VOL. 23 NO. 6

Electronic Design®

FOR ENGINEERS AND ENGINEERING MANAGERS

MARCH 15, 1975

Solid-state technology is having an increasing world-wide impact. Minicomputers, pocket calculators and communications satellites are just a few of the products made possible by advances in signal processing techniques, high-speed logic, memories, optoelectronics and microwave devices. A report on solid state begins on page 22.

Buy our ASCII programmable function generators and you'll be ready for the bus.

If you've been looking for a function generator that plugs into an automatic system about as easily as it plugs into the wall, Wavetek is your stop. Our Models 152 and 159 are both ASCII coded and are fully compatible, which means they can be used with the new general-purpose instrumentation bus . . . and just about any computer. They also have pushbutton manual controls if you'd rather keep them on the bench. Either way, you'll be able to see what's happening with the LED digital display panels.

Model 159 is a general-purpose low-cost function generator with programmable frequency, amplitude, offset and waveform. Its frequency range is 1 Hz to 3 MHz.

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INFORMATION RETRIEVAL NUMBER 2

HP's New 5 Volt 100 Amp Switching Supply is Ready For the Most Important Test in the World...

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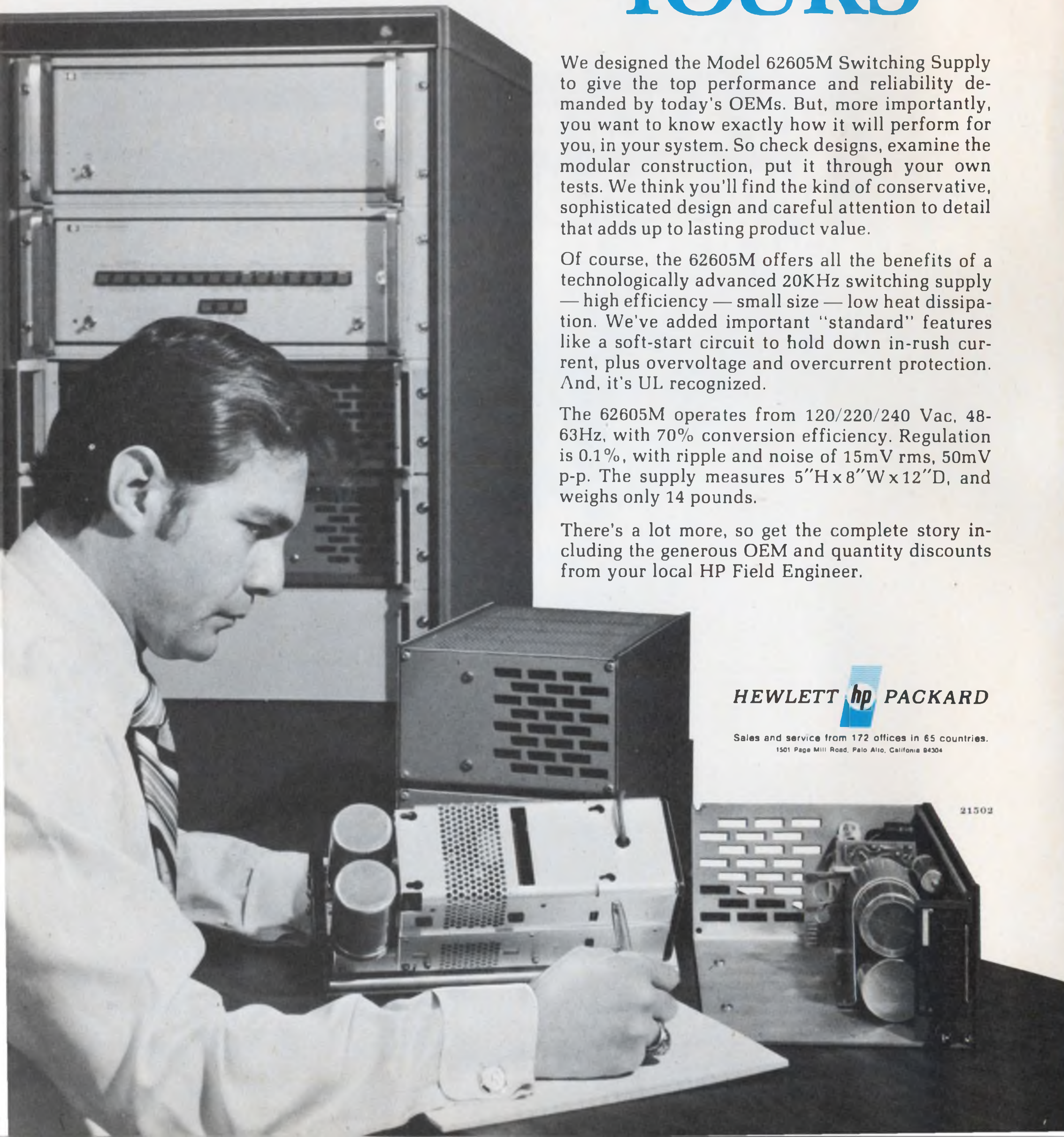

We designed the Model 62605M Switching Supply to give the top performance and reliability demanded by today's OEMs. But, more importantly, you want to know exactly how it will perform for you, in your system. So check designs, examine the modular construction, put it through your own tests. We think you'll find the kind of conservative, sophisticated design and careful attention to detail that adds up to lasting product value.

Of course, the 62605M offers all the benefits of a technologically advanced 20KHz switching supply — high efficiency — small size — low heat dissipation. We've added important "standard" features like a soft-start circuit to hold down in-rush current, plus overvoltage and overcurrent protection. And, it's UL recognized.

The 62605M operates from 120/220/240 Vac, 48-63Hz, with 70% conversion efficiency. Regulation is 0.1%, with ripple and noise of 15mV rms, 50mV p-p. The supply measures 5"H x 8"W x 12"D, and weighs only 14 pounds.

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Electronic Design®

FOR ENGINEERS AND ENGINEERING MANAGERS

VOL. 23 NO. 6

MARCH 15, 1975

NEWS

TECHNOLOGY

PRODUCTS

DEPARTMENTS

Cover: Designed by Art Director, Bill Kelly

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INTEL'S 1K CMOS STATIC RAM FAMILY

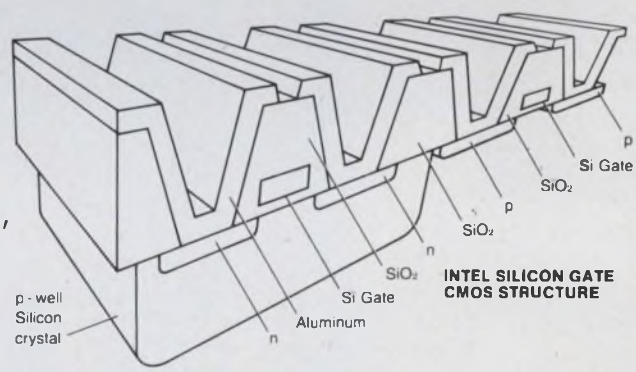
PART NO.	WORST-CASE SPEED*	SIZE	PINS	STANDBY POWER/BIT	AVAIL.
5101	650 ns	256x4	22	75 nW	Now
5101L**	650 ns	256x4	22	75 nW	Now
5101-3	650 ns	256x4	22	1 μW	Now
5101L-3**	650 ns	256x4	22	1 μW	Now
M5101-4	800 ns	256x4	22	1 μW	March
M5101L-4**	800 ns	256x4	22	1 μW	March
M5101-5	800 ns	256x4	22	5 μW	March
M5101L-5**	800 ns	256x4	22	5 μW	March

*Worst case access times and minimum cycle times are guaranteed over full operating temperature range (−55°C to +125°C for M5101-4, M5101L-4, M5101-5, M5101L-5; 0°C to +70°C for all other types).
**Guaranteed data retention at power supply voltage as low as 2V.

The easy to use 5101 is fully static, chip enable clocking is not required during address transitions. It also interfaces directly with TTL or CMOS and operates with a single +5V supply.

The 256 x 4 configuration is optimum for any memory system organization and is an ideal building block for memory expansion. You get two chip enable inputs, four data inputs, four three-state outputs with output disable control, and read/write control. The output disable pin controls bus states, making bidirectional logic unnecessary in common I/O buses.

The 5101, with its high density and ease of use, is the ideal nanopower RAM for portable instruments and microprocessors, advanced calculators, data collection devices, process controllers, POS, OCR, medical, avionics, ground support—for any equipment demanding long battery life, or non-volatility with battery back-up. The 5101 silicon gate CMOS RAM is in full production and in distributor stock, along with our other easy to use n-channel static RAMs.



INTEL SILICON GATE CMOS STRUCTURE

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INFORMATION RETRIEVAL NUMBER 4

INFORMATION RETRIEVAL NUMBER 5

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across the desk

A 'break' discovered in converter code

My joy from reading the Oct. 25, 1974 issue and Eugene Zuch's article "Know Your Converter Codes" (ED No. 22, pp. 130-135) was unbounded. Mr. Zuch's article gathered the multitudes of a/d and d/a codes into a single compendium.

Just the other day, when I confidently retrieved the article from my 8-1/2 × 11-in. electronic-memory system to demonstrate the BCD table on p. 131 to a lesser-equipped associate, I discovered that the code was "broken." Imagine my decline in his esteem as I stumbled through trying to convert those BCD columns into the +10-V FS figures. My mentor in this area, Steve Connors of Dynamic Measurements, pointed out that except for full scale, all the numbers in the BCD table are repeated straight binary from the preceding table.

Joel M. Cohen

BBF Group, Inc.
42 Fourth Ave.
Waltham, MA 02154

The author replies

Here are the corrections to the BCD portion of Table 2 (p. 131) of my article. Mr. Connors and Mr. Cohen are absolutely correct: Binary values were mistakenly put in by me instead of the BCD values.

The BCD coding given in the corrected table columns corresponds to the decimal digits of the +10-V FS column. The +5-V FS column assumes only that a scale-factor change has been made at the input of the converter.

I also found another error in Table 4 (p. 134). Please reverse

(continued on page 14)

Binary coded decimal	Complementary BCD
1001 1001 1001	0110 0110 0110
1000 0111 0101	0111 1000 1010
0111 0101 0000	1000 1010 1111
0110 0010 0101	1001 1101 1010
0101 0000 0000	1010 1111 1111
0011 0111 0101	1100 1000 1010
0010 0101 0000	1101 1010 1111
0001 0010 0101	1110 1101 1010
0000 0000 0001	1111 1111 1110
0000 0000 0000	1111 1111 1111

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.

INFORMATION RETRIEVAL NUMBER 6 ►

This automatic transistor tester works in-circuit when others can't.

B+K PRECISION
520 Dynapeak(TM)
$150.00

Now you can avoid wasting time unsoldering good transistors that test bad in-circuit and good out-of-circuit because of erroneous testing. With B&K-Precision Dynapeak(TM) Transistor Tester you can quickly determine whether a transistor is good or bad in circuits where automatic transistor testers have never worked before. Low impedance circuits are becoming more and more common in TV, audio and industrial controls—and the Dynapeak(TM) pulse testing system will let you test transistors in these circuits which have shunt impedances as low as 10 ohms or 50 mfd!

COMPLETE TEST IN 9 SECONDS:

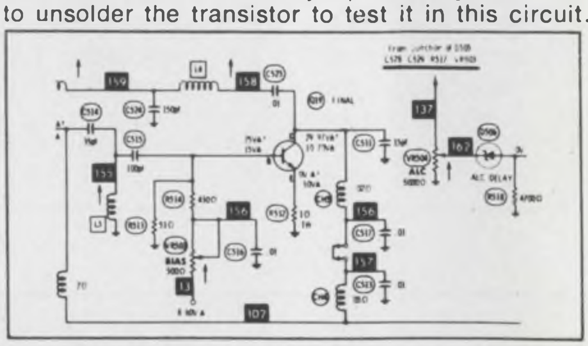
You connect the leads any way, turn the switch and the rest is automatic: Pulsating audio tone and a light automatically indicate a good device. PNP or NPN determination and Germanium or Silicon identification are automatically indicated by LED's. Leakage tests require no charts, because leakage current limits are shown on the meter face for the different kinds of devices.

Actual transistor action is determined in-circuit—not just junction or diode characteristics; you know you're making a valid test.

Write for our full color brochure explaining why the Dynapeak(TM) transistor testing system will stop time-wasting diagnostic errors and speed solid state servicing.

EVEN WORKS IN CIRCUITS LIKE THIS!

If you don't have a 520 Dynapeak(TM), you'll have to unsolder the transistor to test it in this circuit.



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The fastest data acquisition system. Anywhere.

Our 4855 ultra-high speed sample-hold ahead of our 4133 ultra-high speed 12-bit ADC. System aperture time is an ultra-low 1 nsec. Guaranteed throughput rate is 350 kHz. And you get this system speed at 0.03% total accuracy.

The 4855/4133 combination gives you a functional capability you can't achieve elsewhere. For example, the exceptionally low feedthrough of the 4855 allows you to multiplex during conversion without affecting system speed and accuracy.

FFT, high speed data acquisition, video digitizing, radar pulse digitizing and multi-channel simultaneous sample and hold—applications where greater than nanosecond uncertainty slow you down.

The 4855's 250 nsec acquisition time to 0.01% accuracy assures exceptionally high throughput rates for precision systems. The 4133 gives you high linearity, excellent stability and 2.5 μsec max. conversion time.

Together they're unbeatable for highly accurate, high speed data acquisition. And they're only available from Teledyne Philbrick at unbeatable prices ($160 and $485 in 100's).

For complete information, write for our Application Bulletin today. Or "DIAL" (our Direct Information Access Line) 617-329-1600. Teledyne Philbrick, Dedham, MA 02026. In Europe, Tel. 673.99.88, Telex: 25881. Or write, 181 Chausee De La Hulpe, 1170 Brussels.

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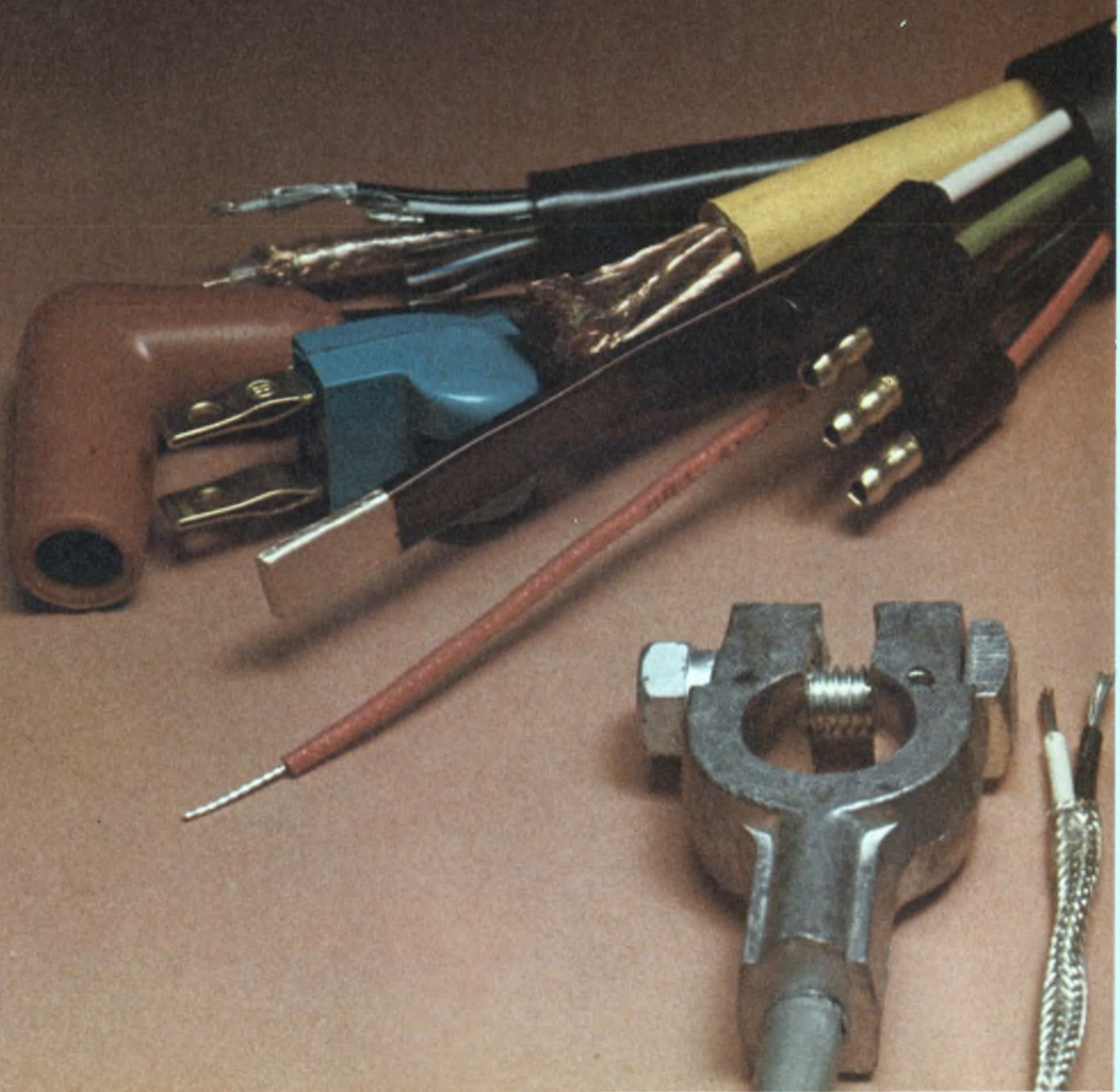
INFORMATION RETRIEVAL NUMBER 8

decoding the codes




UL
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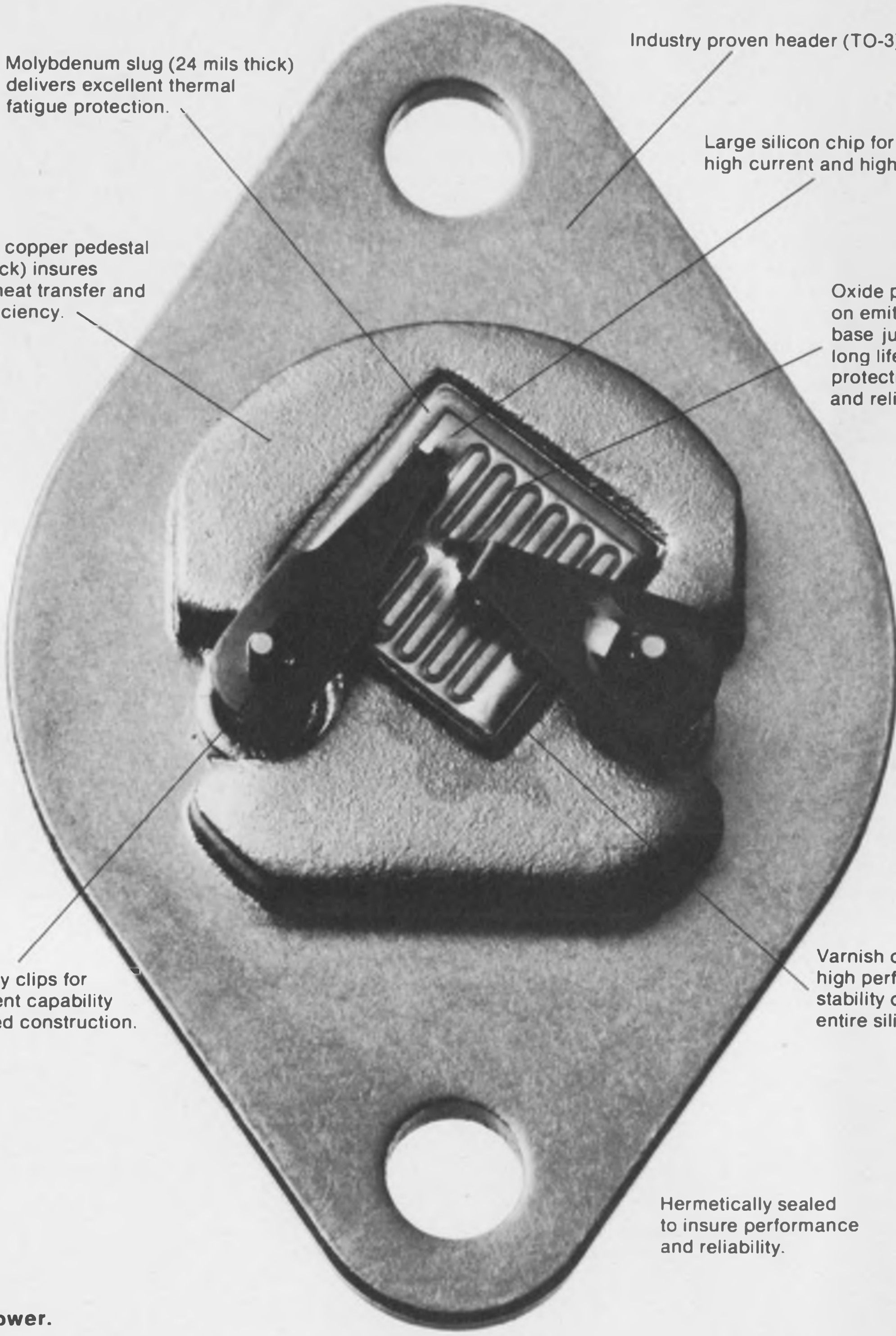
Anatomy of a brute.



