) 557-7161. $0.15/position (100 k up); 4 to 6 wk.

Miniature calculator keyboards have up to 25-key positions and provide redundant scissor spring contacts for 2-oz. touch. They are directly interchangeable with existing 17 to 20-key keyboards. The assembly includes a G-10 PC-board, 25 two-shot integral key/plungers and a 25-position nylon housing with base and throughholes.

CHECK NO. 272

Hybrid regulators handle 5 to 10 W in TO-3 case

Solitron Devices, 1177 Blue Heron Blvd., Riviera Beach, Fla. 33404. (305) 848-4311. from $3.00 (OEM qty); stock.

The SDR 120-12 through 27 series of voltage regulators has a 5-W power-dissipation capability. The units are packaged in a two-lead TO-66 case. The SDR 119-12 through 27 series can handle 10 W and are in a seven-lead TO-3 case. Fixed output voltages for both series range from 11.9 to 27.4 V. The 10 W devices include single-phase full-wave rectifiers in addition to the regulator.

CHECK NO. 273

Analog multiplexer has a switching time of 300 ns

Inter-Computer Electronics, P.O. Box 507, Lansdale, Pa. 19446. (715) 822-2929. $750; 3 wk.

The model 1AM-3216 is a high speed 16-channel analog multiplexer. The entire multiplexer includes logic decoding, precision analog switches and output buffer/driver. The multiplexer is factory expandable up to 64 channels. It has a transfer accuracy of better than 0.01%. Full-scale inputs of up to ±5 V are provided at the output of the multiplexer in less than 300 ns (maximum) including switching times. The output is capable of directly driving a 50 Ω load indefinitely with no degradation in speed or accuracy.

CHECK NO. 274

S/d converter delivers binary and BCD outputs

Transmagnetics, 210 Adams Blvd., Farmingdale, N.Y. 11735. (516) 293-3100. $750 (1-9); stock to 6 wk.

The Model 1623E, Code 12, 14-bit synchro-to-digital converter accepts three-wire synchro, four-wire resolver or flux-gate inputs. Both 14-bit parallel binary and four decade BCD outputs are generated simultaneously. Accuracy is to within 4 min. for the binary output and 0.1 deg. for BCD. The converter is available in two temperature ranges of 0 to 70 C and −55 to +85 C, and will accept either 60 or 400 Hz, low or high level signals. Transformer inputs provide total isolation between input and output. The converter is 3.75 by 4.5 by 1 in. and weighs only 11 oz.

CHECK NO. 275

Low cost time delay can control 5 A at 120 V ac

Omnetics, P.O. Box 113, Syracuse, N.Y. 13211. (315) 455-5731. From $5.81 to $9.02; 10 day to 2 wk.

The series MCR time-delay relays are available with outputs of normally closed or normally open spst contacts. The contacts are rated for 5 A or 1/6 hp at 120 V ac. Delay times are factory fixed from 0.5 to 60 s. Repeatability accuracy under rated conditions is ±5%. Two fixed delay tolerances of ±10% and ±20% are available. Electrical interface is by four 1/4-in. male quick-connect terminals. Expected life of the device is claimed by the manufacturer to be 10^6 mechanical operations and 5×10^5 operations under full-load conditions.

CHECK NO. 276

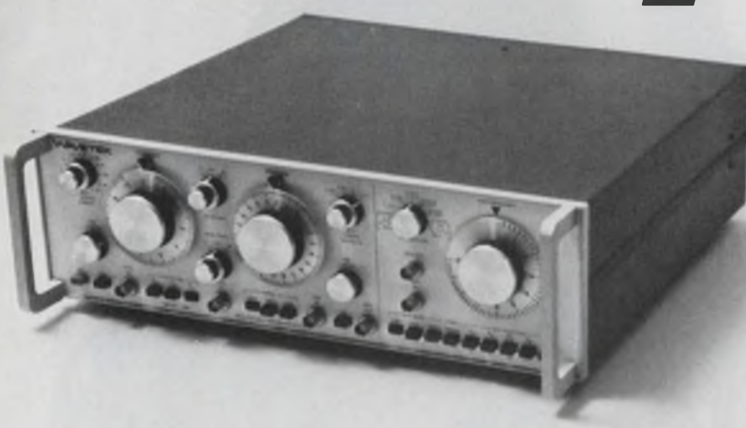
Uhf power amp modules cover 400 to 470 MHz

Motorola, P.O. Box 20912, Phoenix, Ariz. 85036. (602) 273-6900. For 1-to-24 pcs: $49 (710), $43 (709); 2 to 4 wk.

Uhf power modules, the MHW-709 and the MHW710, deliver a minimum of 7.5 and 13 W, respectively. These are complete amplifiers for the 400 to 470-MHz frequency range. Both units operate from a 12.5-V dc supply. The MHW709 delivers its rated output with a driving power of approximately 100 mW, for a power gain of 18.8 dB. The other unit requires only 150-mW of driving power to deliver rated output. Harmonic suppression is at least −40 dB across the frequency range with all spurious outputs more than 70-dB below desired signal. Input impedance is 50 Ω for both modules, and operation with a 20:1 load mismatch doesn't damage the unit.

CHECK NO. 277

Name it and it's yours.



We only screwed up one thing when we introduced our Model 146. Its name. We considered "the generator for the man who has everything." We even entertained such wild possibilities as "the alpha-omega machine." But in desperation, we finally settled for "The Multi-function Generator." Not a bad name, but it just doesn't do justice to the instrument. Read the next paragraph and see if you don't agree that the 146 deserves a better tag.

What the 146 is and does.

The Model 146 is two complete generators in a single package. You can use either one independently, or you can use one to control the frequency and amplitude of the other. The instrument's unique calibrated dial system allows center frequency, sweep width, amplitude and frequency modulation limits to be set — and read — *without* an oscilloscope. We realize you don't *have* to have a 146 for frequency modulation, amplitude modulation or frequency shift keying. But without one, you'll need at least *two* function generators, *plus* an oscilloscope. Probably the best words to describe the 146 are versatility and convenience.

INFORMATION RETRIEVAL NUMBER 69

What you should do.

Put your feet up on the desk for a few minutes and let your imagination run amuck. You're bound to come up with something more appropriate than "multi-function generator." Then, simply fill out the coupon (or a reasonable facsimile) and mail it to us. If we think the name you send in is the best one, we'll send you a Model 146 "whatchamacallit" ABSOLUTELY FREE! You have nothing to lose but a postage stamp and you stand to win an incredible laboratory signal source valued at $1,495. So hurry. Enter today.

Contest rules

1. Enter as often as you please, but each entry must be mailed in a separate envelope.
2. Entries must be postmarked no later than midnight September 15, 1973. All entries become the property of Wavetek and cannot be returned.
3. Entries will be judged on the basis of neatness, originality and aptness of thought. Wavetek reserves the right to supervise the judging and the decision of the judges is final.
4. Only one Model 146 will be given away and the winner will be notified by mail. The winner grants to Wavetek the right to publish his entry and to use his name and photograph for advertising and promotion.
5. Anyone in the United States and Canada may enter except employees (and their families) of Wavetek, its advertising agency and independent sales representatives. Odds of winning depend on the quality of the entry and the number of entries received. Void where prohibited. Federal, state and local laws apply.

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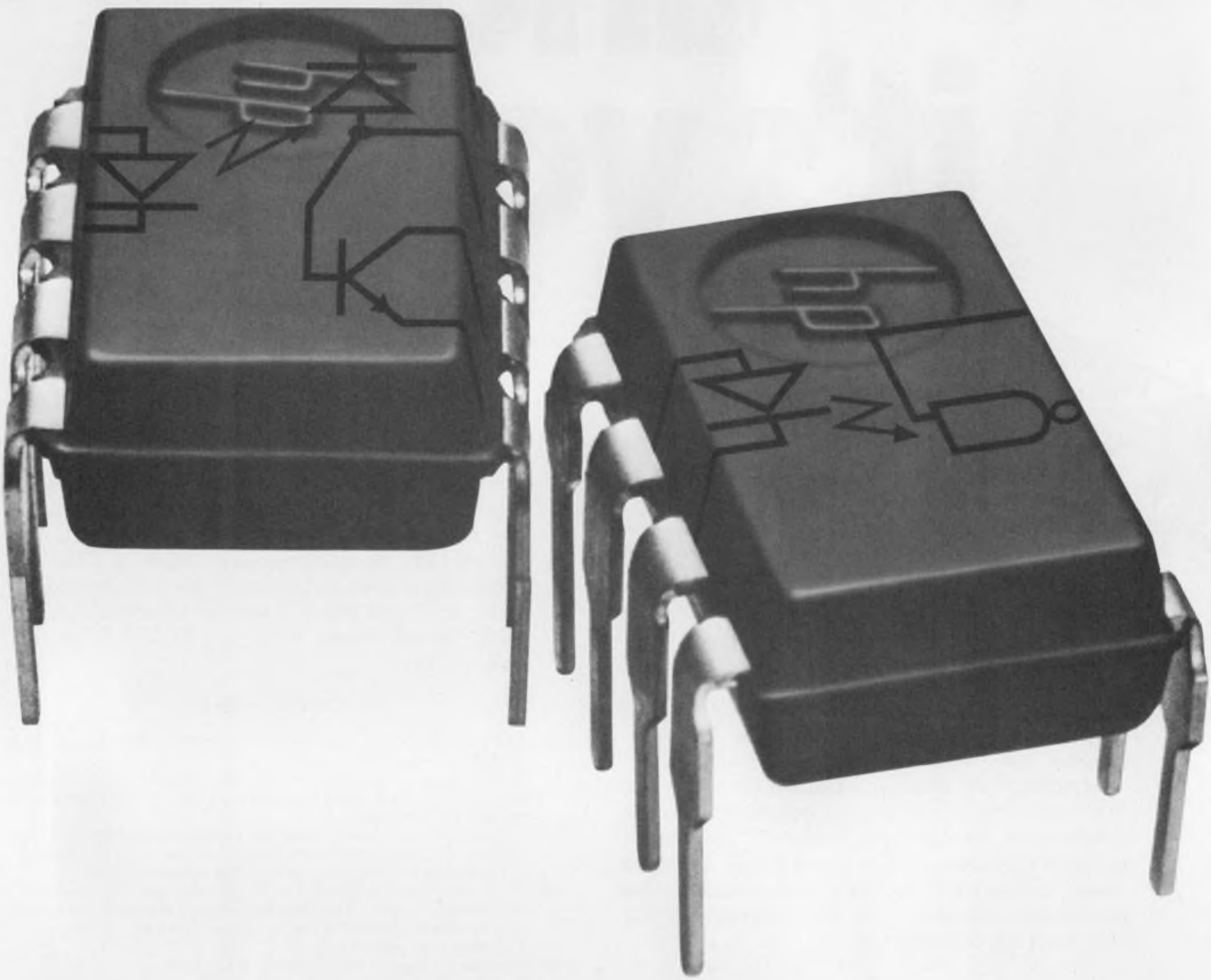

A high-speed isolator breakthrough.

Two new optically-coupled isolators take advantage of our advanced photo IC capability giving speeds four times faster than other opto couplers. The 5082-4360 Series optically-isolated gates operate up to 20M bits. This device has a photo detector IC circuit consisting of a photo diode and high-frequency linear amplifier. It is completely TTL compatible at the input and output and it's capable of feeding eight TTL gate loads. The 5082-4350 Series isolators operate up to 4MHz bandwidth. This device consists of a monolithic photo detector with a photo diode and high frequency transistor on the same substrate, making it ideal for linear and digital applications. The 5082-4350 Series prices start at $2.00 in 1K quantity; the 5082-4360 Series is priced at $4.50 in 1K quantities. Detailed specs are as close as your nearby HP distributor.

01323

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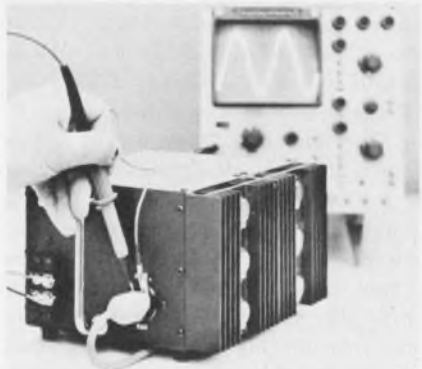
Sales, service and support in 172 centers in 65 countries.
Palo Alto, California 94304. Offices in principal cities throughout the U.S.

INFORMATION RETRIEVAL NUMBER 70

Low cost 120-VA inverter delivers sinewave output



Abbott Transistor Laboratories, 5200 W. Jefferson Blvd., Los Angeles, Calif. 90016. (213) 936-8185. $299 (1-4); stock.

Model KN12T-115-60 inverter operates over an input voltage range of 11 to 15 V dc and delivers an output power of 120 VA. The output voltage is 115 V ac ±2% at 60-Hz ±2 Hz sinewave with 5% maximum distortion. Line and load regulation is 3%. A compact package permits sustained full load operation at +55 C without the need for heat sinking or forced air cooling. The surge-current capability is up to three times rated output power. The unit withstands input transients of 45 V dc for 0.1 s and is overload protected by a magnetic circuit breaker.

CHECK NO. 278

Portable power supplies are short-circuit proof

Lamb Laboratories, 155 Michael Dr., Syosset, N.Y. 11791. (516) 364-1900.

The LPS10-series power supplies are compact, portable units which provide short-circuit-protected, fixed output voltages with a tolerance of ±5%. Models currently available are the LPS10-5A (5 V at 1.2 A), LPS10-6A (6 V at 1 A), LPS10-12A (12 V at 750 mA), LPS10-24A (24 V at 500 mA) and the LPS10-1515A (dual-tracking ±15 V at 300 mA). The 12-V and 24-V unit have less than 600-μV rms ripple. All units operate from 105 to 130 V at 47 to 63 Hz. For single-output models, the size is 7-3/8 × 3-3/4 × 2-1/2 in.; and for the dual-tracking model, it is 7-3/4 × 4-1/2 × 2-3/4 in.

CHECK NO. 279

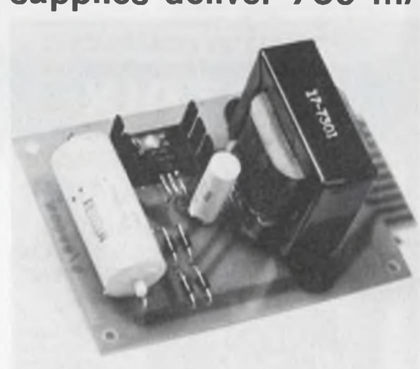
Dc/dc converter offers multiple outputs

Aztec Data Systems, 17805 Sky Park Circle, Irvine, Calif. 92707. (714) 540-8445. $5.00 (10,000 pc); 30 day.

Each dc/dc converter model has provisions for up to three output voltages. Input voltage, depending upon model can be from 3 to 9 V. These converters are meant for point-of-load applications where power requirements are under 1 W. Output regulation follows the input regulation.

CHECK NO. 280

Low cost card-mounted supplies deliver 750 mA



Northwest Engineering, 801 Duchess Rd., Bothell, Wash. 98011. (206) 485-4020. $19.95 (1-9); 1 to 2 wk.

The CBS series of low cost card-mounted power supplies is available in 5, 6, 8, 12 or 15-V-dc models with output current to 750 mA and short-circuit and over-temperature protection. Typical specs include regulation to 0.15% and ripple and noise of 3 mV.

CHECK NO. 281

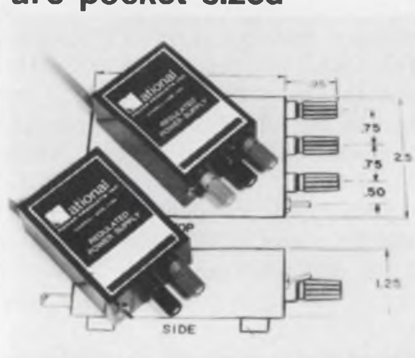
Dc/dc converter delivers 6-W with dual outputs

Integrated Circuits Inc., 13256 Northrup Way, Bellevue, Wash. 98005. (206) 747-8556. $39 (1-9); stock to 2 wk.

The model 200 series of dc/dc converters is designed to operate from a single voltage and deliver dual output voltages for loads up to 6 W. The converters operate from a 5 to 48 V dc supply and provide ±5 to ±15-V output. The devices operate in a nonsaturating mode and feature input to output isolation greater than 100 MΩ at 500 V dc. No additional heat sinking is required over the operating temperature range of 0 to 85 C and efficiency is typically better than 80% at full rated load.