Brute power.

That's what our TRW Types 2N3773 and 2N6259 deliver. So do our other reliable, single-diffused power transistors like the 2N3771, 2N3772 and 2N6258. All 100% power tested.

Send for a set of spec sheets. Or, for faster action or information on volume production of custom units, call Frank Joutras, TRW Capacitors, Solid State Operation, an Electronic Components Division of TRW, Inc., Box 1000, Ogallala, Nebraska 69153. (308) 284-3611.

TRW high-power transistors. So powerful we had to call them, "The Brutes."

TRW® CAPACITORS
SOLID STATE OPERATION

INFORMATION RETRIEVAL NUMBER 9

(continued from page 7)

the terms marked +1/2 FS and +FS −1 LSB in the first column.

Eugene L. Zuch
Product Marketing Manager
Datel Systems, Inc.
1020 Turnpike St.
Canton, MA 02021

Samples are tough all over

My memory of most of your editorials is that they're full of ______. [*Ed. Note: Uncharitable comment.*]

However, the one you ran in the Dec. 20, 1974 issue is really very good ("Making it Tough for European Engineers," ED No. 26, p. 49). You might have included that, even in this country, it's near impossible to get sample quantities of an item (at any reasonable price).

Norman Schwarz, P.E.
7901 Oakwood Rd.
Glen Burnie, MD 21061

Fowl play

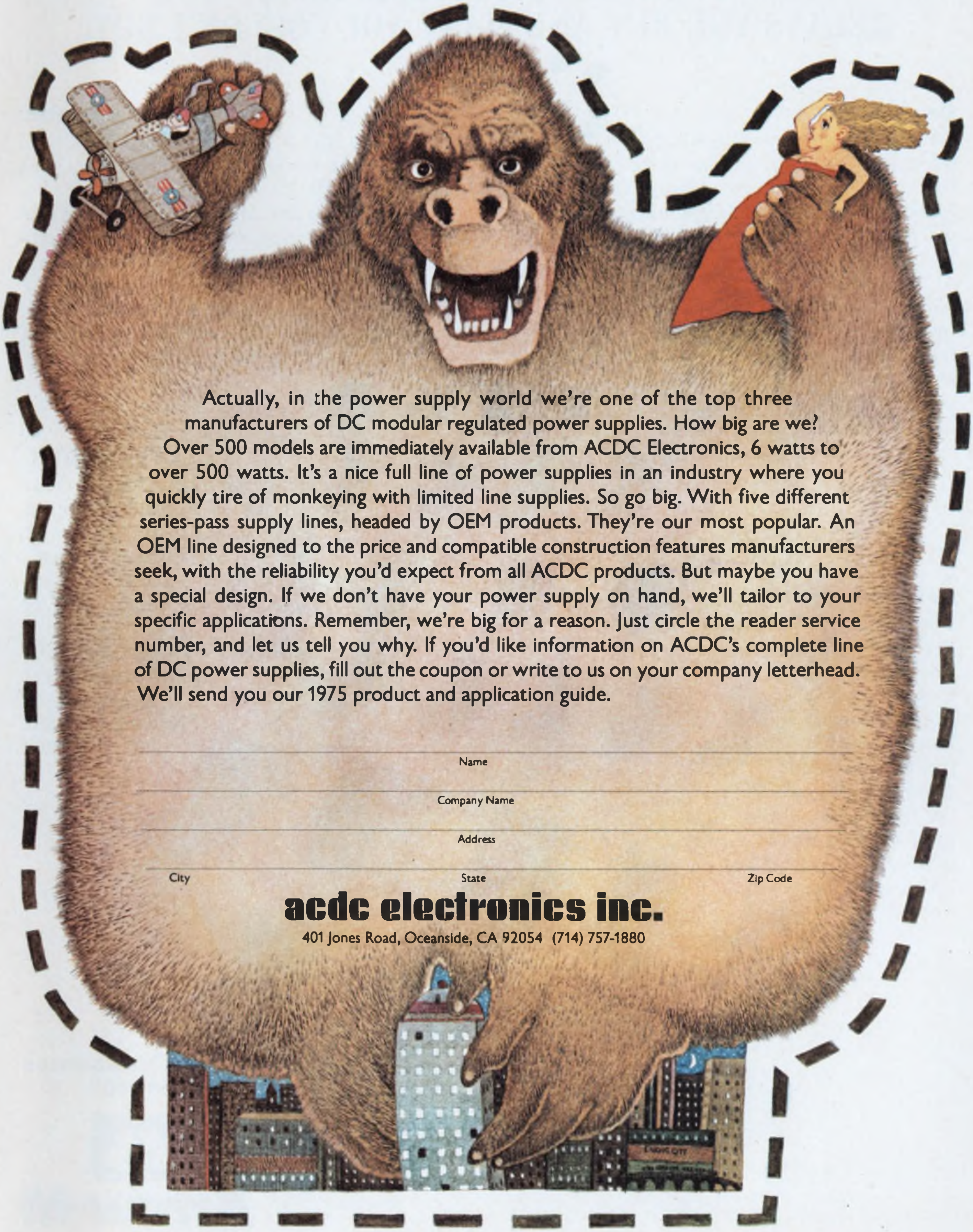
Recalling how ELECTRONIC DESIGN confused hams and Citizen Band operators in an issue last year, Brick McElwain, advertising manager of Clare-Pendar Co., Post Falls, ID, points to a comparable blooper in his company's in-house publication, *The Clare-Pendar Penlite*.

An item in the Dec. 13, 1974 issue, "Turkey Day for All Clare-Pendar," announced the company's intention to distribute Christmas turkeys to its employees.

"Here's how it works," *The Penlite* advised. "The Personnel Department will set up a small table in the Cafeteria, check you off as you enter so we can verify that you work here, give you a ticket which you redeem for a truck parked in back of the turkey from the refrigerated plant. . . ."

McElwain observes: "I had a hell of a time locating 14-lb trucks at $.53 per lb."

LOOK WHO'S CLIMBING UP IN THE WORLD.



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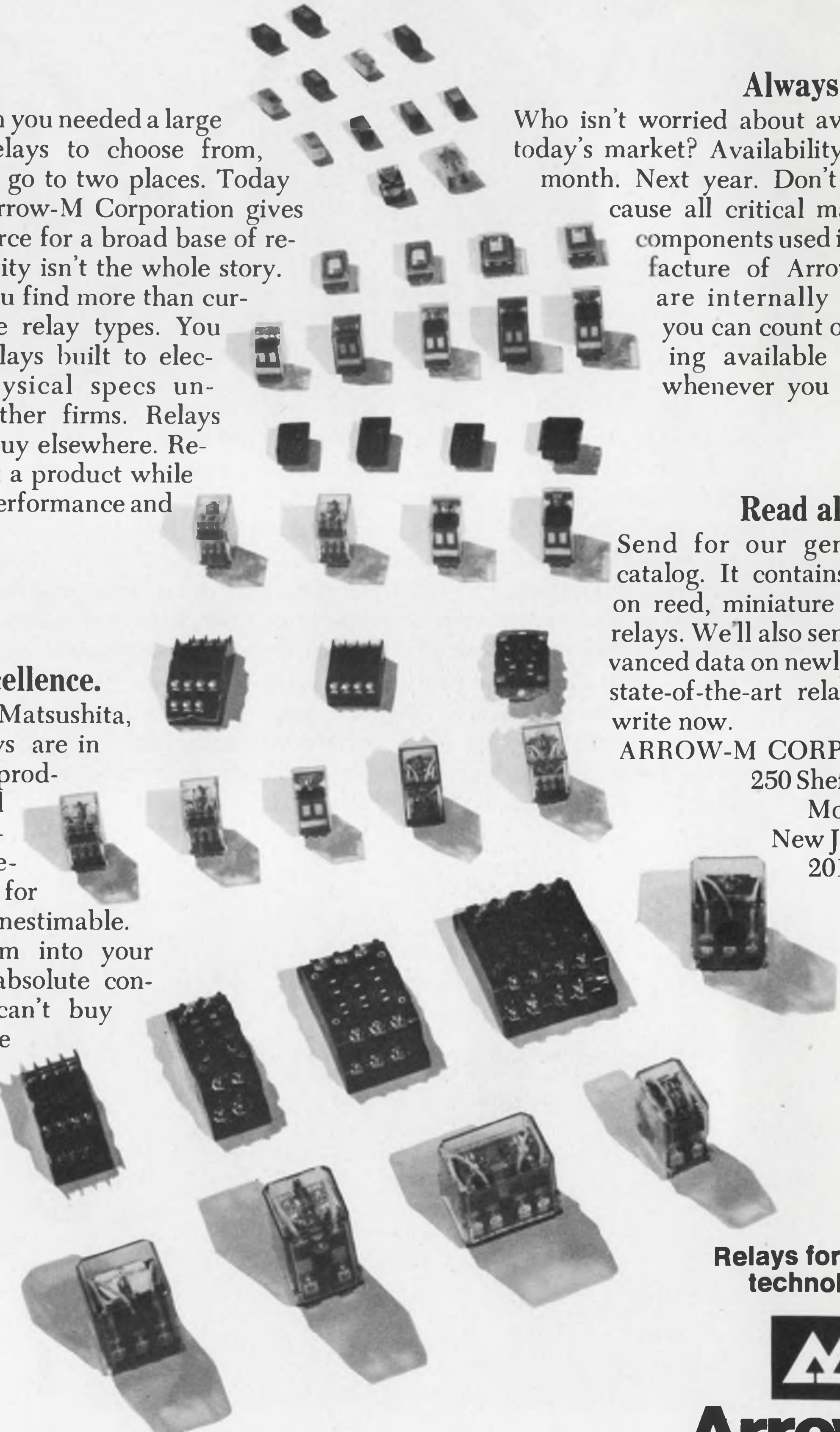
MATSUSHITA LAUNCHES ARROW-M.

NOW YOU CAN BE CHOOSIER ABOUT THE RELAYS YOU BUY AND MANY YOU COULDN'T BUY.



Be choosier.

Yesterday when you needed a large selection of relays to choose from, you could only go to two places. Today Matsushita's Arrow-M Corporation gives you a third source for a broad base of relays. But quantity isn't the whole story. At Arrow-M you find more than currently available relay types. You find quality relays built to electrical and physical specs unmatched by other firms. Relays you just can't buy elsewhere. Relays that shrink a product while expanding its performance and reliability.

Switch to excellence.

Engineered by Matsushita, Arrow-M relays are in use in diverse products the world over. The number of trouble-free field hours for these relays is unestimable. So design them into your product with absolute confidence. You can't buy relays with more integrity.

Always available.

Who isn't worried about availability in today's market? Availability now. Next month. Next year. Don't worry. Because all critical materials and components used in the manufacture of Arrow-M relays are internally controlled, you can count on relays being available from stock whenever you need them.

Read all about it.

Send for our general relay catalog. It contains full specs on reed, miniature and power relays. We'll also send along advanced data on newly-designed, state-of-the-art relays. Call or write now.

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Relays for advanced technology.

Arrow-M

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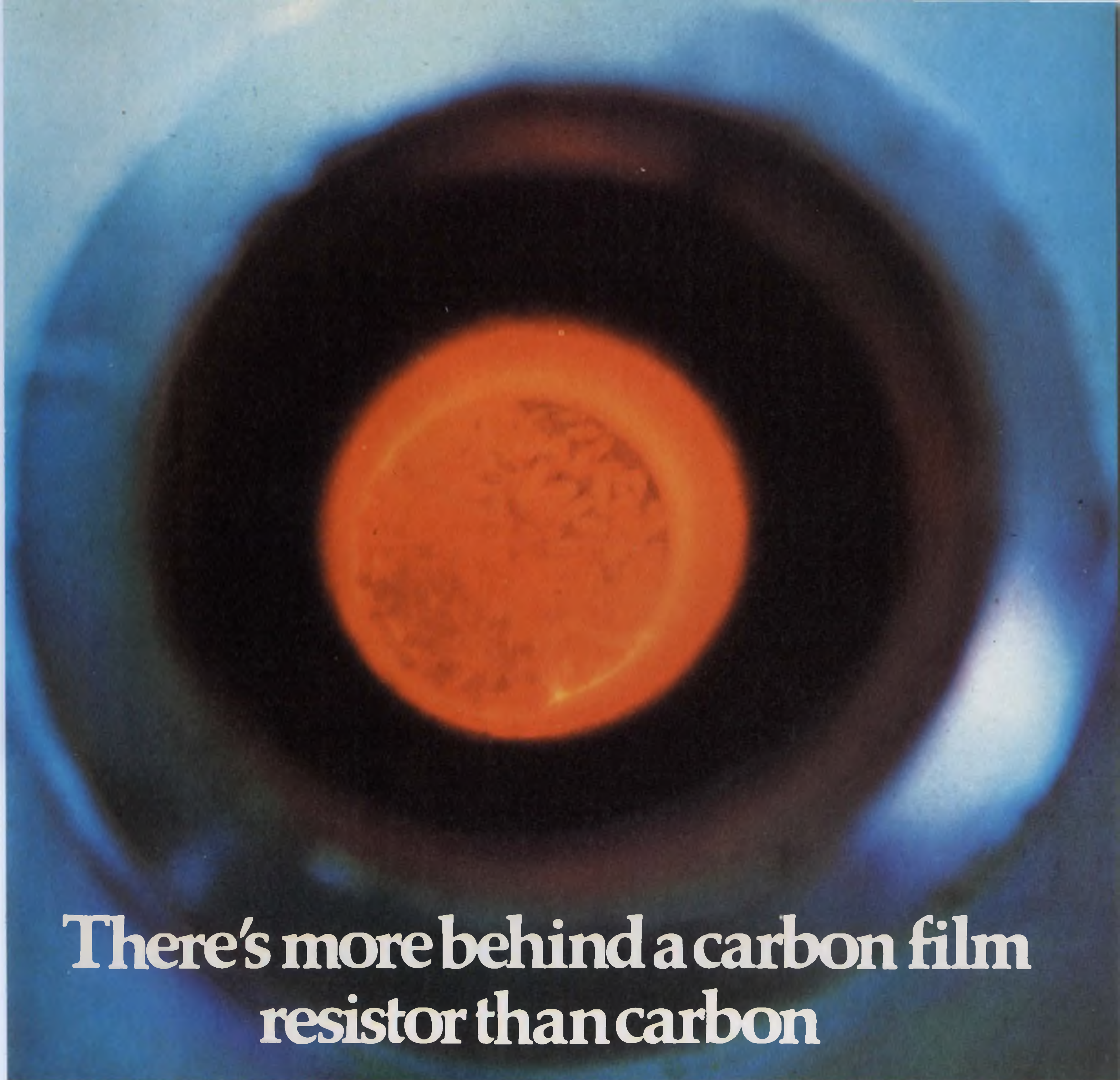

Particularly if the resistor comes from Piher. There's 25 years experience for a start. Which is why we are one of the world's leaders in the carbon film resistor field.

With an output of 10 million resistors *per day*, they are obviously in demand. Everywhere.

Which is why we have opened a manufacturing plant in the USA to help satisfy North American needs, quickly, and help give a bigger share of European production to European markets.

Find out about the Piher resistor range – and all the other products that have made us a leader in component technology.

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INFORMATION RETRIEVAL NUMBER 14

TI's new 3rd generation 4K RAMs.

200ns speeds in 18-pin packages. And availability is now!

Texas Instruments brings you third generation 4K MOS RAMs: TMS4050-2 (200ns), TMS4050-1 (250ns) and TMS4050 (300ns). These compact 18-pin 4K RAMs offer even better board packing density than their 22-pin counterparts, as much as 70 to 100%.

Volume availability is now. The TMS4050s are in full production. They utilize the same single-transistor cell design and reliable N-channel silicon gate process as TI's popular TMS4030 4K RAM. This helps insure on-time delivery.

The TMS4050s have been made easy to use. All inputs, except clock, are compatible with Series 74 TTL, while power dissipation is kept low (420 mW operating, 0.1 mW standby, typically). A full 12-line address and single hi-level clock minimize system timing headaches. Plus, data input and output are multiplexed to provide a simple memory bus interface.

	ACCESS TIME MAX	100-999 PRICE
TMS4050NL	300ns	$19.64
TMS4050-1NL	250ns	$21.64
TMS4050-2NL	200ns	$24.62
TMS4050JL	300ns	$22.78
TMS4050-1JL	250ns	$25.07
TMS4050-2JL	200ns	$28.56

Compare prices (see insert). You can see that TI's TMS4050s offer the best performance at the lowest price. And why shouldn't they? TI has more experience in building 4K RAMs. Plus, volume production experience means lower cost-to-you – and higher PC board density.

The TMS4050-2, TMS4050-1, and TMS4050 are available through TI's authorized distributors in 18-pin plastic (NL) or ceramic (JL) packages. For data sheet, write Texas Instruments at P.O. Box 5012, M/S 308, Dallas, Texas 75222.

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RCA video-disc entry gives hour of inexpensive viewing

RCA's long-awaited entry into the video-disc race is an inexpensive 12-in. record that can provide up to an hour of viewing.

Called SelectaVision VideoDisc, the new system has these key features:

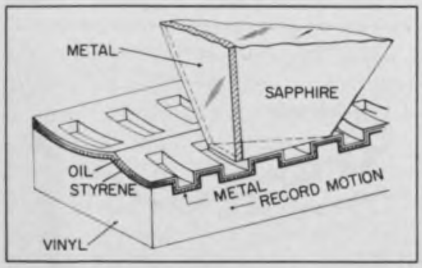
- A grooved metallic and dielectrically coated vinyl disc to provide positive tracking of the stylus by mechanical means.
- A capacitance pickup made from sapphire, with a deposited metallic electrode that can be used to resolve signal elements smaller than the wavelength of light. This makes it possible to use electron-beam recording techniques.
- A low rotational speed of 450 rpm that reduces vibration problems and makes it easier to correct erors in signal timing.

The details will be discussed publically for the first time next month in Washington, DC, at the 1975 international exhibition of The Society for Information Display.

With the exception of the stylus, the RCA VideoDisc player is fabricated almost completely from components that have been used in conventional phonographs. The use of the grooved disc eliminates the need for expensive servo mechanisms to provide accurate tracking.

The spiral groove that is pressed into the disc is roughly circular and contains information recorded as transverse slots of varying width and separation. The information is read out by a stylus that rides in the groove and changes capacitance as the relief pattern of the record passes under the tip of the stylus.