CHECK NO. 300

Fixed-output supplies are pocket sized



National Power Products, P.O. Box 292, Haverhill, Mass. 01830. (617) 374-0777. From $49 (1-9); stock to 2 wk.

There are six models in the "L" series of lab supplies. They provide 5 V at 500 or 1000 mA, ±12, or ±15 V dc at current levels of 100 or 200 mA. Line regulation is 0.05% max and load regulation output supplies and 1-mV rms max. The temperature coefficient is 0.015%/°C, typ. Ripple and noise is 0.5-mV rms max for the dual-output supplies and 1-mV rms max for the 5-V supplies. Output-voltage tolerance is factory set at ±1%. The dual-output supplies typically track to within 0.025%. A current-limiting circuit provides indefinite short-circuit protection. All units are only 2.5 × 3.5 × 1.25 in.

CHECK NO. 301

Supply for mini-CRT has four regulated outputs

AMP Capitron, 1595 S. Mount Joy, Elizabethtown, Pa. 17022. (717) 367-1105.

An hermetically sealed power supply for miniature CRTs provides four regulated output voltages: +5000, +1000 (adjustable with remote potentiometers), +300, and +80 V dc. All outputs are short-circuit protected and the input (+22 to 30 V dc) is protected against reverse polarity. The package is filled with an oil/gas dielectric that provides better heat transfer and insulating properties than encapsulating or potting materials. These units are operable from −54 to +74 C without derating. Weight is only 1.5 lb and package dimensions are 3.5 × 2.34 × 2 in.

CHECK NO. 302

Multiple output supply delivers high currents

Pioneer Magnetics, 1745 Berkeley St., Santa Monica, Calif. 90404. (213) 829-3305.

The Model PM 2408 multiple output computer supply provides immunity to ac line failures and will operate during brownouts and blackouts. Power outages up to 20 ms do not affect normal operation. Holdup for more extended periods can be provided with battery backup. RFI filtering is furnished on both input and output lines. In a 500-W configuration, the unit is supplied with three dc output voltages: +5 at 50 A, +15 at 10 A and −15 at 5 A. Optional features such as automatic output sequencing, overvoltage protection, current limiting, power-fail signal, remote sense, etc., are available. The unit is designed to meet Underwriters Laboratories' spec UL 478, and is 5-1/8 × 10-5/8 × 15 in. in size and weighs 15 lb.

CHECK NO. 303

WHEN IT COMES TO MATCHING UP CONNECTORS AND CABLE...

IT TAKES TWO TO TANGLE

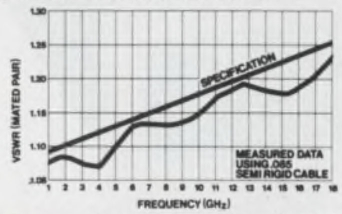
A fact not to forget is that those 3mm SMA connectors you may be specifying were designed for .141 inch cable. Use them with .085 inch diameter and the losses you suffer through a mismatch of connector geometry with cable geometry can be a problem.

In short, it takes two to tangle a signal transmission; the right connector and the wrong cable or the other way around.

That's where Simplicon comes in. They're a remarkable new series of coaxial connectors designed specifically for perfect line match with .085 inch diameter cable, semi-rigid or braided. And, slimmed-down Simplicon connectors will give you the performance equivalent to SMA types without conforming to totally irrelevant requirements that don't make sense in most applications.

If you're faced with the headaches that smaller, higher density packaging can bring, simply specify Simplicon. They're not only made for .085 inch cable but they're small enough to fit where you've never been able to fit a connector before.

Before we ask you to write for our catalog with all the details, check this VSWR. It's our clincher.



Now, will you write for that catalog? Cablewave Systems Inc., 60 Dodge Avenue, North Haven, Connecticut 06473, 203 239-3311.

Cablewave Systems Inc.

A Corporation Owned By Phelps Dodge And Kabelmetal

INFORMATION RETRIEVAL NUMBER 73

PACKAGING & MATERIALS

Spray dries moisture and stops corrosion

WD-40 Co., 5390 Napa St., San Diego, Calif. 92110. (714) 297-4938.

WD-40 has the ability to drive moisture out of the pores of metals. It can dry out wet electric motors and it deposits a thin molecular film that stops re-entry of moisture to prevent corrosion. The material is a nonconductor and will not harm rubber, plastics or fine finishes. It is available in aerosol spray cans or bulk sizes.

CHECK NO. 304

GGG crystal substrates offered for bubble work

Crystal Technology, 2510 Old Middlefield Way, Mountain View, Calif. 94040. (415) 961-9311.

Gadolinium-Gallium Garnet (GGG) in single-crystal substrates is the basis of epitaxial growth of many single-crystal, iron-garnet compositions for use in the emerging field of magnetic-bubble technology. Very small and mobile magnetic domains (bubbles), within the film of the iron garnet, combined with a metal overlay circuit can perform logic, memory, counting and switching functions. The crystals are claimed to be free of inclusions, precipitates, second-phase or core defects. Dislocations due to crystalline imperfections number less than 10/cm^2 and at least 50% of the area is defect free. Wafers up to 1-1/4 in. D are available in research quantities.

CEHCK NO. 305

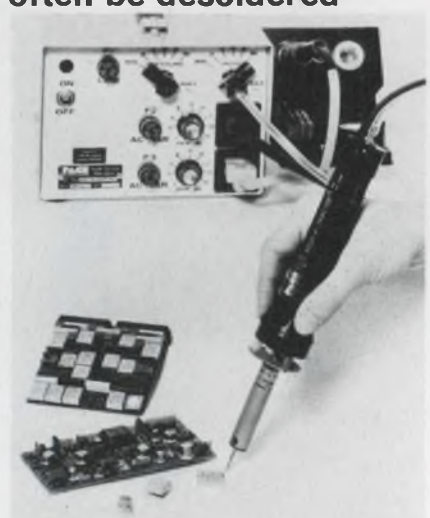
Adhesive has high thermal conductivity

Aremco Products, Inc., P.O. Box 145, Briarcliff Manor, N.Y. 10510. (914) 762-0685. $21 per pint kit; stock.

Aremco-Bond 517 is a two-part adhesive for use in joining materials where a high thermal conductivity bond is required. Besides having a high thermal conductivity, its thermal expansion rate is close to that of aluminum or copper, and it adheres well to metals, ceramics, glass and most plastics. The adhesive is suitable for use at temperatures from −70 to 300 F. When the base and activator are mixed and cured at 370 F for 25 minutes, shear strengths as high as 2000 psi can be achieved.

CHECK NO. 306

What is soldered must often be desoldered



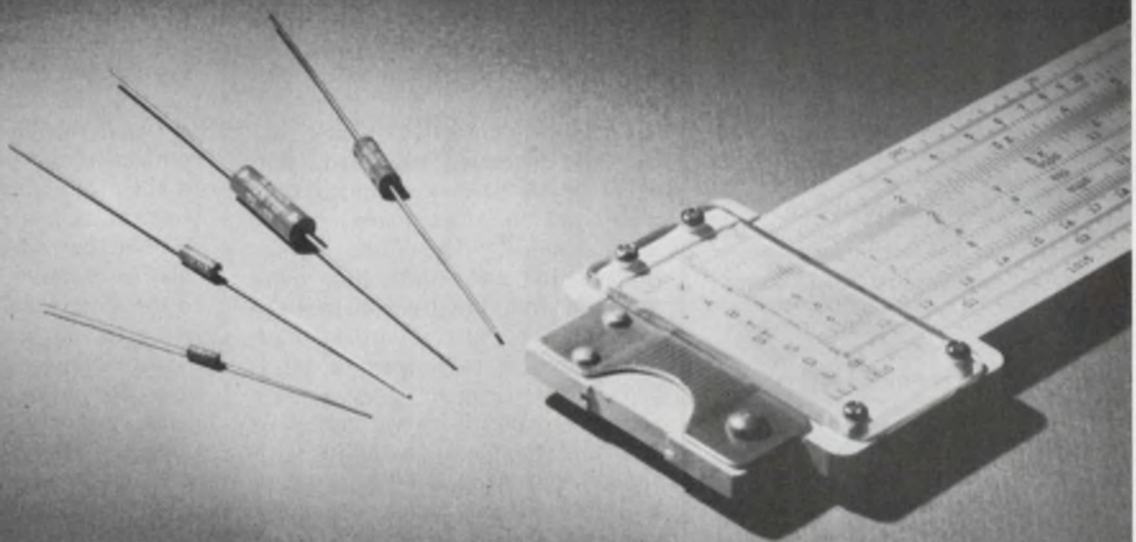
Pace, Inc., 9329 Fraser St., Silver Spring, Md. 20910. (301) 587-1696.

The Model SX-300 Sodr-X-Traction rework system provides the user with pressure, vacuum and hot-air jet modes of desoldering. The unit can handle single or double-sided joints, multipin thru-hole solder joints as well as lap-joint soldered connections and standoff terminations. The SX-300 features a coaxial, inline handpiece with a pencil-like design to provide control sensitivity and a familiar soldering-iron feel. The unit comes complete with tips, cleaning brushes, air line and connectors.

CHECK NO. 307

New generation of high-performance, low-cost, ultra-precision resistors

Tolerances: .01% to 1%
Temp. Coeff.: 5 to 25 PPM/°C
T.C. Matching: to 1 PPM/°C



Caught in a cost/performance bind on precision resistors? Solve the problem with TRW/IRC's new MAR Series of ultra-precision metal film resistors. Where speed and precision count, they offer the ultimate in cost/performance ratio. And by "performance," we mean *better* than premium wirewounds.

With the MAR Series, you get an ultra-stable, ultra-precision resistor with an extremely low temperature coefficient. You also get the non-measurable noise, low voltage coefficient and stress stability previously available only in precision wirewounds. Yet you still have the high-frequency response, reliability, pulse stability and resistance/size ratio of metal film.

Also available as part of the MAR technology are resistor matched sets and modules providing additional performance and cost advantages. For comprehensive technical data and MAR samples, contact your TRW representative. Or write TRW/IRC Fixed Resistors, 2850 Mt. Pleasant St., Burlington, Iowa 52601. Phone: (319) 754-8491.

IRC TYPE	RESISTANCE RANGE* (Ohms)	TEMPERATURE COEFFICIENTS −20° C to +85° C (± ppm/°C)	TOLERANCES (± %)	POWER RATING @ 85° C (Watts)	VOLTAGE RATINGS (Volts)	DIMENSIONS IN INCHES Body Length (L Max.)	Body Diameter (D Max.)	Lead Gage (A)
MAR3	20—100K	T10 = 15	1.00, 0.50, 0.25,	1/20	200	.191	.082	≈26 .016**
MAR5	20—250K	T13 = 10	0.10, 0.05, 0.02,	1/10	250	.281	.102	≈22 .025
MAR6	20—500K	T16 = 5	0.01	1/8	300	.425	.155	≈22 .025
MAR7	20—1 Meg			1/4	500	.650	.195	≈22 .025

*Wider ranges available. Contact factory. **Lead length 1.00 ± .062

TRW® IRC RESISTORS

INFORMATION RETRIEVAL NUMBER 75

Cables woven into flat, flexible forms

Woven Electronics, P.O. Box 189, Mauldin, S. C. 29662. (803) 288-4411.

Computer-controlled looms are used to produce standard, flat, cable forms that are up to 6-in. wide and have as many as 130 leads. Cables with widths exceeding 12 in. and containing more than 200 individual conductors are available on special order. Flat, flexible woven cable may be specified in any length. They can be used as ready-to-install harnesses or IC interconnect assemblies with almost unlimited combinations of lead insulations, sizes, functions and color coding.

CHECK NO. 308

High density DIP-board drawers fit 19-in. racks

Scanbe, 3445 Fletcher Ave., El Monte, Calif. 91731. (213) 579-2300. 8 wk.

Single and double-plane drawers use panels with 510, ME-2, 16-pin socket positions in eight zones of 60 and one zone of 30. Supply voltage and ground planes are on opposite sides of 0.062-in. glass-epoxy panels. A V_{cc} and ground pin are provided at each socket location. Provisions for mounting all forms of bypass capacitors are available on the boards. The single-plane (PN 11500) or the dual-plane (PN 11400) unit is designed for 19-in. EIA-rack mounting. The drawer is 1-3/4 in. (h) by 20 in. (d) for the single plane and 7 in. (h) by 20 in. (d) for the dual plane. An I/O panel is available for either model with from one to eight 120-pin rack-and-panel connectors plus a 100-CFM fan for the double-plane unit.

CHECK NO. 309

Layout paper dissolves in water

Vector Electronic Co., Inc., 12460 Gladstone Ave., Sylmar, Calif. 91342. (213) 365-9661. 8-1/2 × 11 plain; $5.95; 0.1 in. grid: $5.50 (50 sheets).

Component layout and wiring diagrams, when made on the paper called Vector-Sol and placed on the circuit board to aid assembly and interconnection, can be washed away by placing the board in hot water. This method eliminates many redundant steps and reduces wiring errors. The original design layouts can be directly used for construction and documentation. In use, the designer makes his component layout to the same scale as the circuit board. Using another sheet of the same paper, he draws the wiring diagram with wiring tabs in mirror image relationship to the component layout. The 0.100 in. grid pattern facilitates wire listing by use of the X-Y coordinates for later conversion to automatic wrapped-wire techniques. Copies of the original drawings can be made on sheets of water soluble paper using a Xerox 400 type duplicator or by offset printing. Permanent copies for documentation are made on plain paper.

CHECK NO. 310

IC dispenser cuts down on handling damage

Solder Removal Co., 1077 E. Edna Place, Covina, Calif. 91722. (213) 331-0985. $13.94 (1-4); stock.

The Dipsert, IC-dispensing base, provides a convenient fixture for picking up ICs. Most manufacturers' single-tube, IC carriers fit the Dipsert base. Up to four varieties of ICs, for a total of 100 units, are automatically fed before reloading is required. The base will accommodate either plastic or ceramic ICs. The No. 880 Insertic tool is recommended for use with the base to reduce handling damage.

CHECK NO. 320

Fault indicator holds display without power

North American Philips Controls Corp., Cheshire Industrial Park, Cheshire, Conn. 06410. (203) 272-0301.

Series L21603/01 manual-reset, fault indicator is a built-in test-equipment device for monitoring the performance of electrical circuits. When the circuit is functioning normally, the indicator presents an all-black appearance. A fault causes the window to trip to a contrasting black and white design. It responds to a pulse width of 50 ms. The indicator stays in the fault mode even after power is removed. Turning a knurled ring resets the indicator. Operating voltages range from 3 to 28 V dc.

CHECK NO. 321

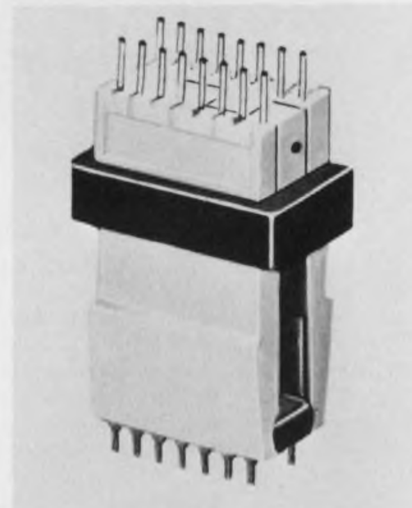
Ionized-air generator stops static charges

Testone Electrostatics Corp., Alpha Industrial Park, Chelmsford, Mass. 01824. (617) 256-3911.

Dynastat, Model DS-120, produces ionized air to neutralize static charges over a triangular region that is up to 6 ft. long with a 60 degree sweep. The unit is portable and can readily be set up to eliminate static hazards in FET and IC handling.

CHECK NO. 322

DIP test clip fits closely spaced ICs



Jermyn, 712 Montgomery St., San Francisco, Calif. 94111. (415) 362-7431. $8.50 (unit qty.).

The original A23-2024 test clip has been redesigned to make it more suitable for use on closely packed PC boards. The suffix "M" is added to the part number to indicate the modification and the original design has been withdrawn. The contacts are gold plated for low contact resistance and the contact extensions on the top of the clip are suitable for clip-on test probes or for solder leads.