The stylus-record capacitance is made part of a tuned circuit—at about 915 MHz—with the tuning varied by the stylus-record capacitance variations. When driven by an oscillator of suitable frequency, the variable-frequency resonant circuit will provide a variable impedance, and thus a variable amplitude, of the oscillator signal as it passes through the resonant circuit. The amplitude modulation is stripped by a diode detector to provide a signal that rises and falls with the passage of the slots. This FM signal is then demodulated to provide a composite video signal.



Capacitance pickup detects variations in the width and separation of slots in record groove that contains recorded information.

The average speed of the playback turntable is 450 rpm, achieved with a synchronous motor that is locked to the power-line frequency. This speed, which is lower than that of many other video discs, has advantages, RCA says. Errors in signal timing that might result from warp or eccentricities of the disc occur at a frequeny that is easier for the television receiver to compensate for. In addition, a simple, inexpensive electromechanical device, the "arm stretcher," can be used to reduce time-base errors.

The arm stretcher is similar to a loudspeaker moving-coil element, driving the stylus arm back and forth parallel to the record groove. If the record runs slow, the stylus is pulled towards the transducer to increase the relative speed between the stylus and the record. If the record is going too fast, the stylus is pushed away from the transducer, thereby reducing the relative speed.

The system is not yet commercially available. Minor problems must still be overcome, RCA says. One is perfecting the real-time capability of the master disc. Less than real-time recording is now possible, but RCA says that the capability is being refined so that all recording will be done in real time when the product is introduced.

'How to' emphasized at computer parley

Six technical sessions at the Computer Society International Conference in San Francisco dealt with microprocessors. But the emphasis was on how to use them rather than on new devices.

A new way of looking at the meaning of the instruction set of a microprocessor has been developed by John Nichols, vice president of Logical Services, Mountain View, CA. He calls it the source-destination matrix of the instruction set.

Nichols explained that most instructions were data transfers. Since the data are transferred from a source to a destination, a matrix can be drawn to give the various sources on one axis and the various destinations on the other. Typical sources and destinations are registers, accumulators, memory and program counter. Entered on the matrix table are the instructions to go from the source of interest to the destination of interest.

Nichols noted that once the engineer defined his problem and the required types of data manipulation, he could use the source-destination matrix to select the microprocessor with the most workable instruction set.

Michael Maples, an electrical engineer at the Lawrence Livermore Laboratory in Livermore, CA, pointed out that utility was often more important than speed and efficiency when selecting a microprocessor for a problem involving basic calculations. He described the development of a microprocessor-based measurement system that uses the Intel 8008 microcomputer for such things as base-line correction calculations. Maples used triple precision arithmetic for these calculations.

A pair of new integrated circuits aimed at use with microprocessors came to light during the conference. Ready for delivery is a programmable bit-rate generator from Fairchild Semiconductor, Mountain View, CA. According to Krishna Rallapalli, staff engineer at Fairchild: "The CMOS IC provides 16 different bit rates programmably. Each bit rate is available on any of eight different lines."

When used with a universal asynchronous receiver-transmitter, a great deal of data communications flexibility is provided, he said.

TV course scheduled on microprocessors

For four days in April, a cram course in microprocessors will be televised for early risers in 20 major cities. Tuition is free. All you have to do, if you can receive the telecasts (see list), is to turn your set on at either 6 AM or 6:30 AM, depending on where you live, on the mornings of April 15 through 18.

Put on by Texas Instruments in Dallas, the first telecasts will cover the evolution of system architecture as a basis for understanding the wide range of applications for microprocessors and the varieties of chip architecture.

Next there will be a detailed discussion of the technological choices involved, including the new integrated-injection-logic (I^2L) technology.

The third session will define the types of systems suitable for microprocessors, discussing the principal parameters of several types of microprocessor equipment and giving examples of applications.

The final lesson will discuss the application of microprocessors to digital communications systems.

If you want to bone up on the subject before the telecasts start, TI will send you for $24.95 a "Microprocessor Handbook," which contains a summary of the microprocessors currently available, a discussion on how to use them and background on digital design along with reference material.

The book also includes lesson summaries for the telecast sessions.

To obtain the handbook, write to Texas Instruments, P.O. Box 3640, MS-54, Dallas, TX 75285.

TV lectures Apr. 15-18

City	Channel	Time
Boston	7	6:20-6:50 AM
Chicago	9	6:00-6:30 AM
Cleveland	8	6:00-6:30 AM
Dallas	5	6:00-6:30 AM
Dayton	7	6:00-6:30 AM
Denver	4	6:30-7:00 AM
Detroit	2	6:00-6:30 AM
Houston	11	6.30-7:00 AM
Los Angeles	11	6:30-7:00 AM
Miami	4	6:30-7:00 AM
Minneapolis	11	6:30-7:00 AM
New York City	5	6:30-7:00 AM
Orlando	6	6:00-6:30 AM
Philadelphia		
Phoenix	5	6:00-6:30 AM
Rochester	10	6:00-6:30 AM
San Diego	6	6:30-7:00 AM
San Jose	11	6:00-6:30 AM
Seattle	11	6:30-7:00 AM
Washington, DC	5	6:30-7:00 AM

Productivity increased in new minicomputer

What may be the most productive minicomputer built so far has been introduced.

Called the 8/32 it is the second 32-bit machine to be introduced by Interdata since its Model 7/32 in September, 1973. The CPU and up to 1-Mbyte of core memory in the 8/32—directly addressable—reside in a single RETMA cabinet. The processor uses Schottky TTL and memory interleaving to give a basic cycle time of 300 ns.

Compared with the 7/32, the new machine uses a 32-bit wide bus with one fetch to memory rather than a pair of 16-bit fetches. Eight stacks, each with 16, 32-bit registers, simplify I/O operations and provide the means for rapid context switching.

To enhance reliability, yet keep fabrication costs down, Interdata has used multiwire board fabrication. A single PC board contains layers of connections sealed with epoxy.

Dual-bus architecture—one slow and one fast bus—also contributes to system throughput. The machine runs typical problem mixes under OS/32 MT (multiple task) or OS/32 ST (single task) at double or triple the 7/32 speed.

Prospective customers are comparing the 8/32's architecture and instruction execution times with those of the IBM 370/158.

16-bit microprocessor operates at 5 MHz

The fastest 16-bit microprocessor announced to date—it operates at 5 MHz—has eight general registers and a selection of software.

Introduced by General Instrument's Microelectronics Div., Hicksville, NY, the microprocessor —the CP-1600—"is the only single-chip, n-channel, 16-bit microprocessor available," says Jess Stein, manager of microprocessor development. "It's about five times faster than the single-chip, p-channel competition."

The eight general registers in the CP-1600 are in contrast with a number of present microprocessors, which are accumulator-based machines having only one active working register and one or two other temporary registers.

The CP-1600 registers can be used for accumulators, address registers, data pointer-to-memory storage and index stores, Stein notes. The CP-1600 also has a memory pointer to maintain a main memory stack.

The designers shortened the development and debugging of the CP-1600 considerably, Stern reports, by laying out the chip in two separate sections: control and data processing.

"Two designers could thus work on their own sections at the same time," Stein explains, "and it allowed us to have two parallel debugging efforts going on."

The CP-1600 is the first of a family of microprocessors that General Instrument intends to introduce over the next year, Stein says.

"All of these microprocessor machines will be single-chip, higher performance devices, and they all will be software-compatible upward," he notes.

CIRCLE NO. 319

news

AT THE INTERNATIONAL SOLID-STATE CIRCUITS CONFERENCE

Advances in bipolar LSI yielding faster, denser low-power devices

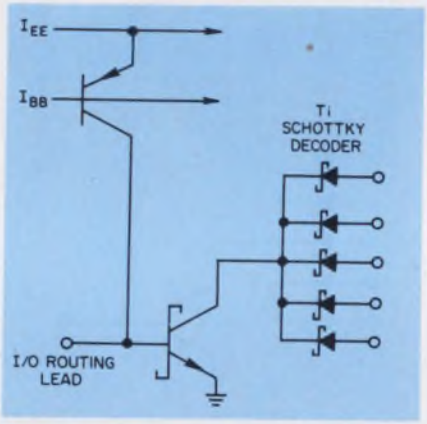
New developments in bipolar large-scale integration that promise to give MOS technology a run for its money were described at the 1975 International Solid-State Circuits Conference in Philadelphia last month. Among the advances detailed were these:

- Complementary constant-current logic (C^3L), a new high-density approach to bipolar LSI that features switching speeds of 3 ns.
- Schottky transistor logic (STL), an improved version of integrated injection logic that has a power delay product that is three times lower than that previously reported for I^2L.
- Current-hogging injection logic (CHIL), which combines the input flexibility of current-hogging logic with the performance and packing density of injection logic.

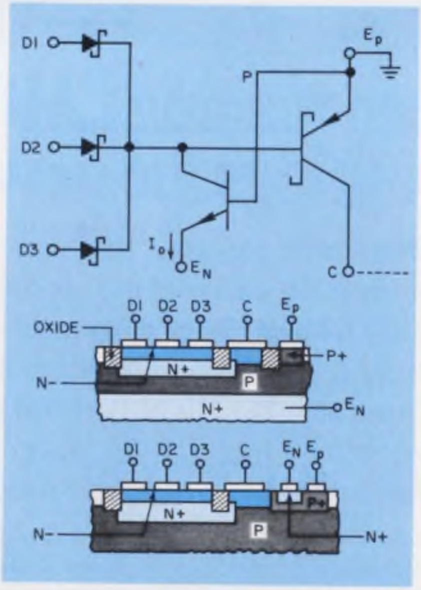
Only one transistor needed

Complementary constant-current logic features not only high speed and density but also low power consumption. Arthur W. Peltier, a Motorola Semiconductor engineer who described the new logic family at a session on "Advances in Solid-State Logic," said C^3L was a version of diode-transistor logic. Low-threshold Schottky diodes form the input AND function, which is inverted and amplified by a single transistor. These diodes, explained Peltier, are actually formed in the collector region of the driving gate's npn transistor.

Jules H. Gilder
Associate Editor



Multiple inputs and outputs are possible with a C^3L NAND gate. The I/O routing lead connects to the collectors of driving gates.



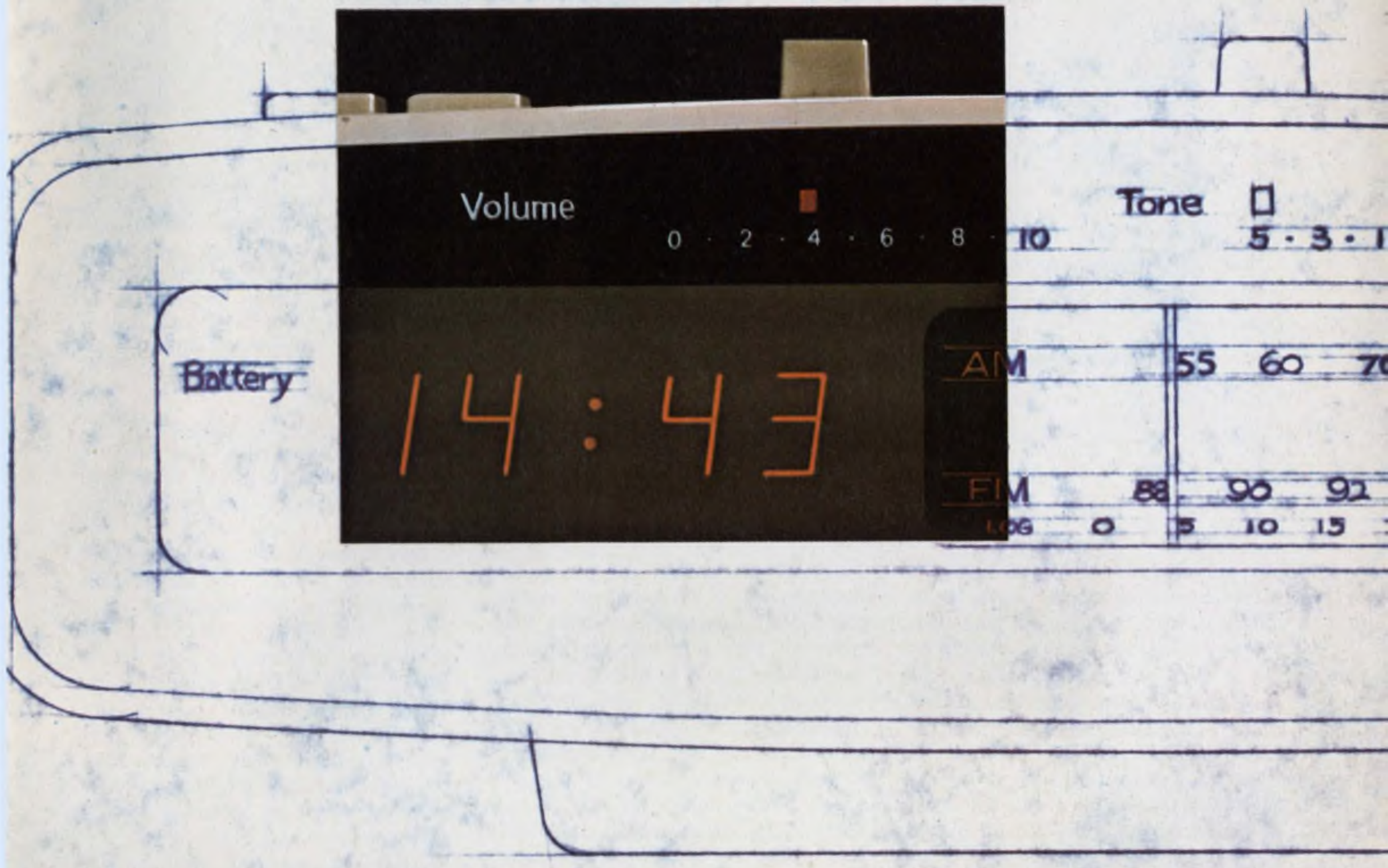
Schottky transistor logic gate (top) uses Schottky diodes and a pnm (m for metal) transistor to get a fivefold improvement in power delay over conventional I^2L. Practical STL structures can have either vertical (middle) or lateral (bottom) supply injection.

Logic operation results when current is steered from the pnp at the base of the output npn. If at least one driving gate is on, the current is directed across the gate's decoding Schottky diode and the npn output transistor to ground. A 0.4-to-0.5-V potential results at the base of the driven gate's output device, holding it off. When the last driving-gate npn turns off, the driven gate's current is steered into the base by the output npn, turning it on.

Turn-on time is governed by the time required for the current supply to charge 2 or 3 pF of parasitic capacitance through about 0.4 V. Turn-off depends on the time required for the driving gate to discharge the parasitic capacitance of its fanout tree through 0.15 V. Thus for a C^3L gate with current of 0.1 mA, turn-on occurs in 12 ns and turn-off in 4 ns.

C^3L has many advantages over other forms of logic, Peltier noted. Among them is the potential for fabricating high-quality linear functions on the same chip as the logic. Another is the fabrication of multilevel logic. With several current levels, it is possible to do a double-decode or double-logic operation before regeneration. This was done in many of the old TTL circuits, and it saves considerably on the layout, Peltier reported. The double-decode operation gives the user a multi-input, multi-output structure.

By separation of the pnp transistors from the npn's, another type of multilevel logic operation, is also possible. Peltier explained that the constant-current-source feature of the device permitted several devices to be placed in layers, one on



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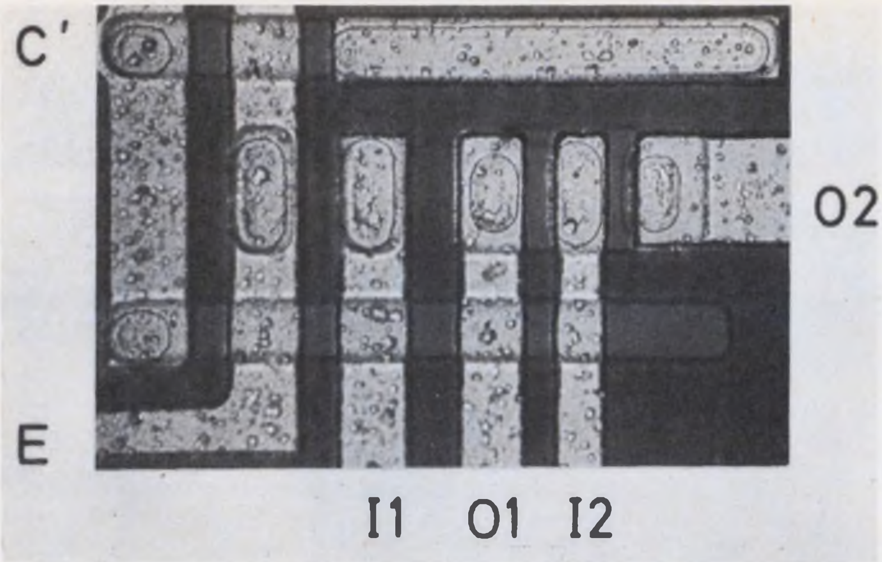
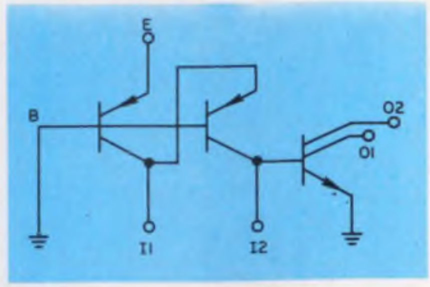




Current-hogging injection-logic NAND gate (left) is 20% smaller than equivalent I²L cells. Schematic of cell (right) shows CHL gate with a functionally integrated output transistor.

top of another. This results in three levels of logic, with level shifting and interfacing between them. Multilevel logic is very useful in some digital operations, and the approach is already being used in some isolated versions of injection logic.

A key advantage of C³L, its high density, stems from the simple structure used in the basic NAND cell. This cell requires only one transistor, regardless of the number of cell inputs or outputs.

Gate-array cells having five connectable outputs occupy 10 to 13 square mils, and nearly 1000 gating operations can be performed on a 130-mil-square chip. Switching speeds, Peltier reported, can be as fast as 3 ns with power consumption of 1 mW per gate, or as slow as 100 ns with power consumption of 0.01 mW.

Injection logic refined

Integrated injection logic (I²L), a technology that has only recently become available in commercial products, is still undergoing intensive research and development. Two advances that have resulted from this work are Schottky transistor logic and current-hogging injection logic.

Schottky transistor logic was described by Horst H. Berger, a researcher from IBM's Semiconductor Device Development Laboratories in Boeblingen, West Germany. He reported several ways to improve the performance of I²L devices. For example, the power-delay product is proportional to the logic swing, which is about 750 mV for I²L. But because bipolar transistors have a high transconductance, internal circuits can operate just as well with a swing as low as 150 mV. This results in a fivefold improvement of the device's power delay.

Another area where improvements can be made, Berger said, is the intrinsic time delay of the device. Part of the long intrinsic delay of conventional I²L is due to excessive charge storage that results from the high inverse current gain of the upside-down-operated npn transistor. By elimination of the need for the high inverse gain, which prevents current hogging, the intrinsic delay can be reduced by a factor of 2.

Both of these improvements can be obtained by use of Schottky technology. The basic logic cell uses Schottky diodes for output decoupling, and thus eliminates the need for the high inverse current gain that limits the intrinsic delay. The Schottky diodes also provide the reduction in logic swing required to decrease the power-delay product.

Comparison of I²L, CHL and CHIL technologies

	I²L	CHL	CHIL
AREA	1.2	3	1
POWER / DELAY	0.8	100	1
DELAY	0.8	100	1
MULTI-INPUT GATES	−	+	+
COMPLEX GATE FUNCTIONS	−	+	+
NO ISOLATION	+	−	+
NOISE IMMUNITY	0	+	0

Development has not advanced enough to permit the fabrication of monolithic Schottky transistor gates, but Berger noted that experimental devices had been fabricated from discrete components. The voltage swing of such a gate was reduced by a factor of 1.4 and the power delay improved by the same amount. The delay of the gate improved by a factor of 2, as was expected.