CHECK NO. 323

Spiral cable wrap retards flame

L. Frank Markel & Sons, Inc., P.O. Box 752, Norristown, Pa. 19404. (215) 272-8960.

A new flame-retardant, vinyl, spiral-cut, wrap tubing that is UL recognized, is designated Flexite HT-105 FR-1. It is an expandable plastic wrap for making harnesses and for the abrasion protection of wires and tubing lines. The spiral tubing provides openings for individual-lead break-out points.

CHECK NO. 324

Our customers...

what do they say about Rotron fans and blowers?

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16314

INFORMATION RETRIEVAL NUMBER 81

S-TTL multiplexer has 12-ns delay

Fairchild Semiconductor, 464 Ellis St., Mountain View, Calif. 94040. (415) 962-3816. $6.50 (100-999).

A high-speed Schottky version of the company's TTL eight-input multiplexer features a typical address-to-output delay time of 12 ns. Called the 93S12, the new circuit has a delay time that is one-half that of the standard TTL multiplexer. The new multiplexer has assertion and negation outputs and on-chip select logic decoding.

CHECK NO. 325

Power transistors are rated up to 250 W

Silicon Transistor, Katrina Rd., Chelmsford, Mass. 01824. (617) 256-3321.

Three power transistors—the 2N6257, 2N6258 and 2N6259—can dissipate 150 to 250 W. These ratings can be obtained from 50 to 170 V and currents up to 30 A. Supplied in the TO-3 package, the transistors are improved versions of the 2N3771 through 2N3773 single-diffused power devices.

CHECK NO. 326

Triple Ex-OR/NOR gate has 2-ns delay

Signetics, 811 E. Arques Ave., Sunnyvale, Calif. 94086. (408) 739-7700. $1.70 (100 up).

A triple, two-input, exclusive-OR/NOR gate offers a propagation delay of 2.0 ns for one set of inputs, and 2.8 ns for the other. An ECL circuit called the 10107, the new gate has a 50-kΩ pulldown resistor at each input. The 10107 has a fanout capacity of six 50-Ω lines and a typical no-load power dissipation of 115 mW.

INQUIRE DIRECT

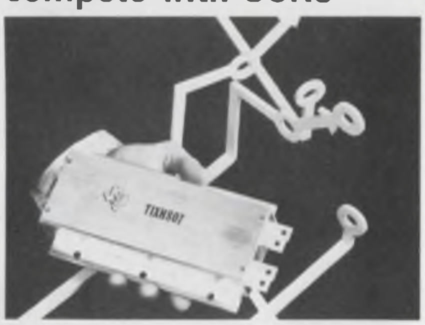
64-bit MECL 10-k RAM accesses in 10 ns

Motorola Semiconductor Products, P.O. Box 20924, Phoenix, Ariz. 85036. (602) 244-3466. MCM10140-AL: $17 (100-999); stock.

Two 64-bit RAMs, part of the MECL 10,000 family, offer a typical access time of 10 ns. One RAM, the MCM10140, drives loads of 90 Ω; the other, called the MCM-10148 is specified for 50-Ω loads. Both memories are organized as 64 one-bit words, have full binary decoding on chip, and contain chip-enable inputs for building large memory arrays. The memories have a temperature range of −30 to +85 C and come in 16-pin DIPs.

CHECK NO. 327

Power switches compete with SCRs



Texas Instruments, P.O. Box 5012, M/S 308, Dallas, Tex. 75222. (214) 238-3741. Tentatively $450 (1000 up); 12 wks. (sample quantity).

Three integrated power transistor switches—the TIXH807, TIXH-808 and TIXH809—are believed to be the first of their type to be used for high-power conversions traditionally performed by SCRs. Each switch, housed in a conduction-cooled aluminum case measuring 7 × 3.5 × 1.6-inches, has a typical turn-off time of 0.5 μs. They operate from dc to 10 kHz and can be driven by DTL or TTL ICs. The TIXH807 is rated at 150 A and 100 V; the TIXH808 at 200 A and 100 V; and the TIXH809 at 60 A and 400 V.

CHECK NO. 328

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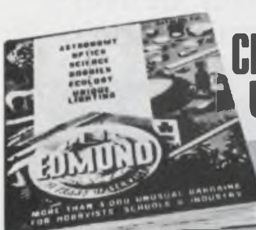

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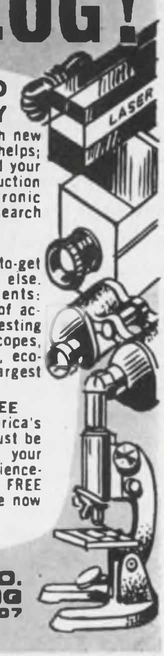

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INFORMATION RETRIEVAL NUMBER 84

World's smallest

power supply for op amps...$14

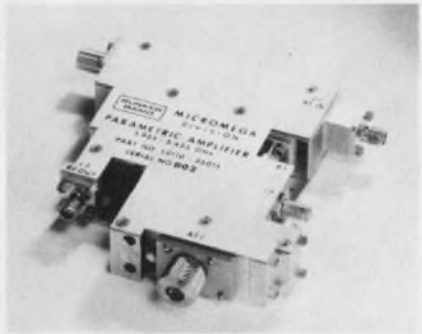
This 2.3 x 1.8 x 1-inch module has tracking outputs of ±15 V @ 25 ma with regulation of ±0.1% and ripple of 1 mv. It costs $14.00 in 1,000 lots and only $24.00 for one. Requisition Model D15-03. (For ±12 V @ 25 ma, order Model D12-03.) Three-day shipment guaranteed.

Acopian

Acopian Corp., Easton, Pa. 18042
Telephone: (215) 258-5441

INFORMATION RETRIEVAL NUMBER 85

Miniature C-band paramp has low noise



Micromega Div./Bunker Ramo, 12575 Beatrice St., Los Angeles, Calif. 90066. (213) 391-7137.

C-band parametric amplifiers weighing only 12 oz feature a 5.9-to-6.4-GHz instantaneous bandwidth and 140 K uncooled noise temperature. The 7.5-cubic-inch units have a typical one-stage gain of 15 dB and a gain ripple over the bandwidth of ±0.20 dB.

CHECK NO. 329

Linear amplifier covers the 1 to 300 MHz range

Amplifier Research, P.O. Box 7, New Britain, Pa. 18091. (215) 822-0161.

Model 2LM1 is a self-contained linear amplifier designed for laboratory applications requiring wide instantaneous bandwidth, high gain and moderate power output. When used with a frequency-swept signal source, the unit has a power output of 2 W with less than 1 dB compression over a frequency range of 1 to 300 MHz. The unit can be used on the bench or rack-mounted in a 5-1/4 in. space. It has a minimum power gain of 33 dB and is flat to within ±1 dB. Input and output impedances are 50-Ω nominal. Harmonic distortion is not less than 25 dB below fundamental at the 2-W output level.

CHECK NO. 330

IC log amp withstands severe environments

RHG Electronics Laboratory, 161 E. Industry Ct., Deer Park, N.Y. 11729. (516) 242-1100. $995; 45 days.

A 120-MHz IC log amplifier, the ICLT120, meets the thermal-shock requirements of MIL-STD-331 and has a reported MTBF of 50,000 hours. The device meets all electrical specifications over the temperature range of −30 to +71 C, 100-G shock, 50-G acceleration and thermal shock of a 100-C change in 5 minutes. The log amp has a bandwidth of 50 MHz, dynamic range of 60 dB and logging accuracy of ±1 dB.

CHECK NO. 331

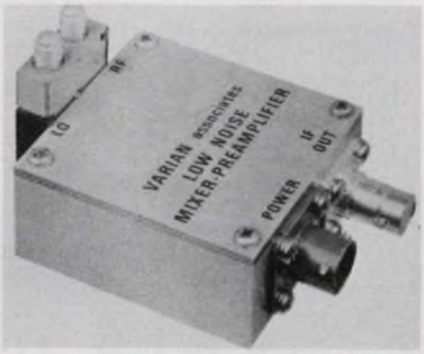
Nd:YAG laser delivers 200-mW multimode

General Photonics, 3004 Lawrence Expwy., Santa Clara, Calif. 95051. (408) 736-7114. $2500; 4 wk.

Model TWO-10 is a continuous-wave, Nd:YAG laser. Its features include modular construction for versatility, a thermostable resonator for output stability, intracavity space for second harmonic generation, single-package design for portability and a water-flow interlock to prevent overheating of the laser crystal. The laser generates 50 mW of TEM_{00} power at 1.06 μm. Multimode output is 200 mW and the beam diameter is 2 mm. It has a length of 14-1/2 in., and a diameter of 3 in. The weight is only 4-1/2 lb. It operates from 117 V ac, 50 or 60 Hz, 500 W, and needs flowing tap water at 3/4 gal/min.

CHECK NO. 332

Low-noise mixer-preamp delivers 10 dBm



Varian, Salem Rd., Beverly, Mass. 01915. (617) 922-6000. $525.

The KC-7A series of L through K_u-band coaxial mixer-preamplifiers combine noise figures of 7.5 dB in L and S-band and power outputs of +10 dBm at 1-dB compression. Noise figures for C and X-band units are 8.0 dB; for K_u-band, it's 8.5 dB. Minimum rf to i-f gain is 20 dB for all models. Separate units cover bands between L and X with 3-dB bandwidths of 10, 20 or 40 MHz and intermediate frequencies of 30, 50, 60 or 70 MHz.

CHECK NO. 333

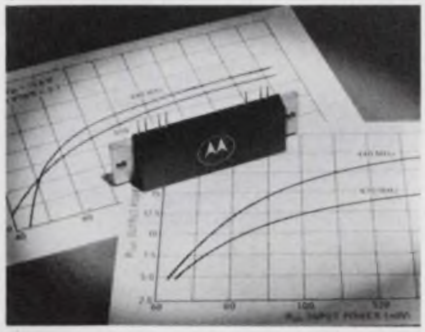
L-band YIG oscillator provides 30 mW ±2.5 dB

Omniyig Inc., 2325 De La Cruz Blvd., Santa Clara, Calif. 95050. (408) 241-1226.

Covering the 1-to-2-GHz frequency range, a YIG-oscillator provides more than 30 mW of rf power with less than ±2.5 dB of variation. Rejection of the second harmonic exceeds 18 dB and other spurious signals are down more than 60 dB. Called the YOL30, the YIG oscillator exhibits a tuning linearity of ±0.10% (3 MHz) over the entire band. Full-octave tuning speed is 3 ms and frequency drift vs temperature is less than 5 MHz from 0 to 60 C.

CHECK NO. 334

Hybrid rf amps provide 7.5, 13 W

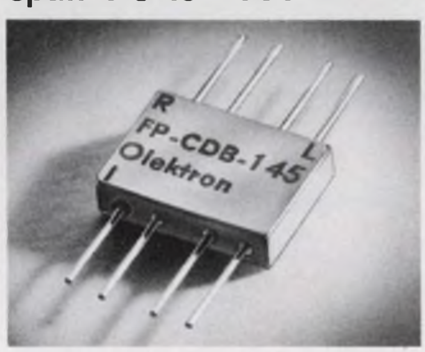


Motorola Semiconductor Products, P.O. Box 20924, Phoenix, Ariz. 85036. (602) 244-3466. MHW710-1/2; $42.50, MHW709-1/2; $38 (25-99); 2 to 4 wk.

Two amplifier modules, offering more than 18-dB power gain, deliver a minimum of 7.5 W—the MHW709—and 13.0 W—the MHW-710. These are complete amplifier units that cover the 400-to-470 MHz frequency range in two bands and operate from a 12.5 V-dc supply. The MHW709 provides its rated power with a 100-W input; the MHW710, with 150 mW. Harmonic suppression is at least −40 dB down across the frequency range with all spurious outputs more than 70 dB below the desired signal.

CHECK NO. 335

Double-balanced mixers span 0.5 to 1350 MHz

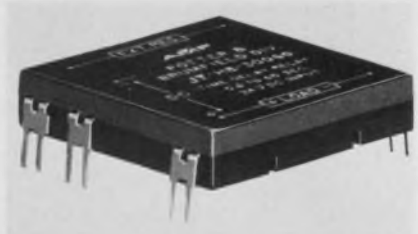


Olektron, 6 Chase Ave., Dudley, Mass. 01570. (617) 943-7440. $29 (unit qty.); stock to 4 wk.

Model FP-CDB-145 double-balanced mixer has a frequency range of 0.5 to 1350 MHz. The manufacturer states that the mixer exhibits 1-to-2 dB lower conversion loss than earlier designs across its broad frequency spectrum. Typical conversion loss is 7 dB at 1 GHz, and 6.5 dB at 500 MHz. Size of the mixer is 3/8 by 1/2 by 1/8 in.

CHECK NO. 336

Time-delay module mounts on PC boards



Potter & Brumfield, 1200 E. Broadway, Princeton, Ind. 47670. (812) 385-5251.

A low-profile, (0.35 in.) solid-state, delay-on-operate module series for PC boards, designated the JT, is suitable for driving a reed relay or reed-triggered triac. Two styles are offered—fixed and external-resistor adjustable. In the fixed style, nine time-delay ranges are available, from 0.05 to 120 s ±5%; in the adjustable, five ranges from 0.05 to 120 s ±10%. The JT provides an output of 250 mA steady state, but will safely handle 800 mA recurrent surges for up to 10 ms. Recycle time and release time are each 50 ms. Input requirements are 12, 24, or 48 V dc ±10% at a steady-state 4 mA during timing. The unit has built-in polarity protection. When used within rated conditions, the JT has a life expectancy of over 10-million operations.

CHECK NO. 337

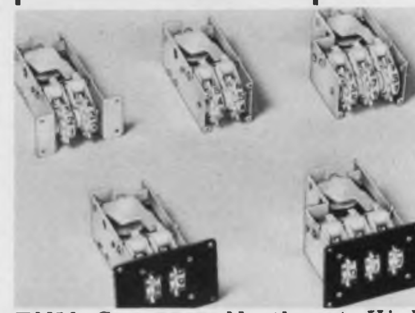
Test clip helps with trouble-shooting chores

Pomona Electronics Co., Inc., 500 E. 9th St., Pomona, Calif. 91766. (714) 623-3463.

The Grabber minitest clip, model 3925, permits the user to quickly assemble his own test leads. The unit will accept any wire up to 0.090 in. diameter. It features a plunger-action contact hook that firmly holds component leads or terminals without damage. The special probe tip can slip over a 0.025 in. square Wire-Wrap pin and make positive connection.

CHECK NO. 338

Predetermined counters provide DPDT output

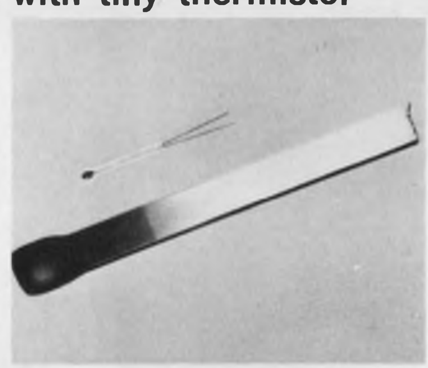


ENM Co., 5342 Northwest Highway, Chicago, Ill. 60630. (312) 775-8400. $8.36 up (1000 up).

Series PE80 line of five electrical predetermined counters are UL recognized. Digits are manually set to the desired count by rotating the thumbwheels. Electrical pulses cause the device to count down and activate a double-pole, double-throw switch at zero. Figures are black on white and 0.250 in. high. Speed rating is 200 pulses per minute. The double-pole, double-throw switch is rated for 5 A at 250 V ac.

CHECK NO. 339

Measure temperature with tiny thermistor



Fenwal Electronics, 63 Fountain St., Framingham, Mass. 01701. (617) 872-8841.

This tiny glass thermistor probe, a little over 1/4-in. long, features an extremely fast response time. The thermistor bead is sealed in a shock-resistant, thin-wall glass tube, and the unit has corrosion-resistant platinum-iridium leads. A time constant of about 25 ms (in moving water) makes the unit particularly well suited to dynamic temperature measurements in liquids and gases. Standard probes are available with nominal resistances of 500 Ω to 300 kΩ, and they can be used at temperatures to 300 C.

CHECK NO. 340

evaluation samples

Aluminum-oxide washers

Two aluminum-oxide washers, slightly thicker than the original TO3 and TO66 versions, have increased thermal resistance. Jermyn.