Another approach for implementing STL in monolithic form is being investigated, Berger noted. This involves the use of a pnm (m for metal) transistor. This would have a genuine Schottky collector that would replace one of the active semiconductor regions with metal. This would result in a simple structure that had only three active semiconductor regions, compared with four in regular I²L.

Experimental vertical pnm transistors have been fabricated, Berger reported, and the results look promising.

The best of two worlds

CHIL, the technique that combines the input flexibility of current-hogging logic with the packing density and performance of injection logic, was described by Rudiger Muller, an engineer from Siemens AG in Munich. The new technology results in area reduction of 20% when compared with I²L and 300% when compared to CHL, according to Muller. He said the total area of a complete

circuit could be reduced even further, because like CHL, CHIL offers the possibility of realizing complex multifunction gates.

In use, the inversely operated transistor of a two-input CHIL gate can be turned off when a LOW-level voltage of less than 300 mV is applied to either of the I_1 or I_2 inputs. If both inputs are turned off, the output transistor is in the ON state, since current-hogging takes place between the injecting emitter, E, and the floating control collectors I_1 and I_2 of the lateral pnp transistor.

Thus, Muller noted, the operation of a CHIL gate can be explained as an I^2L inverter with controlled injection or as a CHL gate with a functionally integrated output transistor.

A disadvantage of the CHIL approach is slightly increased pulse delay per stage compared with that for I^2L. But this is more than compensated for, Muller noted, by a significant reduction in the number of stages resulting from higher fan-in per gate. ■■

4-k RAM race still wide open as designers try different paths

The winner of the 4-k RAM race could be a dark horse. One year after 4096-bit dynamic memories "finally arrived," manufacturers are still jockeying for position with upgraded versions and new models. And the latest entries underscore the field's surprising lack of standardization.

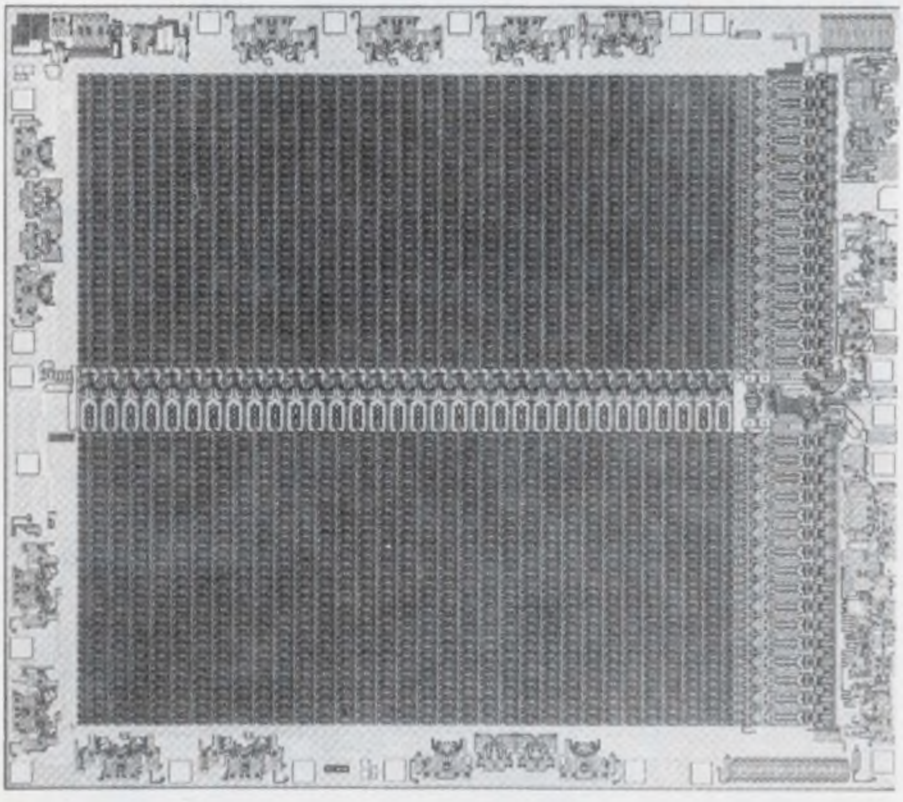
Edward A. Torrero
Associate Editor

Virtually all chip designers, for example, agree on the need for an n-channel process to achieve high speeds and high chip densities. But there are supporters of special metal-gate, standard silicon-gate and coplanar silicon-gate variants.

And different designers argue for different circuit configurations. Primarily these are based on a three-transistor inverting cell or one-transistor cell. Versions of the latter can have a single-ended sense amp or balanced sense amp (often with a dummy cell).

At the system level, memory chips come in 22, 18 and 16-lead DIPs. Both the 18 and 16-lead package permit higher PC-board densities than is possible with a 22-lead DIP. However, some vendors with more than one package option are designing the 22-lead version to have the highest speeds. Moreover different manufacturers employ different pin configurations for both 22 and 18-lead packages. And although at present there's only one 16-lead version (Mostek's), it requires external multiplexing of addresses.

The merits of the various approaches were debated in a panel session of the 1975 Solid-State Circuits Conference entitled "Which Way the 4-k RAM?" The panel contained representatives of most manufacturers that have announced products, and each naturally tended to promote the approach used in his company's IC. Nevertheless the often spirited discussion was at times remarkably candid.

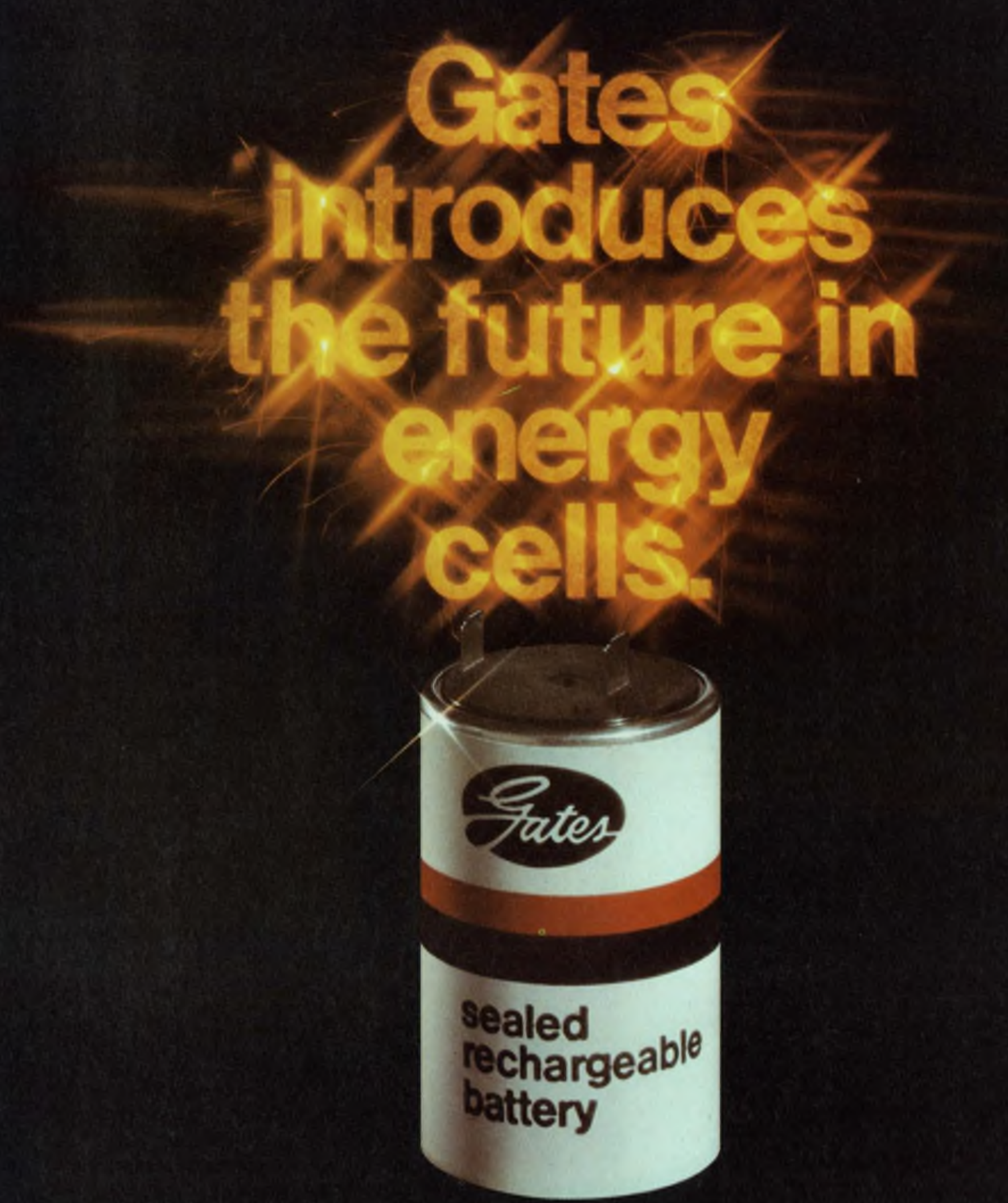


Aiming for ECL-oriented systems, Intel's latest 4096-bit MOS RAM has access time of less than 80 ns. The ECL-compatible chip employs charge-pump techniques to obtain operational features of static units.

Reliability still a goal

All manufacturers agreed, for example, that they have yet to reach their reliability goal of 0.01% per thousand hours, or 10^7 hours mean-time between failure.

"For many systems this value is almost essential to cut costs," said Reese Brown, a senior staff engineer at Burroughs and the only user of memories on the panel. However, Brown conceded that with error-correction circuit-



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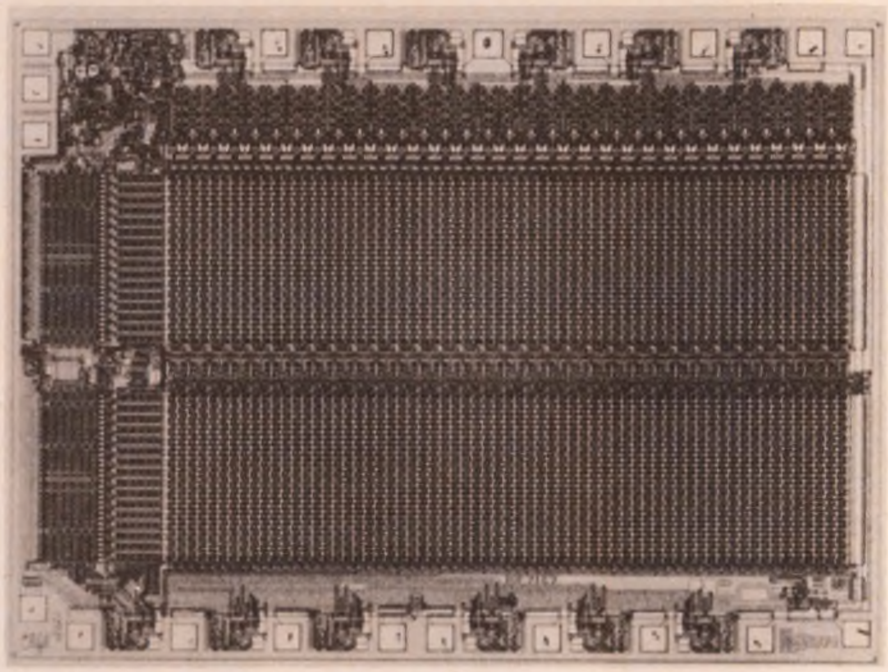
ry, a lower MTBF could be tolerated.

Clinton Kuo of Texas Instruments—the company generally conceded to be the leading 4-k-RAM supplier—reported that his products had an average reliability of 0.09% per thousand hours at present. Other manufacturers reported smaller percentages.

Similarly panelists felt that a package size smaller than the 22-lead DIP was gaining in popularity. But there was no agreement on whether the winner would be an 18 or 16-lead version. Some manufacturers liked an 18-lead approach because they could readily modify existing chip designs intended for the larger package. But most appeared to be moving toward a multiplexed 16-pin version.

"The usual arguments involving multiplexed addressing is irrelevent," said Richard Foss, manager



Avoidance of dummy cells simplifies circuit tolerances and reduces on-chip circuitry in Microsystems' 2107C, the company's latest 4-k RAM.

Representative 4096-bit dynamic RAM chips

Supplier Model No.	Process	Chip area (mil²)	Transistors per cell	Number of masks (including scratch protection)	Access time (ns)	Supplies (V)	Leads per package	Number of high level clocks	Refresh cycles	Refresh time at 70 C (ms)
*Intel 2107A	Si gate	22,700	3 (non-standard)	6	350	+12, ±5	22	1	64	1
2107B	Si gate	18,400	1	7	200	+12, ±5	22	1	64	2
*Microsystems 7112	Si gate low res	24,700	3	6	400	+12, −2	22†	3	16	2
2107C	Si gate coplanar	20,100	1	5	300	+12, ±5	22	1	64	2
Mostek 4096	Met gate special	28,700	1	7-9	350**	+12, +5, −9	16	0	64	2
Motorola, American Microsystems 6605	Si gate coplanar	32,600	3	6	230	+12, ±5	22†	1	32	2
Signetics 2604	Si gate coplanar		1			+12, ±5	22	1	64	2
Texas Instruments 4030	Si gate coplanar	28,600	1	6	300**	+12, +5, −3	22	1	64	2
4050	Si gate coplanar	28,600	1	5	200	+12, ±5	18	1	64	2
Western Digital 1701			3		200	+12, ±5	22	1	16	2

* Being phased out of manufacturer's line
** Upgraded version has 200-ns access
† Pinout differs from TI/Intel 22-lead package

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of new products at Microsystems International. He pointed out that virtually any one-transistor-cell memory lent itself to address multiplexing. This is because the bits defining the column cannot be used until some time after charge has been dumped from each of the 64 cells on a row, and after the sense amps have been strobed. Also, the circuit's speed can be enhanced when operated in a "page" mode rather than the usual random-access.

"However, it's still not easy for TI, Intel or anyone else with a balanced flip-flop sense amp to replicate the Mostek part," Foss said in an interview. The Mostek circuit's unbalanced, or single-ended, sensing scheme requires heightened stored charge. Hence process complexity must increase to obtain the needed dielectric (nitride) or area, or both. But the result is decreased power dissipation in an almost totally dynamic part.

"To convert to a 16-lead DIP, the tradeoff is low power vs low manufacturing cost—not both at the same time," Foss said.

One-transistor cell vs three

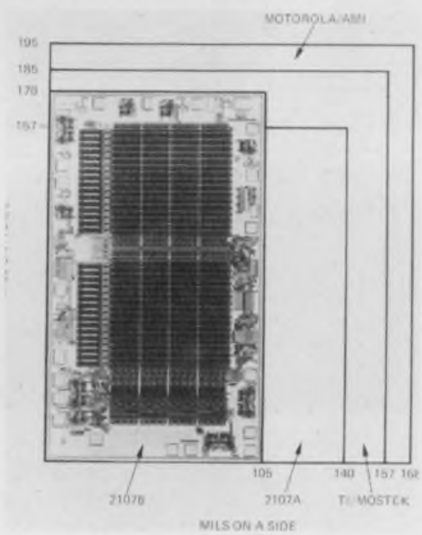
The speed benefits of a three-transistor cell vs one-transistor were conceded by Bob Proebsting, a senior circuit designer of Mostek, which employs the one-transistor. "A three-transistor cell has a 10 to 15% speed advantage," he said. "You get a decent signal out of the matrix, so that you don't have to slowly process a very small signal, like that from a one-transistor cell." However, the latter generally provides the fabrication-cost advantage.

But for Motorola's Bud Broeker, a three-transistor-cell design was somewhat more reliable because of reduced thin-oxide, or active, area on the chip. At the 4-k level, he noted, both circuit techniques result in about the same over-all chip size. But the three-transistor chip design has about one-half the active area of a corresponding one-transistor design.

Countering Broecker's contention, Rampower's Joel Karp pointed out that the thin-oxide areas on chips have been increasing steadily as RAMs have evolved from 64-bit levels up to the present 4 k. But reliability hasn't gone down correspondingly. Instead poor reliability has been linked to circuit designs and manufacturing techniques.

Dissipation woes

On more solid ground, Broeker compared the lower power needs of his company's 4-k RAM with the higher requirements of Intel's latest RAM (both are 22-lead DIP versions). Assuming a 1/4-megabit system in operation 16 hours a day 250 days a year, Broeker estimated that the Motorola memories would have an average consumption of 76 W against 25 W for Intel's 2107B.



One of the smallest 4-k RAM chips is Intel's 2107B. The memory has 200-ns access.

"And for each million devices, it woud take another 719 barrels of oil to run the 2107B," he said.

In defense, Mike Geilhufe, Intel's MOS memory manager, linked the IC's high dissipation of a watt to the internal sense amp. The basic design seeks to achieve a fast read-modify-write cycle—an important feature for large systems employing error correction. But the result is a classic speed-power tradeoff. The sense amps draw dc power.

"Also, we didn't fine-tune the peripheral circuitry," Geilhufe said. "They probably draw more power than they should." In a rarely heard admission, he concluded: "It was an engineering error."

However, improved circuits are on the way. "There's nothing magic about that sense amp," said Karp, who pointed out that the problems cited were fundamental to the amps used. Alluding to developmental work, Karp predicted that newer sense amps would maintain the differential character of flip-flops while operating in a dynamic mode. And read-modify-write times will not be degraded, he said.

Karp's company, a Palo Alto consulting team, is reported to have worked on National Semiconductor's forthcoming 4-k RAM in an 18-lead package.

The National version won't have the same pinout as the 18-lead model from Texas Instruments. The TI RAM multiplexes input and output data on a single terminal, and it eliminates the chip-select terminal by having the chip-enable clock and read/write-mode control perform the enable function. The National unit replaces three leads with one that serves the functions of read/write, logic chip select and V_{CC}. Neither circuit requires address multiplexing.

Larger memories ahead

The current scramble of 4-k RAMs hasn't stopped manufacturers from looking ahead to larger memories. Arguing for the 16-lead rather than 18-lead package, Broeker said that the smaller package could also serve as a forerunner of the 16-k bit RAM, "which we're all working on and don't want to talk about." Among the panelists who did talk was a Siemens senior research specialist, Karl Stein, who exhibited a photo of an experimental 16-k RAM chip.

However, papers presented at the conference dealt with RAMs having capacities no larger than 4-k bit. At this density level, new chips were unveiled by both Microsystems International and Intel. The Microsystems' entry, the Model 2107C, was described by Richard Foss in a paper, "Simplified Peripheral Circuits for a Marginally Testable 4-k RAM." The Intel development, geared for high-speed ECL-oriented systems, was described by John Gionis in "A

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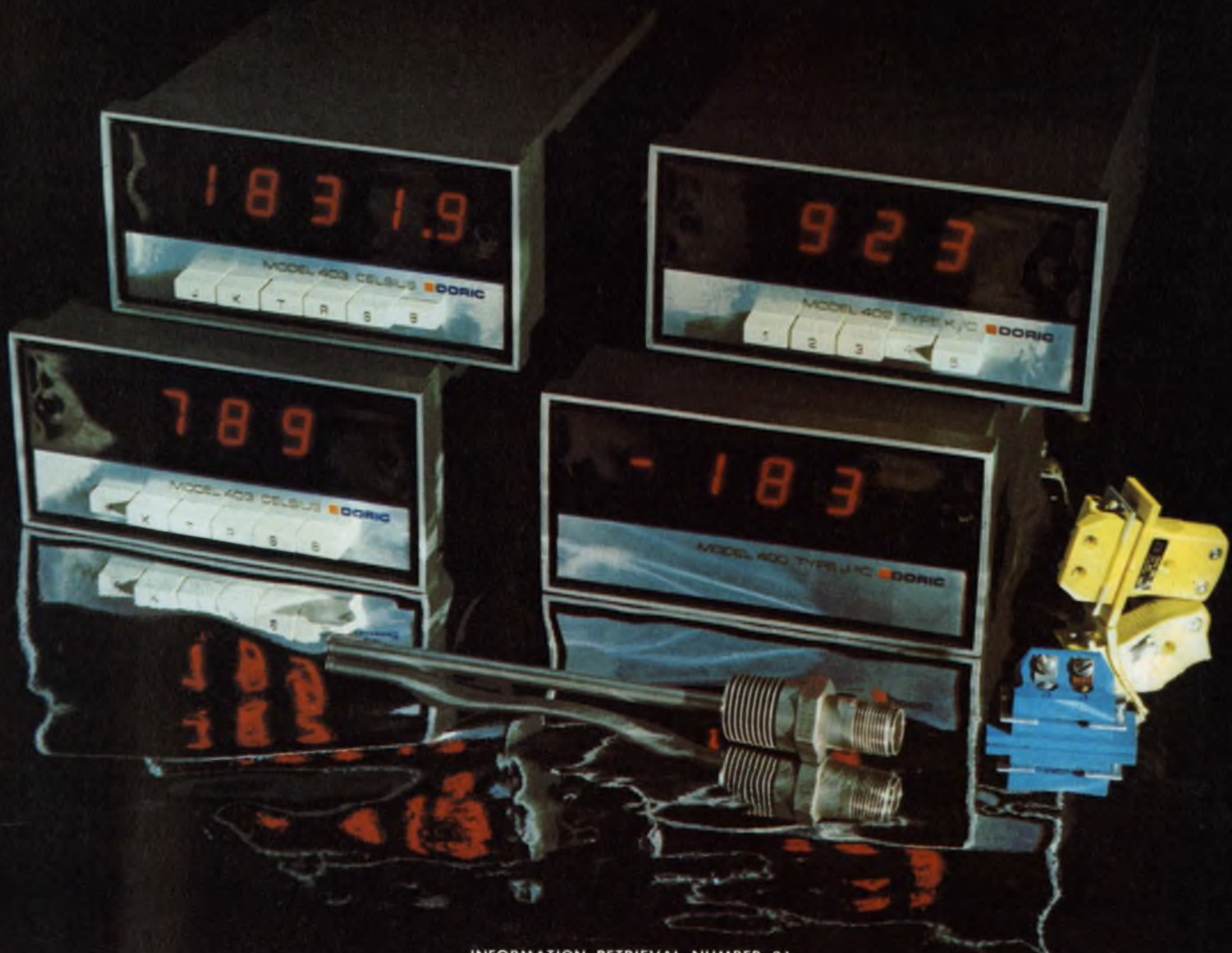


4096-Bit, High-Speed, ECL-Compatible RAM."

The Microsystems' chip employs TI's one-transistor cell with a balanced sense amp, but without the usual dummy cell. Hence associated on-chip level-setting and timing circuits can be eliminated for a reduction in fabrication complexity and area. The chip measures about 20,000 mil^2—only about 30% larger than a standard 1-k bit RAM.

The chip permits the testing of internal operating margins through the use of V_{CC} as the reference potential. Variations of V_{CC} to failure provide the internal ONE and ZERO margins.

The new Intel chip, also an MOS memory, features high speeds and static operation through the use of charge-pump techniques. Access and cycle times are less than 80 and 150 ns, respectively. And dissipation is typically 500 mW in the operating mode and 300 mW in standby. ■■

Analog circuit specialists battling to survive the digital onslaught

While analog circuit designers announced no dramatic breakthroughs at the Solid State Circuits Conference, they did give some clear indications of how they planned to survive in an increasingly digital world.

We can expect to see increased use of sampled-data techniques for analog processing—many such systems will harness the ubiquitous charge-coupled device (CCD). We can also expect a proliferation of converter circuits that cleverly exploit the latest process technologies to perform analog functions in addition to the original digital function. Here CMOS will probably be used for low-cost circuits, while integrated injection logic (I^2L) may be used for the digital portions of high-performance bipolar circuits.

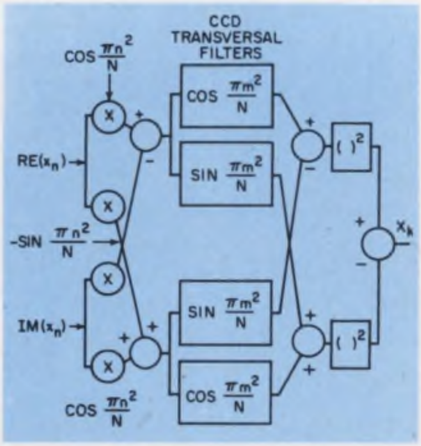
An impressive example of how I^2L logic can be combined with analog circuitry on a single chip surfaced during a panel discussion of "Compatible Analog/Digital Techniques for a Monolithic Process." A pioneer of I^2L, Case Hart of Philips Research, Eindhoven, the Netherlands, described and demonstrated a monolithic tone generator for pushbutton telephones. The system, whose performance met European telephone standards, used I^2L for such digital functions as frequency division, while the same bipolar chip included such sophisticated analog circuits as a gyrator and line drivers. To ensure that the circuit would be relatively inexpensive to manufacture, Hart limited himself to just four masks for device fabrication.

Michael Elphick
Managing Editor

Better passive components

As evidenced by papers at the conference, analog designers are showing considerable ingenuity in improving the precision of passive components for analog ICs. Resistors have long been a limiting factor in IC performance—especially in the bit-weighting networks of a/d and d/a converters and in the offset-nulling and gain-defining networks of operational and instrumentation amplifiers.

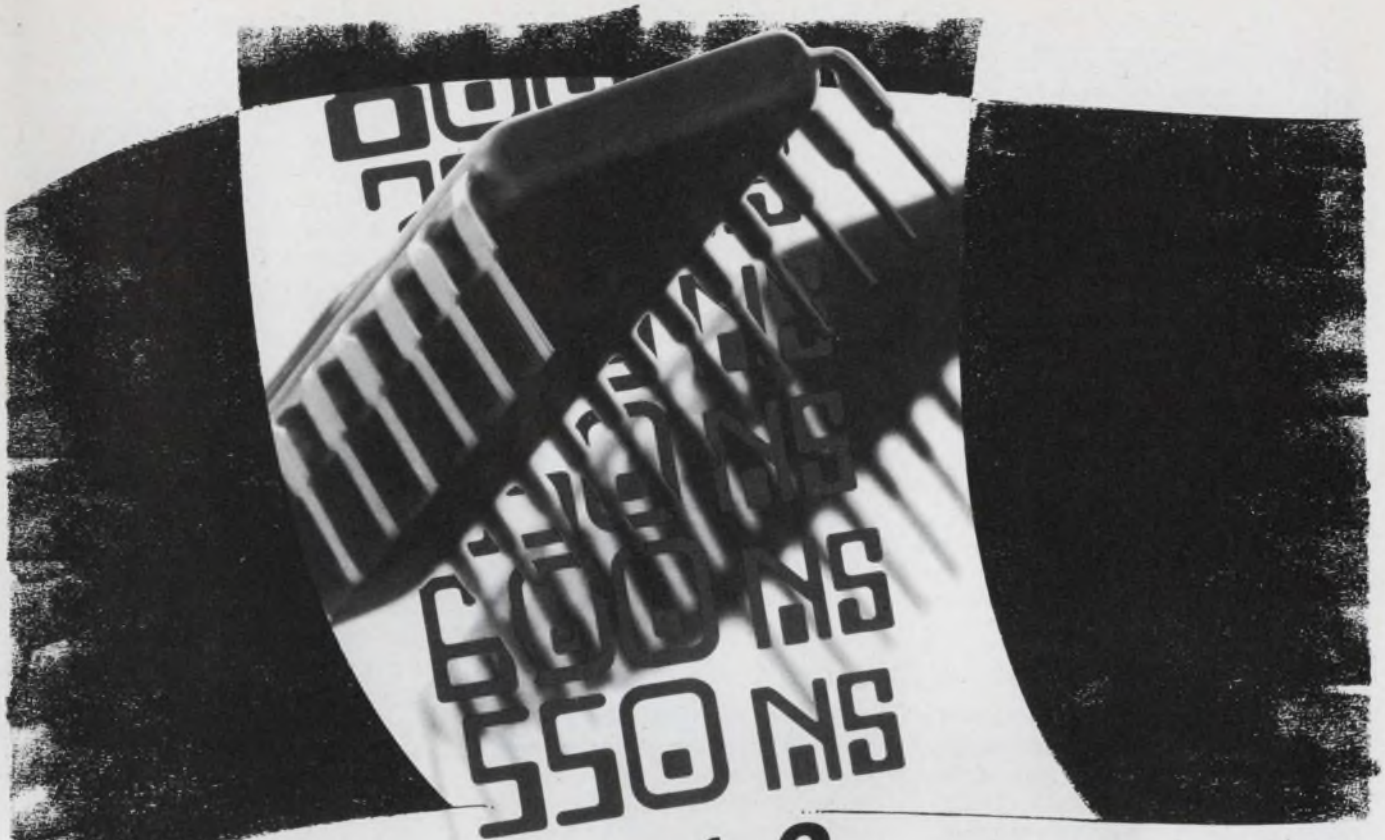
An extreme solution—throw out the resistors and use capacitors instead—was advocated in a paper by James McCreary and Paul R. Gray of the University of California, Berkeley, CA. The authors described a successive-approximation a/d converter that exploited the excellent matching characteristics exhibited by area-ratioed MOS capacitors. The experimental n-channel metal-gate circuit performed a 10-bit conversion in 20 μs. Measurements on experimental chips made by conventional photolithography showed that if capacitor ratio error were the only factor affecting yield, the yield to ±1/2 LSB would be 98% for 8-bit resolution and 45% for 10 bits.



An analog Fourier transformer can be built by use of charge-coupled devices as transversal filters. The technique shown employs a sliding chirp Z transform for periodic waveforms and stationary signals. A practical system has been built to generate a 500-point transform.

The experimental chip contained the capacitor array, an offset-compensated comparator and the output latch. However, it did not include the reference source, clock generator or control and sequencing logic. Though the capacitive-weighting technique had been proposed before, the authors' circuit avoided a parasitic-capacitance problem that had hitherto restricted the attainable resolution.

Another way to eliminate the resistors from converter circuits was proposed by Thomas Hornak and John Corcoran of Hewlett-Packard Laboratories, Palo Alto, CA. Hornak, who delivered the paper, described an a/d converter that consisted of an analog signal-processor chip, containing both MOS and bipolar devices, and an external transformer with a precise ratio that essentially defined the converter's accuracy. The accuracy was said to be consistent with a resolution of better than 12 bits. The conversion technique was re-



They're running 1-2 in the 16K static ROM speed race

Someday, someone may produce a faster static 16K ROM than Motorola's new MCM6832. Chances are, it will be Motorola. Until we developed the MCM6832 with its 550 ns access time, our own MCM-6590 was fastest at 800 ns, and it's still much faster than any other.

The MCM6832 was developed to provide a large ROM which allows the MC6800 microprocessor to operate at its full speed capability. As such, it's naturally the first one fast enough to permit full speed operation of any MOS MPU system. The MCM6590 is still the most cost effective 16K ROM, though, when ultimate speed isn't the primary requirement.

These mask programmable memories are identical in most vital characteristics, with but one other significant difference. The MCM-6590 uses +12, +5 and −3V supplies, for compatibility with the popular MCM6560, 6570, 6580 series of 8K ROMs. The MCM6832 uses −5V in place of the −3V supply for direct compatibility with NMOS RAMs. Both are ideal for fixed program storage, look-up tables, terminal character generators, and of course, microprogramming for microprocessors.

Three-state outputs permit common busing, and programmable chip selects and wire-OR capabilities help minimize unwanted external components in memory expansion. Programming is easy. Prototype parts are typically delivered six weeks after receipt of a mask pattern.

For system characterization of parts prior to ordering custom programmed ROMs, the MCM6591 and the MCM6832L91 are pre-programmed versions, containing a potpourri of conversion codes and USASCII characters.

One to 24 prices are $35.90 for the MCM6591, $43.08 for the MCM-6832L91. Minimum MCM6590 and MCM6832 orders are 500 units per custom mask. From there to 999 they are priced at less than 15/100 and 2/10 cent per bit respectively, excluding the mask charge. For information, write Motorola Semiconductor Products Inc., P.O. Box 20912, Phoenix, AZ 85036, or circle the reader service number.

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Device	Access Time ns	Power Supplies V	2048 x 8 Organization	Power Dissipation (max) mW	TTL Compatible	CMOS Compatible	Price per bit (100-999)¢	Ceramic Dual In-line Package
MCM 6590	800	+12, +5 −3	✓	<500	✓	✓	<15/100	24-pin
MCM 6832	550	+12, +5 −5	✓	<500	✓	✓	<2/10	24-pin

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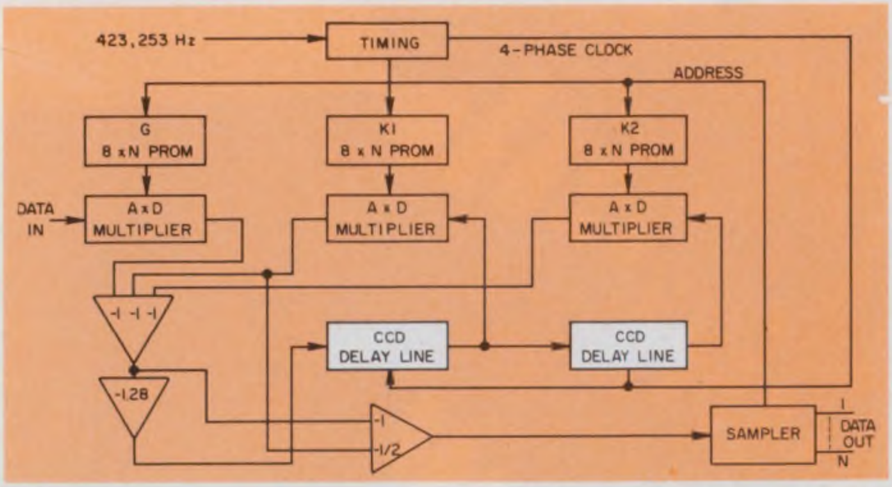

A 32-channel multiplexed filter uses a single tapped CCD delay line. The center frequency, bandwidth and gain of each channel can be programmed independently by data stored in just three PROMs. The basic filter is the canonic form of the two-pole, one-zero recursive filter network.

cursive (bit at a time) and based on the Gray Code (absolute value) algorithm. A conversion rate of 20 kHz was used to evaluate circuit performance. Hornak pointed out that the circuit's Gray Code output could easily be converted to binary code by external logic.

Improved trimming techniques

Of course, proponents of resistors argue that these components pose a performance and yield problem only if one is trying to use diffused resistors in a truly monolithic circuit. If one is allowed to use external components, why not stay with precision resistors?

This was the approach chosen by Robert B. Craven of Analog Devices Semiconductor, Wilmington, MA. In his paper, Craven described a 12-bit d/a converter that consisted of two chips in a single package. One chip contained a laser-trimmed, thin-film resistor network, while the companion chip contained bipolar circuitry for current switching. For the resistor chip, laser trimming was performed automatically at the wafer level. The switching-network chip included a new type of biasing circuit that reduced sensitivity to device parameter variations. Settling time for the converter was 1.5 μs to within 0.01% of full scale. The circuit was designed to accept both CMOS and TTL inputs and to operate from ±15-V supplies.

A technique that may give new life to diffused resistors for analog ICs was described in a paper by George Erdi of Precision Monolithics, Santa Clara, CA. He showed how the offset voltage of a precision operational amplifier could be nulled at the wafer-probe phase, where circuits are handled in mass. This economical approach involved short-circuiting zener diodes that had been designed into the chip to shunt strategically placed diffused resistors. According to Erdi, the current required to perform the short-circuiting operation was around 100 mA, though the exact value depends on the duration of the pulse. When the current pulse is passed through the emitter-base junction, the localized power dissipation is of such magnitude that metal from the emitter and base contacts fuses into the silicon thus shorting the two contacts. The fusion is permanent and typically results in a 1-Ω resistor.

Though the basic technique of shorting diodes to program circuits was first proposed by J. E. Price of Fairchild Semiconductor in 1962, Erdi said that designers were only now starting to use it for linear ICs. Other engineers at the conference, however, indicated that they had been using the technique for several years.

Data sampling gains favor

While progress in digital processing of analog signals is temporarily stymied by a lack of suitable compact, low-cost converters, analog circuit designers are paying increasing attention to sampled-data processing. With this "semi-digital" approach, of course, the data samples are still handled as analog signals, but the timing and control functions can be handled by digital logic.

Recently the development of CCDs gave sampled analog processing a powerful shot in the arm. Compared with digital filters, CCDs offer potential advantages in cost, weight, size, power consumption and reliability. But CCDs have several disadvantages that presently curb the range of applications. The number of delay stages is limited by charge-transfer loss, the total time delay is limited by thermal leakage, and filter bandwidth is limited by speed restrictions. Several papers at the conference described practical applications for CCDs, while others showed how CCD performance could be improved.

The enormous potential of CCD processing was demonstrated in a paper by Robert W. Broderson, Horng-Sen Fu, Robert C. Frye and Dennis D. Buss of Texas Instruments, Dallas. The paper was delivered by Broderson, who described how CCDs could be used as transversal filters in a system to perform a 500-point discrete Fourier transform.

Instead of using a true DFT, the Texas Instruments engineers used an approximate algorithm called a sliding chirp Z transform (CZT). This approach required three signal-processing steps: premultiplication of the samples by a complex chirp waveform, convolution in a filter having a complex chirp impulse response and postmultiplication by a complex chirp waveform. Custom CCD filters were fabricated with electrode weighting on 160 × 100-mil chips. The devices were found to have 99.98% charge-transfer efficiency from 1 kHz to 8 MHz.

According to Broderson, it's possible to build real-time Fourier transformers that operate to 10 MHz, but the technique is presently limited to 1000-point resolution. Chirp generation, premultiplication and output squaring were performed off chip, but a future de-

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velopment program will integrate these functions to produce a self-contained spectral-analysis IC.

The sliding version of the CZT is significantly less affected by charge-transfer efficiency than the true CZT. But it has the disadvantage of not yielding a true DFT for some waveforms, though it does give the power-density spectrum of a DFT for periodic waveforms and stationary random signals. Broderson predicted important applications in doppler processing for radar and sonar, image processing for bandwidth compression, and spectral analysis for target identification and speech recognition.

Use of CCDs in a reprogrammable filter bank for doppler processing was described in a paper by John Mattern and Donald Lampe of the Westinghouse Defense and Electronic Systems Center, Baltimore. The system used a 32-stage CCD analog shift register to provide the delay for a recursive two-pole, one-zero network. The serial data output was demultiplexed onto parallel output lines. Though a 32-stage CCD can theoretically provide up to 32 filter channels, the version described was limited by the output sampler to just 16 channels.

The center frequency, bandwidth and gain of each filter channel were independently programmable. Three PROMs contained the necessary three programming constants for all channels, while three multiplying d/a converters accomplished the required instantaneous weighting of the analog signals. According to Mattern, who delivered the paper, each of the nonuniformly spaced center frequencies, in the range of 150 to 250 Hz, were within 1 Hz of the design frequency—a tolerance of about 0.5%.

Some members of the audience questioned the usefulness of the Westinghouse filter bank, saying that it would be more economical to use 16 separate active RC filters built with inexpensive op amps. But Mattern explained that his approach became more economical as the number of channels increased, because the system still needs only a single CCD and three PROMs and converters. Also, the PROMs can be replaced with computer generated codes to allow continuous readjustment of filter characteristics.