CHECK NO. 341

Varactors

Varicap varactors include types with capacitance from 2.2 pF to 1000 pF at 1 MHz; Q of 100 to 700; and capacitance-change ratios from 2:1 to 8:1. TRW Semiconductors.

CHECK NO. 342

4-position temp recorder

A 3/16 inch diameter and 0.01 inch thick four-position temperature recorder, Model 440, features an accuracy of ±1%. Temperatures in ranges from 110 to 450 F (43 C to 232 C) with an accuracy of ±1% are measured. When exposed to rated critical temperature, the four round-window indicators turn from pastel to black for a direct readout which is permanent and irreversible. It self-adheres to any small surface. William Wahl Corp., Temp-Plate Div.

CHECK NO. 343

Circuit-card puller

A nylon circuit-card puller fastens to the card without rivets. The puller is 1.5 in. × 0.87 in. × 0.28 in. and attaches to the card by snapping into two 0.125 in. D holes. It fits all cards up to 0.045 in. thick. A horizontal pull on the flaired handle of the puller withdraws the card. Richco Plastic Co.

CHECK NO. 344

Endless belts

An envelope-sized folder contains samples of endless belts for power-transmission applications. Included are Posi-Drive belts, ultra-speed types, untreated cotton woven types, neoprene impregnated cotton varieties, hi-speed nylon, single-ply polyester and custom belts. Letterhead inquiries only. Fenner America, Ltd., Russell Manufacturing Div., 400 E. Main St., Middletown, Conn. 06457.

application notes

Microwave diode switches

Anyone who uses diode switches or limiters in high-frequency systems or equipment can benefit from "Selection and Use of Microwave Diode Switches and Limiters." The topics featured are effects of mismatches and how to minimize them; selecting the right switch for switching, attenuating, or modulating; how to change the threshold and slope of a limiter; tradeoffs in selecting coax, stripline modules or complete switches; designing bias networks; multithrow and driver circuits; how to test switches and limiters. Hewlett-Packard, Palo Alto, Calif.

CHECK NO. 345

Hardeners for epoxy resins

A booklet on selecting hardeners for epoxy resins provides descriptions and selection factors for 20 Bakelite hardeners or curing agents. Advantages, disadvantages and uses are detailed in the 18-page brochure. Typical starting formulations are given for epoxy applications including electrical, flexible and machinable castings, laminates, adhesives, grouts and coatings. Toxicological properties are discussed. Union Carbide Corp., New York, N.Y.

CHECK NO. 346

Video systems

A six-page brochure describes narrowband video equipment applications, transmission-line requirements and signal characteristics. Colorado Video, Inc., Boulder, Colo.

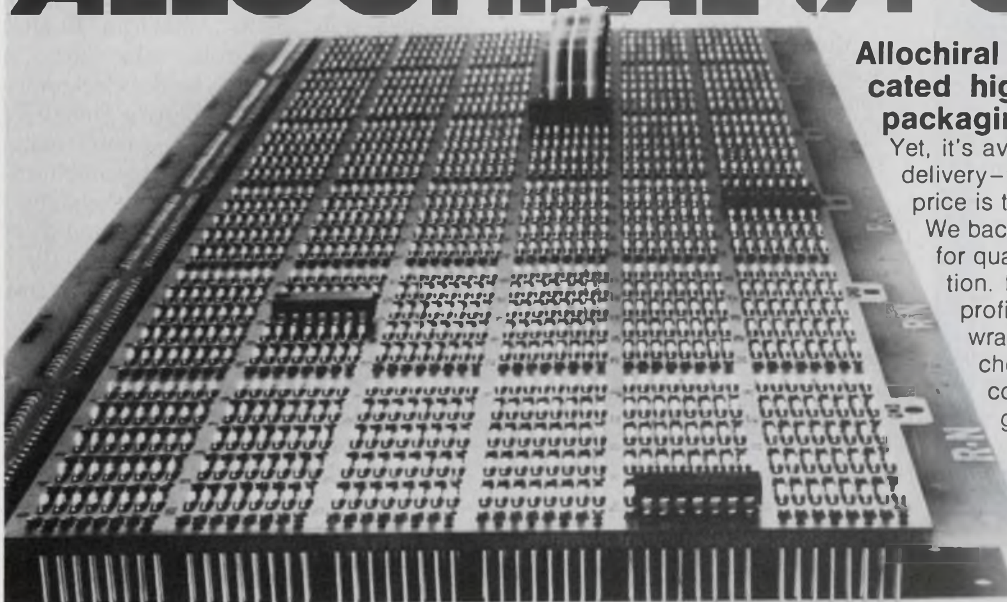
CHECK NO. 347

Magnetic shielding

How to solve the problems of designing and manufacturing a magnetic shield for CRTs that meets three specific requirements including low cost is detailed in Data Sheet 208-3PS. Included are performance data and test procedures. The use of magnetic and nonmagnetic materials is related. Ad-Vance Magnetics, Rochester, Ind.

CHECK NO. 348

IMMEDIATE DELIVERY ALLOCHIRAL (A-OK)



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INFORMATION RETRIEVAL NUMBER 93

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.900" x.980" FRONT PANEL SIZE FOR SINGLE MODULE ASSEMBLY.

CDI Series TSM mini-thumbwheel switches mount on ½-inch centers . . . can be furnished with decimal, binary, or binary with complement output—or with specified code characters. Available with extended PC boards for mounting additional components if desired. Large, easily-read numerals . . . positive detent . . . 8, 10 and 12 positions. Completely O-ring sealed against hostile operating environments.

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INFORMATION RETRIEVAL NUMBER 94

new literature

Two-channel FFT analyzer

The Omniferous FFT analyzer, which operates like an instrument and calculates like a computer, is highlighted in a 12-page catalog. Federal Scientific, New York, N.Y.

CHECK NO. 349

Eight-channel recorder

An illustrated six-page brochure describes an eight-channel recorder. Included is a description of the variable-speed chart drive and details about the Astro-Tip stylus. Astro-Med, West Warick, R.I.

CHECK NO. 350

Converters and amplifiers

Electrical specifications and prices for digital-to-analog converters and operational amplifiers are included in a short-form catalog. Dynamic Measurements Corp., Winchester, Mass.

CHECK NO. 351

Microwave and rf connectors

A fully illustrated, colorful 74-page catalog includes data on microwave and rf connectors, miniature semirigid coaxial cable plus coaxial cable assemblies and delay lines and accessories. The catalog is divided into four sections—SMA connectors, SMB and SMC connectors, assembly and installation and miniature cable. Cablewave Systems, North Haven, Conn.

CHECK NO. 352

Insulated materials

Metal-sheathed, ceramic-insulated thermocouple materials, high-temperature cables and sheathed heaters are highlighted in a 36-page catalog. The catalog includes numerous tables and graphs showing properties of wire, insulator and sheath. Semco Instruments, North Hollywood, Calif.

CHECK NO. 353

Semiconductor materials

"Semiconductor Materials from Dow Corning," a 16-page, full-color brochure, describes polycrystalline silicone, float-zone or Czochralski-grown single crystal and wafers. Other products covered are silicon furnace tubes and silicon-carbide coated susceptors, along with information on quality control procedures and equipment. Dow Corning, Midland, Mich.

CHECK NO. 354

Volt-level detectors

Time and money-saving "building blocks" for automatic alarm, instrumentation, testing or control functions in new or existing systems are explained in a 16-page catalog. Voltsensors, power supplies, amplifiers and two families of industrially oriented detector packages are detailed with specifications, block diagrams, operation curves and prices. Calex, Alamo, Calif.

CHECK NO. 355

He-Ne lasers

A helium-neon laser product guide contains information on the major parameters of He-Ne laser tubes, exciters, heads and laser subsystems. RCA, Harrison, N.J.

CHECK NO. 356

Ac^2 instrumentation

"ac^2 Instrumentation Concepts," a 16-page brochure, presents installation and maintenance information, design features and operating procedures for a line of analog control instruments. Fisher Controls, Marshalltown, Iowa.

CHECK NO. 357

Product guide

"Motorola Product Guide," a 48-page book, covers the product and service capability of automotive, consumer, communications, government electronics and semiconductor products divisions. The book also tells about American Regitel Corp., a Motorola subsidiary in the retail point-of-sale electronics business; the company's timepiece electronics program, hotel/motel electronic management, communications and entertainment systems; and training and educational film business. Motorola, Chicago, Ill.