Overcoming CCD limitations

A couple of papers at the conference showed how some of the problems of CCDs could be circumvented. For example, Miles A. Copeland and Dipak Roy of Carleton University, Ottawa, Canada, in a paper coauthored by Chong C. Chan of Bell Northern Research, showed how a 10-channel multiplexed CCD and delay line could be constructed for video delay applications. This approach allowed the analog sampling rate to be 10 times the CCD clock rate, thus avoiding the inherent sampling-rate limitation of CCDs. The system was designed to delay a color TV signal by one line duration, thus allowing synchronization and bandwidth compression. Though bandwidth, linearity and phase behavior were adequate, the authors encountered problems with fixed pattern noise. This noise had components concentrated at harmonics of the CCD clock rates, and it was caused by imbalances of bias and gain at the inputs and outputs of the CCD channels.

Another paper, by John Shott and Roger Melen of Stanford Electronics Laboratory, Stanford, CA, showed how a "razorback" structure could be used to place multiple input taps on a CCD while achieving high transfer efficiency and large bandwidth. With this type of CCD delay line, the input taps can be used singly to provide a selectable bit delay, or in parallel to perform delay-sum and multiplexing operations. ■■

Papers, anyone?

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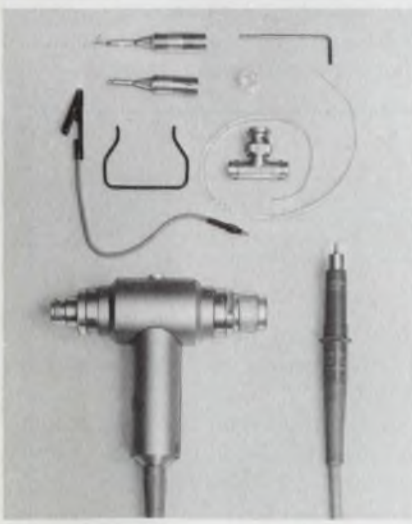

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PLL ICs taking on dedicated jobs as temp and voltage ills recede

Monolithic phased-locked-loop devices—one of the most promising electronic developments to emerge in recent years—are maturing with semiconductor-chip design experience.

Temperature sensitivity has been improved substantially, especially at higher frequencies. As a result, the operating ranges have been extended into the rf and vhf regions.

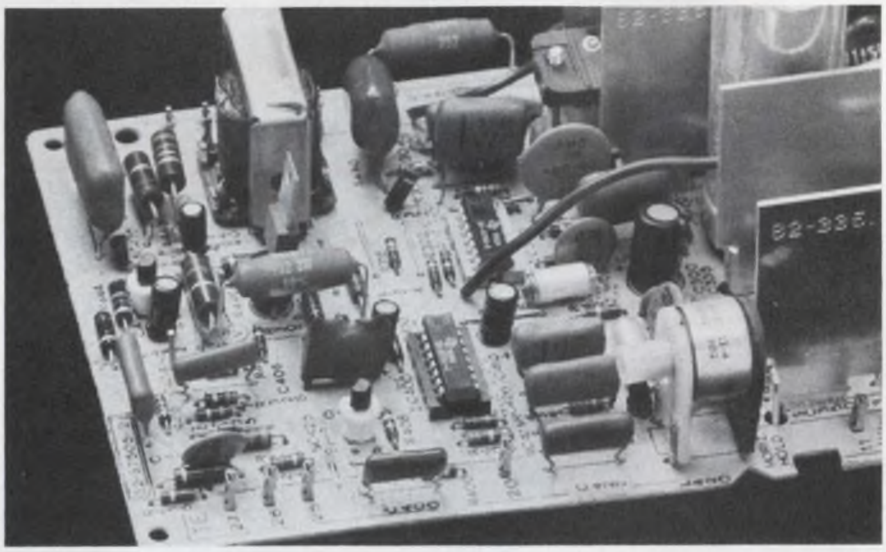
Voltage sensitivity is being controlled by inclusion of regulators on the chips.

Most important, the attempt to develop general-purpose PLL devices has given way to the design of a variety of special circuits that do one dedicated job. They do it better and at lower cost than other approaches do. These special PLL circuits are being used in the following applications:

- FSK data modulation and demodulation.
- Tone detection and decoding.
- Data-stream synchronization.
- Digital tuning (frequency synthesis).
- Stereo multiplex decoding.
- Discrete four-channel sound decoding.
- TV chroma subcarrier regeneration.
- TV horizontal oscillator sync.
- FM i-f demodulation.
- TV-sound i-f demodulation.
- TV-picture demodulation.

Phase-locked-loop integrated circuits, first fabricated by Signetics in 1969 as frequency-selective circuits, are designed for a wide range of filter, demodulator and signal-conditioning applications. But the performance of first-generation IC devices was disappointing, because of temperature instability of the key element of the loop—the voltage-controlled oscillator (see box).

Jim McDermott
Eastern Editor



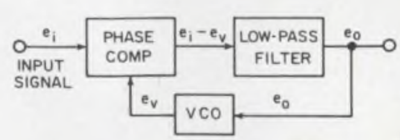
The horizontal oscillator and phase detector of this Sylvania TV-set PLL used for horizontal hold are in the IC (center, front). The oscillator tuning coil shown at the right stabilizes the oscillator frequency.

Temperature instability limited application to noncritical circuits with wide tolerances. And this instability, which increases with the VCO operating frequency, limited the upper frequency at which the devices could be used.

In addition undesirable drift of the VCO frequency was present with variations in supply voltage.

A number of the new PLL circuits, particularly those for consumer electronics—like FM stereo radios and TV sets—are being used by the millions. *(continued)*

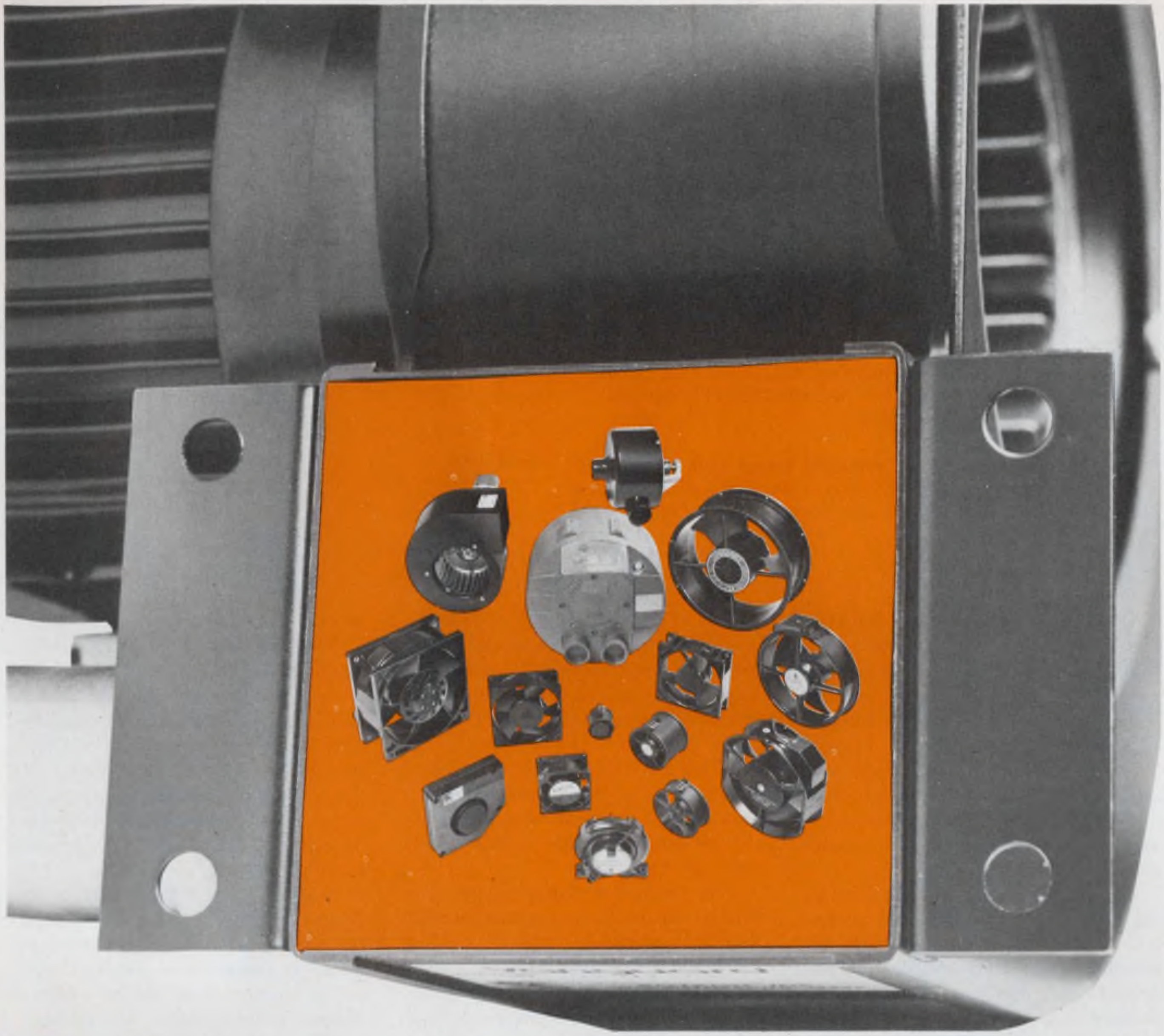
Basic phase-locked loop theory



The basic phase-locked loop (PLL) is a feedback system in which the frequency and phase of a voltage-controlled oscillator (c_v) is compared with that of an input signal (c_i). When there is a difference an output appears at the comparator.

This output is passed through a filter and applied to the voltage controlled oscillator (VCO) to bring it back in step with the input signal. In this manner, the frequency and phase of the VCO tracks that of the input to provide frequency selection filtering without a tuned circuit.

In discrete form the PLL has been highly developed in NASA and military receivers for extracting signals from noise. And this application continues to be a major reason for its use in IC form.



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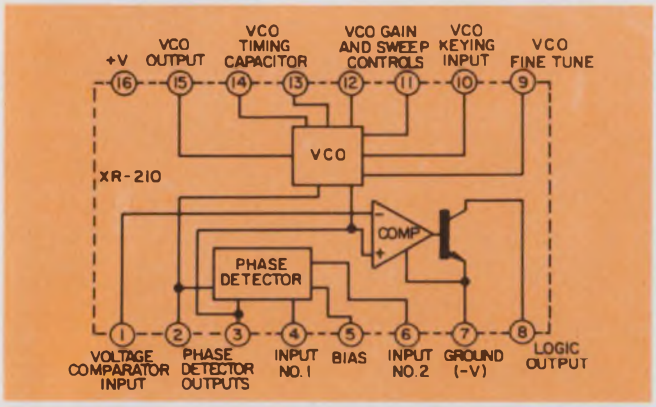
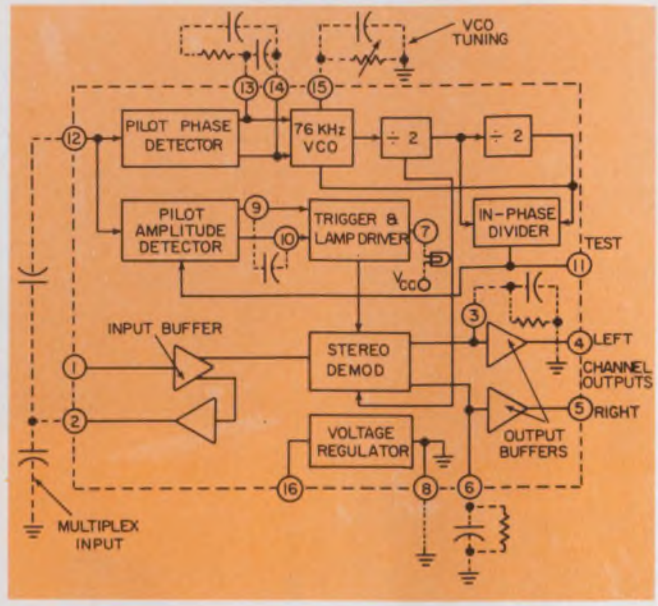


1. **Designed for data communications, this Exar 210 phase-locked-loop IC** is used in modems for FSK demodulation and for tone decoding.



2. **Monolithic PLLs for decoding stereo multiplex signals in FM receivers** eliminate the coils and tuning formerly required. Shown here is the Sprague ULN-2244A.

One phase-lock device bucking the trend to specialization is a micropower CMOS unit developed by RCA (CD4046) and second-sourced by Motorola (MC14046). It has been designed for a number of applications, including FM modulation and demodulation, frequency synthesis, data synchronization, tone decoding and motor-speed controls.

The improvement in temperature stability has expanded the potential uses of PLL devices. One example is Exar's new XR-2211 FSK demodulator and tone decoder. This package has a high VCO stability of 20 ppm/°C, compared with 600 ppm or more for first-generation units.

"The 2211 has improved the state of the art—so far as temperature sensitivity is concerned—by a factor of five," says Alan Grebene, Exar's president and developer of the first practical monolithic PLL at Signetics. He adds: "It opens up a wide range of telephone and FSK modem applications where channel widths require a higher stability than that currently available."

Stanley Canter, engineering manager of Omnitec Corp., Phoenix, AZ, one of the largest suppliers of acoustic modems and telephone couplers for computer time-sharing and data communication, uses PLLs for FSK modulation and demodulation.

"We have to pay careful attention to the temperature characteristics of the monolithic PLLs we use," he says. "Excessive VCO frequency variations with temperature show up as bias distortion, which changes the mark-to-space ratio."

"The use of a PLL is more cost-effective as well as more reliable," Canter says, adding that the PLL device also provides higher tolerance to line noise.

The push for higher speeds in PLLs, for both analog and digital use, is continuing.

"For analog signal work," says L. J. Reed, Motorola Semiconductor Products design engineer, "we have a linear PLL that will be available this summer. The part, the MC12030, will operate above 50 MHz. At present there are typical parts that can operate at 30 MHz but that have guarantees of only 15 MHz.

"Another feature of the MC12030 will be the fact that it is a 5-V device, as opposed to the 8-to-12-V devices now on the market. This part will directly interface with ECL, for example, in the divide-feedback chain of a synthesizer. For existing products, translators must be added to both input and output for interfacing with any kind of digital circuit."

Another high-speed product that Motorola plans to release in July is a high-frequency balanced modulator that can interface with linear circuits or be driven directly by ECL. Called the MC12002, it will operate above 500 MHz, Reed says.

The largest application of a dedicated PLL IC—on the order of a few million a year—is in FM-radio stereo multiplex decoders. One basic type, the RCA CA3090, employs an LC-tuned, 76-kHz VCO. An externally tuned coil is used, says RCA, because of its better long-term drift and temperature stability.

A second basic type, which employs RC-tuned oscillators, is popular with radio manufacturers because it requires no external coils or production-line tuning—only a simple potentiometer adjustment.

"The use of the RC-tuned type stereo decoder is the most cost-effective way to go," says Les Wilkinson, supervisor of radio IC development for Delco Electronics, Kokomo, IN. "You eliminate a tuned circuit, the labor of aligning it, plus a few extra capacitors."

While present stereo decoders are reasonably well-refined circuits, temperature and other effects cannot be ignored.

"The dynamics of stereo decoders is no problem," says Wilkinson. "You don't have to worry about overloading the loop. But you do have to be concerned about your capture and lock range.

"You have to make sure that your VCO capture and lock range are wide enough so that the VCO won't wander out of the range due to temperature changes. However, the capture range must be small enough to provide good selectivity

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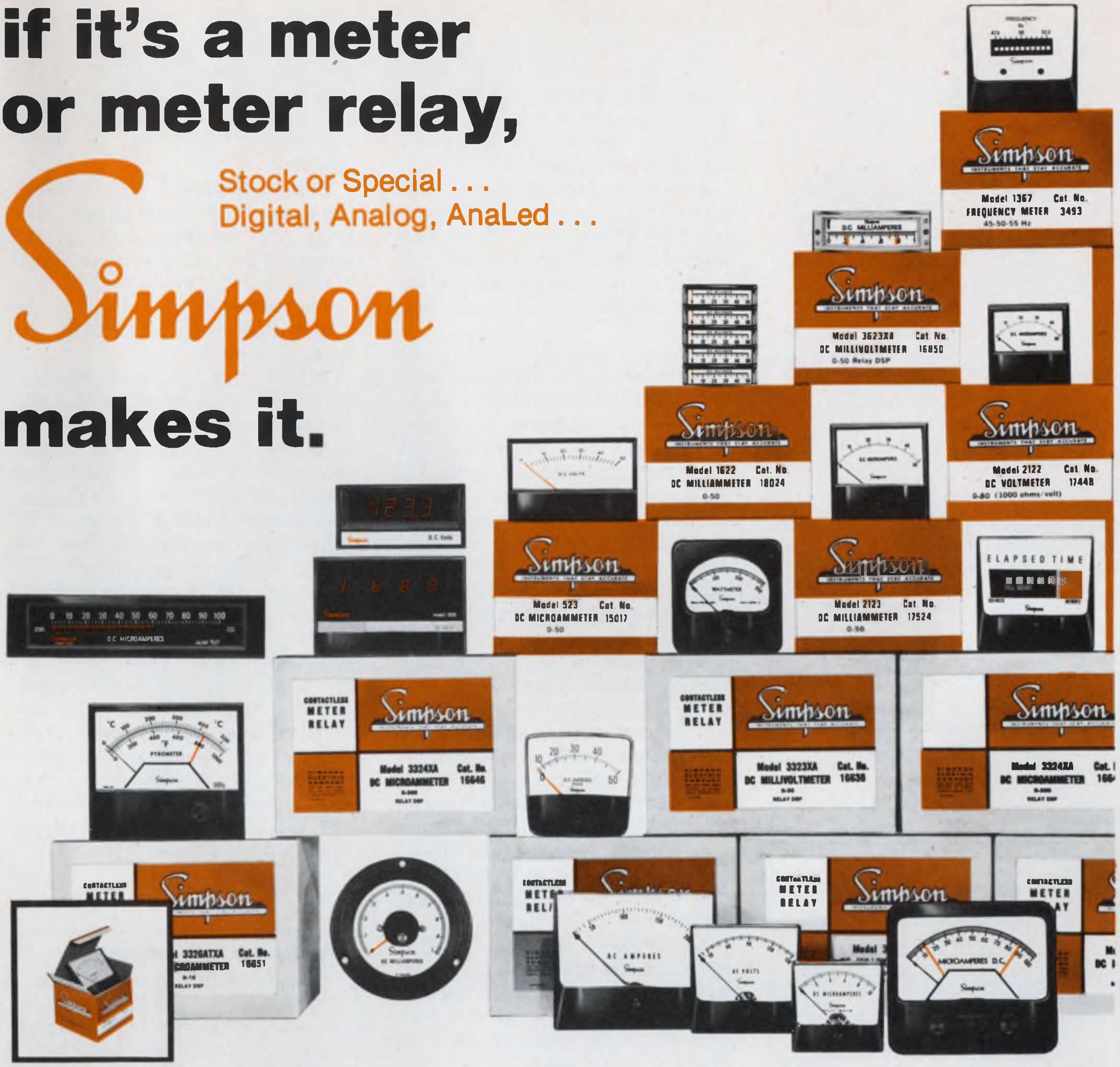

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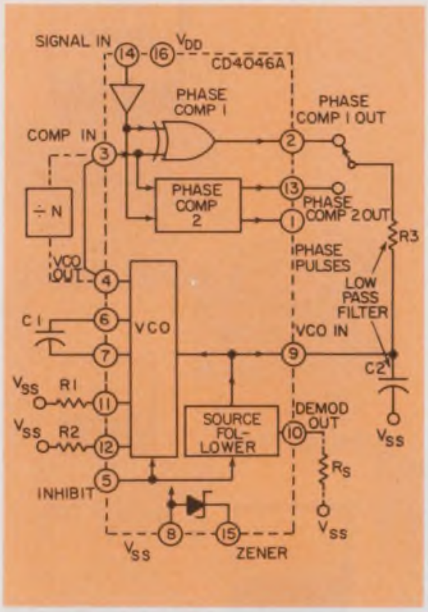
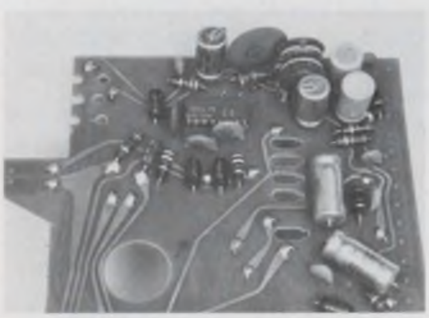


3. **Micropower CMOS PLLs,** like this RCA CD4046, draw but 75 μW. They are general purpose circuits.

Phase Locked-Loop Applications	PLL Manufacturers								
	Exar	Fairchild	Harris	Motorola	National	Plessey	RCA	Signetics	Sprague
FSK demodulation	●		●		●	●		●	
FM demodulation Less than 5 MHz	●		●					●	
Above 5 MHz	●		●		●	●		●	
Frequency synthesis Less than 5 MHz	●		●					●	
Above 5 MHz	●		●	●	●	●		●	
Signal conditioning	●		●		●	●		●	
Tone detection	●				●			●	
AM detection					●			●	
Motor speed control	●		●			●			
Stereo decoder		●		●					●
TV networks				●	●		●	●	
CMOS PLL				●			●		



One mass-produced PLL IC is the FM stereo demultiplexer, shown here on a Delco FM auto radio PC board. This IC has a 76-kHz VCO, which is divided into 38-kHz segments for demodulating stereo information.

for the 19-kHz pilot.

"If it's too wide, it is possible for a 15 or 18-kHz audio signal to fool the decoder into thinking that it has a stereo station. In this case the stereo light mistakenly signals a stereo station."

Two types of high-volume dedicated PLL circuits are those in color TV horizontal oscillator hold-control systems and in chroma subcarrier regenerator circuits. Refinements remain to be made in these ICs.

"We've had discrete PLLs for many years in the horizontal oscillator system," says Joseph Thomas, engineering manager for large-screen color TV receivers at Sylvania Entertainment Products, Batavia, NY. "The biggest problem we have putting it into an IC is getting a controlled, balanced phase detector that will remain balanced over a wide spectrum of noise frequencies, yet also be balanced from device to device.

"For example, the kind of horizontal oscillator you're using—RC, blocking or sine wave—has an effect on what kind of phase detector and loop gain are needed, particularly from the noise and pull-in requirements and stability standpoints. The choice of the oscillator somewhat dictates the kind of systems you can use in front of it—the tuner, the i-f and the agc system.

"A problem with ICs is that some are designed totally by IC manufacturers and their application engineers, who haven't been exposed to the peculiar problems involved in TV sets."

For best temperature sensitivity, Sylvania uses an LC oscillator. Only the tuning coil and capacitor are external to the IC. Thomas notes: "We frankly don't have enough experience with RC oscillators—which are highly sensitive to temperature, even in a discrete component circuit—to have much confidence in them."

The increasing use of CMOS in circuits requiring low-power dissipation has created a demand for these PLLs and RCA has developed one—the CD4046. (Motorola's MC-14046 is a pin-for-pin replacement.)

Suitable for data-communication circuits and motor-speed controls, the 4046 consists of a linear VCO and two separate phase comparators (Fig. 3). Comparator 1 is an exclusive-OR network that operates analogously to an over-driven balanced mixer. It enables the system to remain in lock despite high amounts of noise in the input signals.

Phase comparator 2 is a pulse-edge-controlled digital memory network that operates only on the positive edges of the input signal and comparator networks.

The operating frequency of the CMOS PLL is up to 1.2 MHz, according to RCA.

A unique PLL package, the Signetics 563, is essentially a complete i-f strip for either narrow or wide-band FM. It incorporates a double-conversion technique in which the second oscillator is a VCO that demodulates the FM signal.

Specifications indicate that the high-frequency response of the 563 is better, the sensitivity greater and the distortion lower than they would be with use of a separate monolithic PLL. The circuit requires no alignment in most applications, Signetics says. For circuits that do, only a single potentiometer adjustment is required.

Peripheral functions such as agc, afc, signal-strength meter drive and variable muting are incorporated in the 563. ■■

Need more information?

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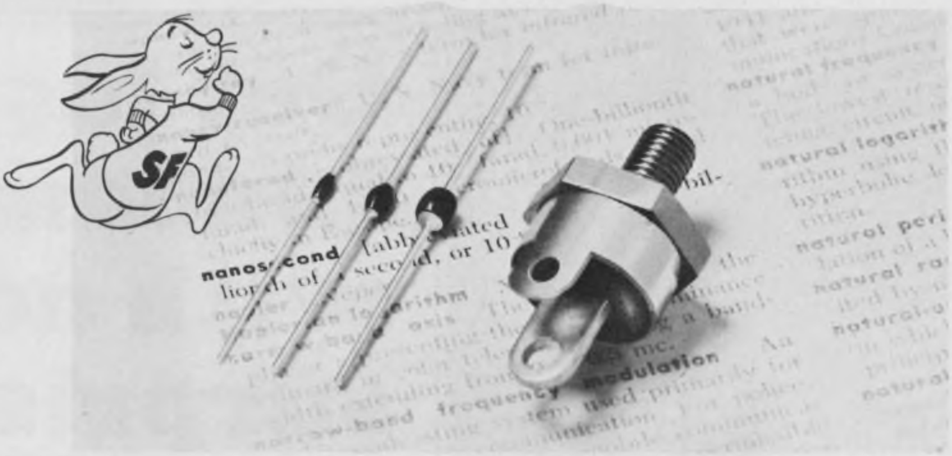
New Super-Fast Silicon Rectifiers!

30 Nanosecond Recovery Time



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Semtech's Super-Fast Silicon rectifiers are stocked for immediate delivery.

*Typical readings are as low as 15 ns.

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TYPES: FF05, 10 & 15

Peak Inverse Voltage @ .25°C: 50, 100 and 150 V
Reverse Current (Max): @ 25°C 1.0 μA
Instantaneous Forward Voltage @ 1.5 A (Typical): 0.97 V @ 100°C
Capacitance @ 12 V DC (Max): 24 pF
1 Cycle Surge Current (tp = 8.3 ms): 25 A
Reverse Recovery Time, Trr (Max): 30 ns
Dimensions (Max): Body; .070" D x .165" L
Leads; .031" D x 1.25" L

TYPES: 3FF05, 10 & 15

Peak Inverse Voltage @ .25°C: 50, 100 and 150 V
Reverse Current (Max): @ 25°C 5 μA
Instantaneous Forward Voltage @ 3 A (Typical): 1.0 V @ 100°C
Capacitance @ 12 V DC: 58 pF
1 Cycle Surge Current (tp = 8.3 ms): 50 A
Reverse Recovery Time, Trr (Max): 30 ns
Dimensions (Max): Body; .110" D x .165" L
Leads; .040" D x 1.10" L

TYPES: 5FF05, 10 & 15

Peak Inverse Voltage @ 25°C: 50, 100 and 150 V
Reverse Current (Max): @ 25°C 10 μA
Instantaneous Forward Voltage @ 5 A (Typical): 0.8 V @ 100°C
Capacitance @ 12 V DC: 230 pF
1 Cycle Surge Current (tp = 8.3 ms): 125 A
Reverse Recovery Time, Trr (Max): 30 ns
Dimensions (Max): Body; .165" D x .165" L
Leads; .040" D x 1.10" L

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30 Amps; @ 25°C .96 V, @ 100°C .85 V and @ 150°C .78 V.
50 Amps; @ 25°C 1.05 V, @ 100°C .93 V and @ 150°C .90 V.
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NOTE: V_F is measured @ pulse if duration = 8.0 millisec. Maximum.

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Electronic Attenuator/Switch

		Model PAS-1 ZAS-1		Model PAS-3 ZAS-3	
Frequency Range, MHz	OUTPUT	5-450		1-200	
	INPUT	5-450		1-200	
	CONTROL	dc-0.05		dc-0.05	
Insertion loss, dB		Typ	Max	Typ.	Max
One Octave From Band Edge		3.5	4.0	1.4	2.0
Total Range		3.5	4.7	1.6	2.5
Signal, 1 dB Compression Level		Greater than 1 Watt			
Isolation, dB		Typ	Min	Typ.	Min.
Lower Band Edge to One Decade Higher	IN-OUT	65	50	65	50
	IN-CON	35	25	35	25
Mid Range	IN-OUT	55	45	50	40
	IN-CON	25	15	20	15
Upper Band Edge to One Octave Lower	IN-OUT	35	25	50	40
	IN-CON	20	10	15	10
Impedance, All Ports		50 ohms		50 ohms	
Price (Quantity)		PAS-1: $27.95 (5-24)		PAS-3: $28.95 (5-24)	
		ZAS-1: $42.95 (4-24)		ZAS-3: $43.95 (4-24)	

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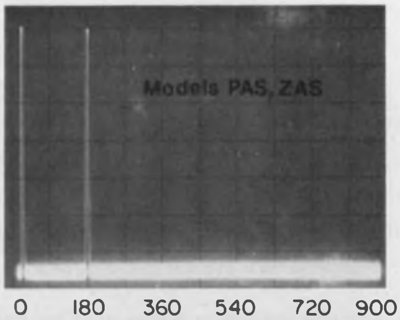

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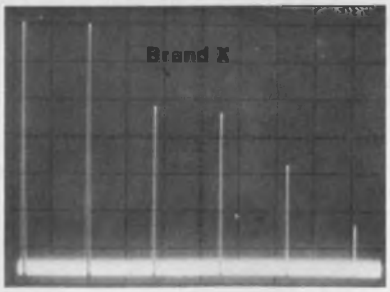

Control current set for 10dB attenuation,
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Signal power: 0 dBm Vertical scale: 10 dB per cm
Horizontal scale: 100 MHz per cm

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INFORMATION RETRIEVAL NUMBER 29

washington report

Air Force to check production of contractors

The Air Force plans to get more involved in the production end of contracts, to make sure that the processes and technology are the most efficient possible.

Air Force officers and civilian engineers have begun training with industry and will be assigned to program offices and other key spots to check on performance.

"Ideally," says Lt. Gen. John B. Hudson, vice commander of the Air Force Systems Command, "there ought to be (Air Force) manufacturing engineers involved in the planning and design of major new products, and they should stay with the program to completion. Unless they are there when the plans are made, the chances are poor that we'll get an end product that will be producible in the desired quantity and quality at the right time and the right cost. Getting the manufacturing analysts involved early helps us make more accurate cost estimates and to lay out more realistic schedules. It also improves the likelihood that once production starts, it will proceed without glitches and without waste."

1975 defense spending cuts sought

While the spotlight is focused on fiscal 1976 budgets, the Ford Administration is still flailing away at Government spending in fiscal 1975. If Congress approves of recently proposed cuts and deferrals, there will be some shrinkage in defense and R&D spending.

The Army would not buy $5.7-million worth of UH-1H helicopters, and the Air Force would not buy 24 A-7D and 12 F-111 fighter aircraft at $152.5-million. The Bureau of Standards' Telecommunications Office would have $4.63-million deferred. Most of this—$3.54-million—would slow technology "incentive" projects and would delay, to beyond 1976, the development of an electromagnetic measurement program. Slightly over $7.76-million would be deferred from the Maritime Administration authorization, including $3.47-million for R&D on a nuclear-powered tanker and advanced communications.

CATV warned on interfering radio signals

Growing concern about flight safety may force cable-television operators to shut down abruptly during equipment malfunctions. The Federal Communications Commission has warned the industry of possible interference with air traffic control services in the 108-to-136-MHz bands.

Cable television systems carry high level signals falling within a typical bandwidth of from 50 to 300 MHz.

Recent studies indicate that improper termination of the shielded coaxial cables that CATV employs could result in the radiation of sufficiently strong signals to disrupt other transmissions in the atmosphere including those in the critical 108-136 MHz range. The FCC is strongly suggesting that operators consider the use of alternate frequencies until it has reviewed the problem.

Major concern is with the delay expected in locating and repairing malfunctions. Should malfunctions arise, the FCC will require service to be terminated immediately.

Inputs sought on world radio allocations

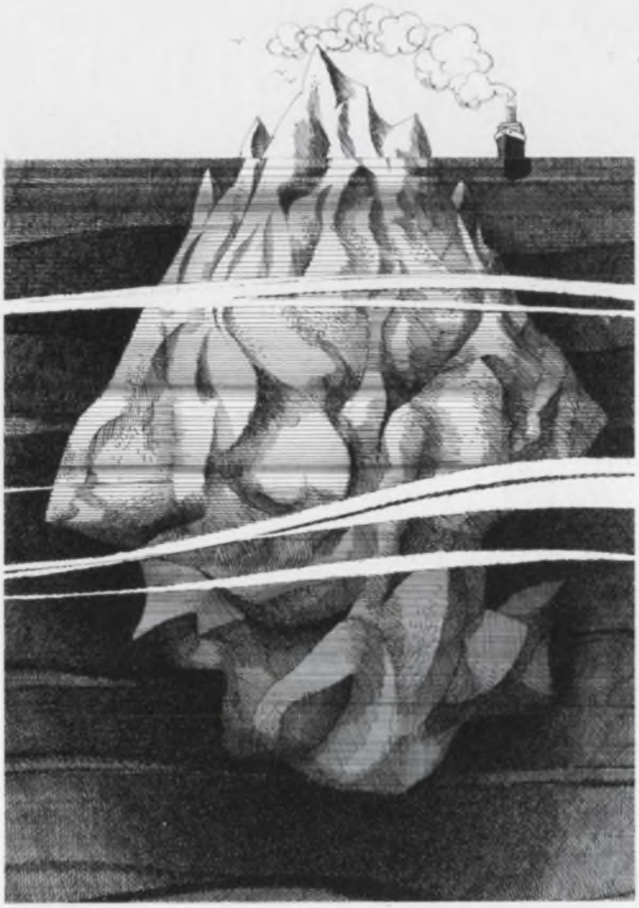
The Federal Communications Commission is facing a rugged job in developing the American position for negotiations at the World Administrative Radio Conference to be held in Geneva in 1979. High on the agenda at the conference will be international frequency allocations to cover the communications spectrum for the remainder of the century. The FCC's major problems will be to reach compromises between users of the services.

The commission is asking for inputs from Government, industry and the public for use in reaching agreements with some 140 nations on regulation of the various radio services—broadcasting, space, aeronautical and amateur.

Capital Capsules:

A contractor is being sought by the Air Force Systems Command at Eglin AFB in Florida to **design and fabricate an optical communicator system that will transmit and receive data from one point on an aircraft to another point on the same aircraft.** Data consisting of 70 analog parameters, having a frequency of 100 Hz or less, are to be transmitted by a light source over a maximum range of 50 ft. The receiver will have to detect and present the data with accuracy to within 1%. . . . If Congress agrees, **the General Services Administration's automatic data-processing fund will be $73.2-million in fiscal 1976,** up from $56.9-million in the current budget. . . . NASA's Goddard Space Flight Center has issued **a request for proposals for providing telecommunications services** for a Tracking and Data Relay Satellite System. A ground terminal in the continental U.S. would relay data, commands and voice to and from mission spacecraft through two specialized relay satellites in synchronous earth orbit. The envisioned network would support all orbital spacecraft below 5000 kilometers. The system would be developed and operated by industry to NASA requirements. . . . A very flexible electron pre-ionized research laser system is on the shopping list of the Los Alamos Scientific Laboratory. It's to be used to study a wide variety of molecular gases. . . . Concern over data-communications security has prompted the Federal Reserve System **to seek information on ways to raise the security of its communications system,** a national network of 14 computer switching centers with many remote terminals. . . . The Labor Dept.'s Office of Foreign Economic Research plans to award a contract for a research study on the **marketing and employment changes to be expected in the electronics industry brought on by the new foreign trade bill.** Products to be covered are electronic components and accessories, radio and TV receivers and transmitting equipment, electronic calculators and industrial controls.

There's more to than



Putting a microprocessor to work for you involves a whole lot more than buying a few LSI chips and slapping them together.

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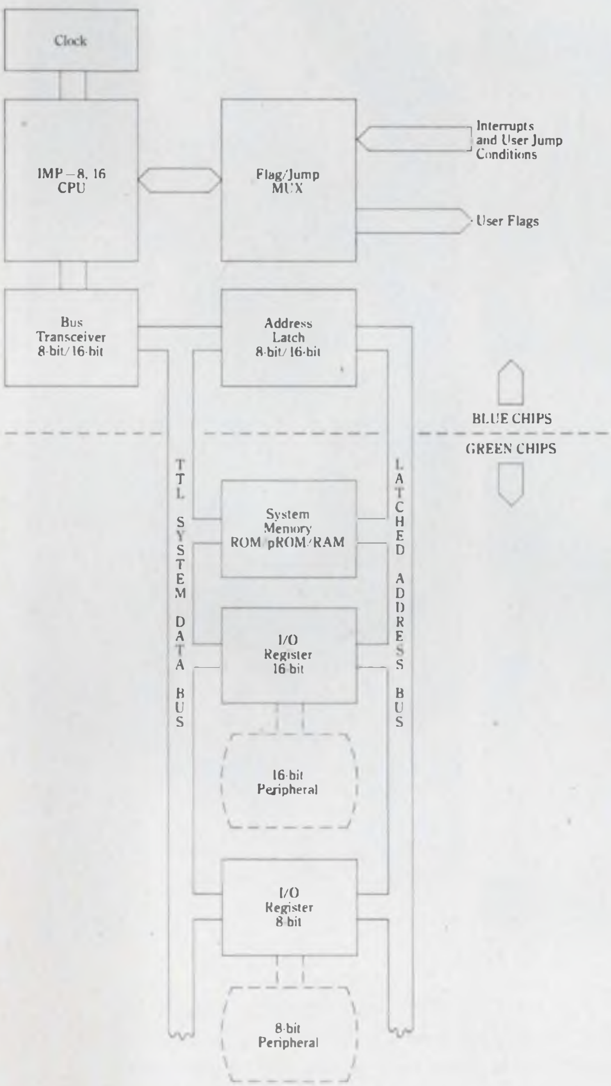
microprocessing microprocessors.

Here's a diagram of how it all goes together:



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INFORMATION RETRIEVAL NUMBER 32

editorial

One plus six makes one

If anybody were to call Steve a tyrant, he'd be shocked. He sees himself as a most reasonable person, a guy who's very democratic and always ready to hear what his subordinates have to say. But the engineers who work for him feel he stifles them.

Steve happens to be an excellent engineer but, without realizing it, he thinks he's the only one. He insists that everybody do things his way, that everybody think about problems the way he thinks about them. He acts as if there's only one possible approach to the thinking process. That, in itself, wouldn't be bad. Nobody objects to the way Steve thinks and, in fact, he's often brilliant. The problem lies in the fact that if anybody on his staff takes a different approach, Steve raises hell.

As a result, his engineers have pretty much stopped thinking. They simply try to figure out how Steve would want the problem solved—even if it's not a good way. They often waste their company's money catering to Steve's whims because Steve, like many of us, occasionally has some nutty hang-ups. They go through exercises that have no practical value because Steve thinks they're useful.