CHECK NO. 358

Multilayer ceramics

A bulletin on co-fired multilayer ceramic products describes chip carriers and dual-inline, hybrid, power transistor and LED packages as well as multilayer substrates and multichip packages. American Lava Corp., Chattanooga, Tenn.

CHECK NO. 359

Flexible circuit laminates

Three data sheets cover flexible-circuit laminated products—PC-2000 polyester/copper film laminates, AC2300 adhesive-coated copper system and HS2400 adhesive-coated polyester film. Keene Corp., Chase-Foster Div., East Providence, R.I.

CHECK NO. 360

Motor/potentiometer

An accurate dynamic shaft (pointer) positioning device that incorporates a conductive plastic potentiometer element and a dc torque motor is described in a bulletin. The five-page bulletin details operating characteristics of the motor-pot device and provides motor specifications and line drawings of flange and servo-mounting models. Amphenol Connector Div., Broadview, Ill.

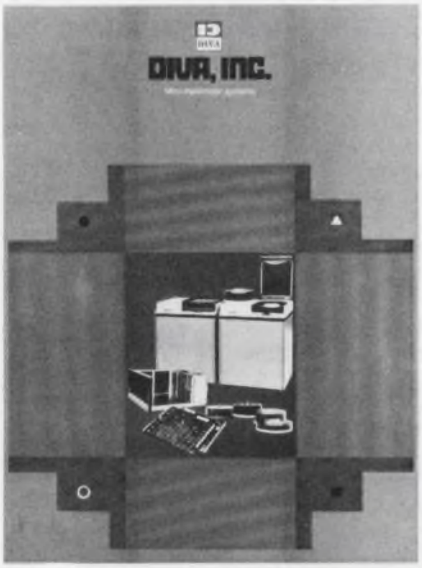
CHECK NO. 361

Disc storage system

Capacity, optional configurations, speeds, compatibility, reliability features and price/performance of the 8830/8330 plug-compatible disc storage system are detailed in a catalog. Mohawk Data Sciences, Utica, N.Y.

CHECK NO. 362

INFORMATION RETRIEVAL NUMBER 96



Disc systems

Specifications and descriptions of seven basic magnetic-disc-drive systems, ranging in storage capacity from 7.5-million, eight-bit bytes to 232-million bytes per disc-drive unit, are described in a brochure. A discussion is included on the use of up to eight disc drives to provide a billion-bytes of on-line storage. Diva, Inc., Eatontown, N.J.

CHECK NO. 363

Graphic display

The Anagraph display system is described in an eight-page brochure. Typical graphic displays are pictured in full color, as is the system. The applications, hardware and software capabilities are detailed. Data Disc, Sunnyvale, Calif.

CHECK NO. 364

Instruments

Operational amplifiers and current boosters, d/a and a/d converters, sample-and-hold analog memories, analog multipliers/dividers and V-to-F and F-to-V converters are among items listed in a 36-page catalog. Optical Electronics, Tuscon, Ariz.

CHECK NO. 365

Resistor networks

A range of standard and custom thin-film resistor networks, substrates and hybrid circuits are described in a folder. LRC, Inc., Hudson, N.H.

CHECK NO. 366

Core and coils

Control transformers for machine-tool applications are featured in a two-page data sheet. Included are pricing information, features, a selection guide, modification information and wiring and dimension data. General Electric, Scotia, N.Y.

CHECK NO. 367

Power transistors

Silicon and germanium power transistors are described in a 40-page short-form catalog. Characteristics of over 1000 types covering power levels of 1 to 350 W, voltage to 800 V and current to 100 A are given. Several application guides and a section describing process-parameter relationships are included. Silicon Transistor Corp., Chelmsford, Mass.

CHECK NO. 368

Laminates

Specifications on Micaply epoxy glass laminates and prepregs for multilayer and rigid printed circuits are featured in a 20-page catalog. The Mica Corp., Culver City, Calif.

CHECK NO. 369

Heat exchangers

Heat exchangers for use with semiconductors are described in a 12-page bulletin. The bulletin includes air and liquid-cooled thermal characteristics, standard drilling patterns, air-cooled performance curves (natural and forced), steady-state thermal-resistance curves, transient thermal-resistance curves, temperature-rise curves, liquid-cooled performance curves and dimensions. International Rectifier, El Segundo, Calif.

CHECK NO. 370

Photosensitive devices

Specifications on hundreds of photosensitive devices including photomultipliers, phototubes, photoconductive cells, light sources, visible, X-ray and infrared vidicons are given in a catalog. Also included are regulated power supplies, refrigerators and counters for photodetectors and video equipment. Hamamatsu Corp., Middlesex, N.J.

CHECK NO. 371

Plastic fasteners

An instant-identification guide is provided in a 24-page plastic fasteners catalog. Featured are screws, nuts, washers, rivets, as well as specialty fasteners—all presented with illustrations, schematics, properties, specifications and applications. Full pricing schedules are included for each unit. Product Components Corp., Mount Vernon, N.Y.

CHECK NO. 372

Microwave products

Solid-state microwave instrument systems and components and millimeter-wave devices are highlighted in a four-page booklet. Hughes Electron Dynamics Div., Torrance, Calif.

CHECK NO. 373

Disc memory testing

The DT-300 series of automatic disc-memory certifiers is highlighted in a four-page brochure. The brochure includes descriptions of each product in the series and describes the operation of the certifier. Specifications are listed. Computest Corp., Cherry Hill, N.J.

CHECK NO. 374

Capacitors and filters

Standard high-voltage capacitors and filters are detailed in a six-page, two-color catalog. Specifications, diagrams, photographs and comparative-size charts are included. The Elmag Corp., Newark, N.J.

CHECK NO. 375

Auto-photometers

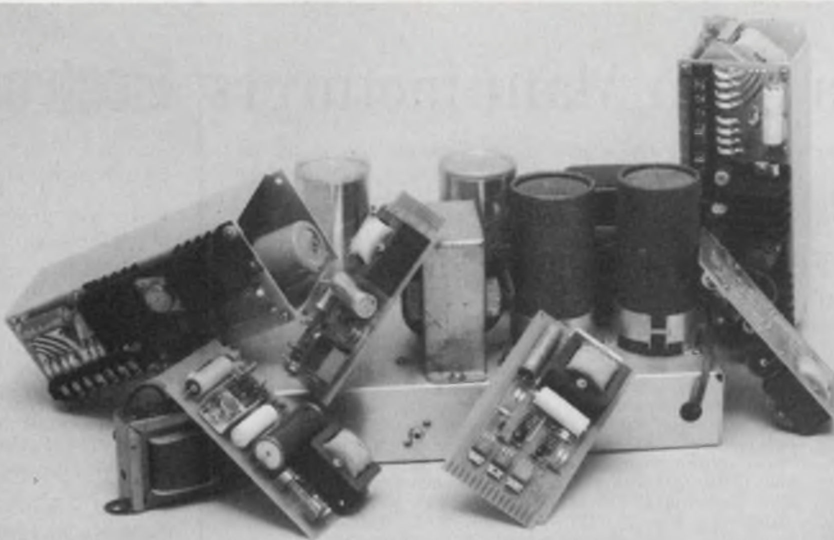
A bulletin describes the 2900 auto-photometer and the 2400 manual photometer. These photometers are the basic building blocks in the company's light-measurement systems. Gamma Scientific, San Diego, Calif.

CHECK NO. 376

Panel meters

Panel meters with plastic-dial light-diffusing illumination, panel meters that provide a "window into the product," panel meters with quick-change dials are included in a 36-page catalog. Modutec, Inc., Norwalk, Conn.

CHECK NO. 377



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advertiser's index

INFORMATION RETRIEVAL NUMBER 103

INFORMATION RETRIEVAL NUMBER 104

product index

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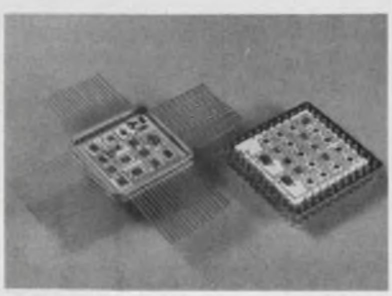

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