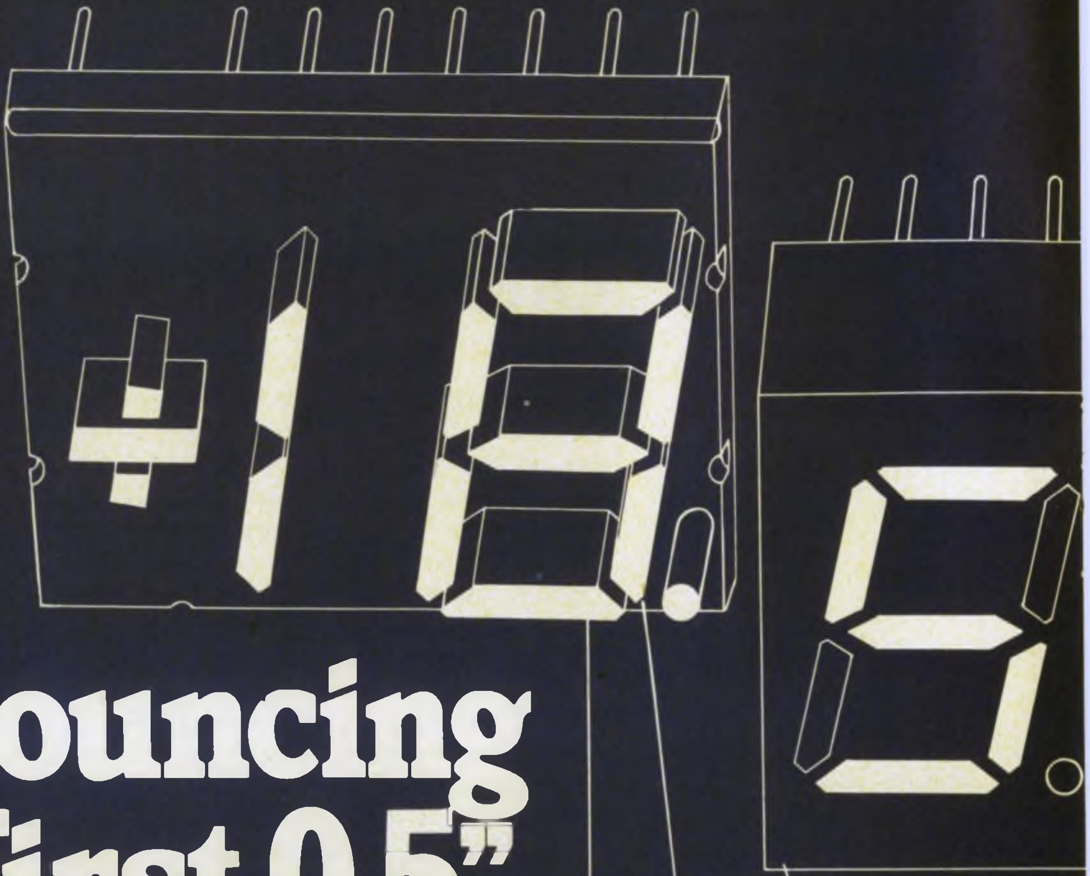
He's made it impossible for anybody to challenge him. Some years ago one of his engineers worked up the courage to say, "Hey Steve, this procedure is a complete waste of time. It's never done us a bit of good. It's expensive and it slows us down. Why can't we drop it?" In a fury, Steve turned on him and told him he was being negative. That effectively terminated the conversation because Steve was the boss and, when he said something was negative, that meant it was bad and therefore forbidden.

Well, Steve finally succeeded in surrounding himself with Yes-men. But he doesn't realize it. He sincerely thinks he has molded a great team because his engineers are astute enough to analyze problems the right way—his way. By weight of his authority, he crushes criticism. He has created an atmosphere that stifles creative thoughts, though he's a strong advocate of creativity. Steve doesn't see that he's using authority to crush arguments. He sees only the mastery of his impeccable logic.

Steve has six engineers working for him, but only one mind—his own.

George Rostky
Editor-in-Chief

Announcing the first 0.5" multi-digit LEDs



Here we go again. It's another first from Litronix: multi-digit 0.5″-high LEDs.

These two-in-one packages are tailor made for anyone who wants to save money in lower production costs. They require only half the inventory. Half the handling. Half as many components to assemble and test.

Makers of digital time pieces will find them ideal, as will those who manufacture point-of-sale terminals. FM digital readout tuning systems. TV channel tuners, and instrumentation.

The modules are end-stackable to produce any combination of 0.5″ digits on 0.5″ centers. The DL-727 is a two-digit module that's ideal for clocks. And our DL-721 module offers a ± sign and a "1" for polarity and over-range indications on instruments.

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No wonder we're No. 1 in LEDs

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Choose switching regulators for your computer power-supply design. Two major benefits are high efficiency and protection against line dropouts.

For the best efficiency in power supplies, the supply designer's choice is clear: The switching regulator is several times more efficient than the conventional linear regulator.

This is especially important in computer and computer-related applications, which usually need relatively high power levels, and where battery-operated standby systems are a must to prevent loss of memory or catastrophic errors. For these applications, not only does the switching regulator allow the use of smaller batteries. It provides another benefit: high energy-storage capability.

With such storage—provided by filter capacitors working at high voltages—it's possible to sustain from two to 10 cycles of line dropouts before an error occurs. For example, a switching regulator working from a 12-V NiCd battery can maintain a 32-k bit MOS memory for two hours.

But for all its benefits, the switching-regulator supply isn't as easy to design as the linear type. Here's what you should know to do the job.

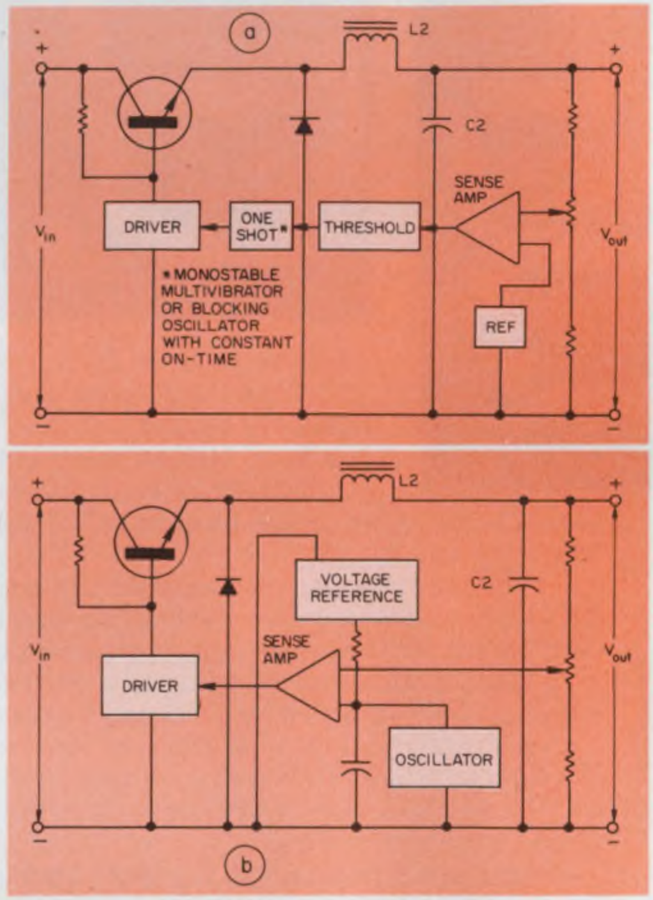
Two types of regulators

Switching regulators can be either free-running or of fixed frequency, depending on whether the transistor switch operates at variable frequency with a fixed pulse width or at fixed frequency with a variable ON time (Fig. 1).

In the fixed-frequency regulator, one switch transition is always performed by the external source; the other transition occurs when the output voltage reaches a predetermined threshold level. The sampling period is fixed by the external frequency, and the duty cycle is free to vary.

The fixed-frequency type, when thought of as an op amp, has a response time limited to one-half cycle of the switching frequency. Since all switching regulators require an output LC filter, the over-all system has two predominant low-frequency time constants—one determined by the LC filter and the other by the switching frequency of the oscillator.

For high efficiency, the fixed frequency is made

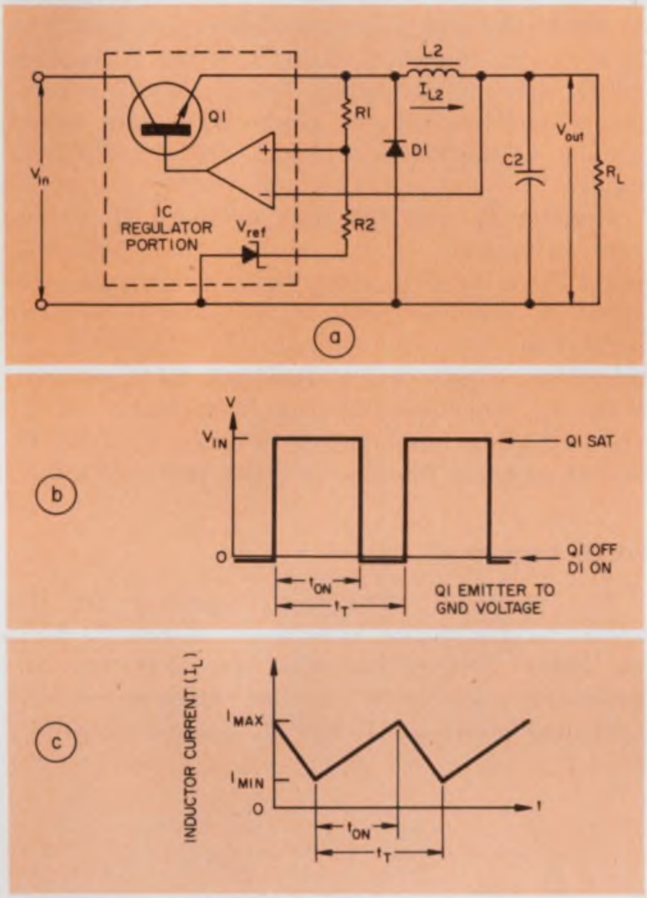


1. **Switching regulators** can be of the free-running type—in which the transistor operates at constant pulse width and variable frequency (a)—or of the fixed-frequency type, in which the transistor ON time varies (b). Efficiencies exceed those of conventional linear regulators.

low—about 10 to 20 kHz. Consequently it becomes extremely difficult to stabilize the fixed-frequency regulator and still achieve good attenuation of input ripple coupled with low output impedance.

In the free-running unit, both switching transitions are controlled by the sensed voltage. and the regulator cycles between an upper and a lower threshold of the output voltage; both the duty cycle and frequency are free to vary. Frequency is primarily a function of L_2, C_2 and threshold range, but it also varies with V_{in} and,

Eugene R. Hnatek, Director of Marketing, DCA Reliability Laboratories, 645 Clyde Ave., Mountain View, CA 94040.



2. **Basic elements of a switching regulator** consist of a transistor switch, a voltage reference, a comparator and an output filter (a). Regulation is achieved by variation of the relative on/off times of the switch (b). The load current varies as shown in "c."

to some extent, with the load current.

Since the free-running regulator's bandwidth is limited only by the rise and fall times of the various transistors in the circuit, response times run from 2 to 4 μs. Now, in any switching regulator, the output ripple depends on the frequency (higher frequency gives lower ripple but also lower efficiency) and its input voltage. Since the free-running regulator operates from its own ripple—which remains fairly constant—the frequency adjusts to the minimum necessary for the specified output ripple. The free-running circuit also operates well over a wide range of output load currents.

Duty cycle controls regulation

The basic free-running regulator contains a switch, a comparator, a voltage reference and a filter (Fig. 2). Regulation is achieved by control of the duty cycle of Q_1 with an op amp that compares the output voltage with a reference: ON time is increased in proportion to OFF time to raise the output level, or the ON time is decreased to lower the output level.

Transistor Q_1 is either on (saturated) or off, so that its power dissipation is minimized. Freewheeling, or commutating, diode D_1 conducts during the interval Q_1 is cut off, and thereby maintains current flow through inductor L_2. The diode also limits the induced voltage, $L_2\, di/dt$, whenever the transistor switch is turned off. When Q_1 turns on, the load current through L_2 increases according to:

$$V_{in} - V_{out} = L_2 \left(\frac{\Delta i_L}{t_{on}}\right). \qquad (1)$$

This current flows through the load and charges capacitor C_1.

When V_{out} reaches V_{ref}, the voltage comparator turns Q_1 off. The current through L_2 then decreases until D_1 is forward-biased. At this point the inductor current flows through D_1 and decreases at a rate given by:

$$V_{out} = L_2 \left(\frac{\Delta i_L}{t_{off}}\right). \qquad (2)$$

When the inductor current falls below the load current, C_1 begins to discharge and V_{out} decreases. When V_{out} decreases to slightly less than V_{ref}, the comparator turns Q_1 back on and the cycle repeats. The output voltage is given by

$$V_{out} = \frac{V_{in} \times t_{on}}{t_{on} + t_{off}}. \qquad (3)$$

In the circuit of Fig. 2, both Q_1 and D_1 must switch fast to minimize the losses that occur primarily during the transitions between saturation and cutoff—when semiconductor devices are resistive. The source voltage is selected to be two to five times greater than the output—within the voltage limitations of the input-circuit components, of course.

Choosing a commutating diode is a relatively simple task—mostly one of looking through data sheets. In addition to safely handling all peak currents, the diode must have a short recovery time, a small forward-voltage drop and a peak inverse-voltage rating that is at least twice as large as the input voltage.

The diode's recovery time is important because of its influence on output noise. After the switching transistor shuts off, the diode conducts, charging capacitor C_2. When Q_1 turns on again, D_1 is still in its conducting state and shorts Q_1 to ground for a little while. This double conduction dissipates power in both Q_1 and D_1 and is a prime source of noise.

Switching time: A prime spec

Selection of the switching transistor also involves looking through data sheets for sufficient peak and average current-handling capabilities, as well as a safe collector-emitter breakdown voltage rating. This voltage is generally 1.2 times larger than V_{in}. In addition, the transistor's saturation voltage should be as small as possible when the collector current is at a maximum.

Switching time is the most important transistor spec. Maximum efficiency is achieved when the transistor is either saturated or in cutoff. However, since transistors cannot switch instantaneously, a considerable amount of power (say 10%) can be dissipated during the switching time. To minimize the losses, keep switching times small compared with the period of the frequency.

The switching frequency should be high enough to keep the values of inductor L_2 and capacitor C_2 small, but not so high that Q_1 and D_1 become prohibitively expensive. Typical operating frequencies range from 10 to 50 kHz. Since the faster the switching, the greater the noise, this must be traded off against EMI requirements.

Note that the catch diode (and any bypass capacitance at the unregulated input) should be grounded separately from other parts of the circuit. This is because the diode carries large current transients, which can develop high voltage drops across even a short length of wire.

To select a core for L_2, look for materials with "soft" saturation characteristics. A core that saturates abruptly can cause excessive peak currents in the switching transistor if the output current goes high enough to bring the core close to saturation. A material such as powdered molybdenum-permalloy exhibits a gradual reduction in permeability with increasing current, yet the material retains excellent high-frequency characteristics.

Since the filter capacitor's ripple current will be quite high, the capacitor should be rated accordingly. Low dissipation factors and voltage ratings that exceed the dc circuit voltages are called for.

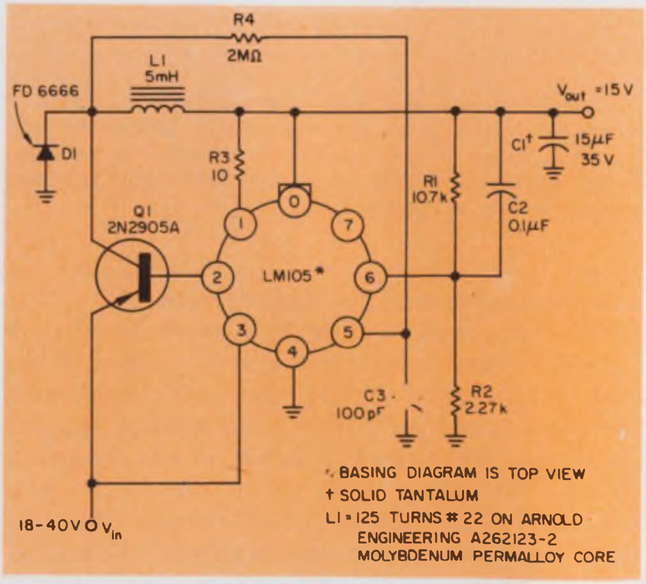
IC switching regulators include the comparison amplifier and pass transistor. Most also have an internal voltage reference, which may be supplemented in some applications by an external zener diode.

In the IC design of Fig. 3, an on-chip voltage reference is used, but an external pass transistor, Q_1, is added to get the current capability up to about 500 mA. The transistor is a pnp type so it can be connected directly to the IC booster output (an npn transistor would require a compound emitter-follower connection that would not be as sensitive to small voltage differentials).

Resistor R_3 sets the base drive of Q_1 to ensure saturation. If I_{max} is less than 500 mA, select R_3 to keep Q_1 from being overdriven. Resistor R_4 provides positive feedback to prevent oscillations in the comparator. Capacitor C_2 minimizes ripple by a feedback arrangement, while C_3 prevents the shunt capacitance of R_1 from coupling input spikes into the IC. Both Q_1 and D_1 are fast devices, so losses are kept low.

Which frequency?

The optimum switching frequency for IC switching regulators is between 10 and 50 kHz. At lower frequencies the core becomes unnecessarily large; at higher frequencies the switching losses in Q_1 and D_1 become excessive.



3. **An IC regulator can be used** as the basis for a switching design. Transistor Q_1 is added to increase the current-handling capability.

The output ripple of the regulator at the switching frequency is determined mainly by R_1. The peak-to-peak output ripple is nearly equal to the peak-to-peak voltage fed back to pin 5 of the LM105. Since the resistance measured at pin 5 is approximately 1000 Ω, this voltage will be

$$\Delta V_{ref} \cong 1000 \frac{V_{in}}{R_4}. \quad (4)$$

In practice, the ripple will be somewhat larger than that given by the equation. When the switching transistor shuts off, the current in the inductor will exceed that of the load so the output voltage will continue to rise above the value required to shut off the regulator.

It's important that the value of the inductor be large enough to keep the current through it from changing drastically during the switching cycle. Thus the switching transistor and the catch diode don't have to handle peak currents that are significantly larger than the average load current. The change in inductor current can be written as

$$\Delta i_L = \frac{V_{out}\, t_{off}}{L}. \quad (5)$$

For the peak current to be about 1.2 times the maximum load current, it is necessary that

$$L_1 = \frac{2.5\, V_{out}\, t_{off}}{(I_{out})\max}. \quad (6)$$

A value for t_{off} can be estimated from

$$t_{off} = (1/f)\,[1 - (V_{out}/V_{in})], \quad (7)$$

where f is the desired switching frequency and V_{in} is the nominal input voltage. The size of the output capacitor can now be determined from

$$C_1 = \left(\frac{V_{in} - V_{out}}{2L_1\, \Delta V_{out}}\right)\left(\frac{V_{out}}{fV_{in}}\right)^2, \quad (8)$$

where V_{out} is the peak-to-peak output ripple and V_{in} is the nominal input voltage.

Now determine if these component values just obtained give a satisfactory load-transient response. The overshoot of the regulator for increasing loads is

$$\Delta V_{out} = L_1\, (\Delta i_L)^2/(C_1\, V_{in} - V_{out}). \quad (9)$$

For decreasing the loads, the overshoot is

$$V_{out} = L_1\, (\Delta i_L)^2/(C_1\, V_{out}), \quad (10)$$

where i_L is the load-current transient. The recovery time, t_r, for increasing and decreasing loads is, respectively:

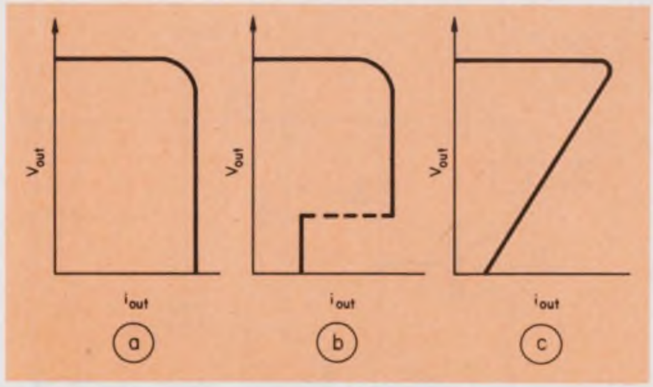
$$2L_1\, \Delta i_L/(V_{in} - V_{out}) \quad (11)$$

and

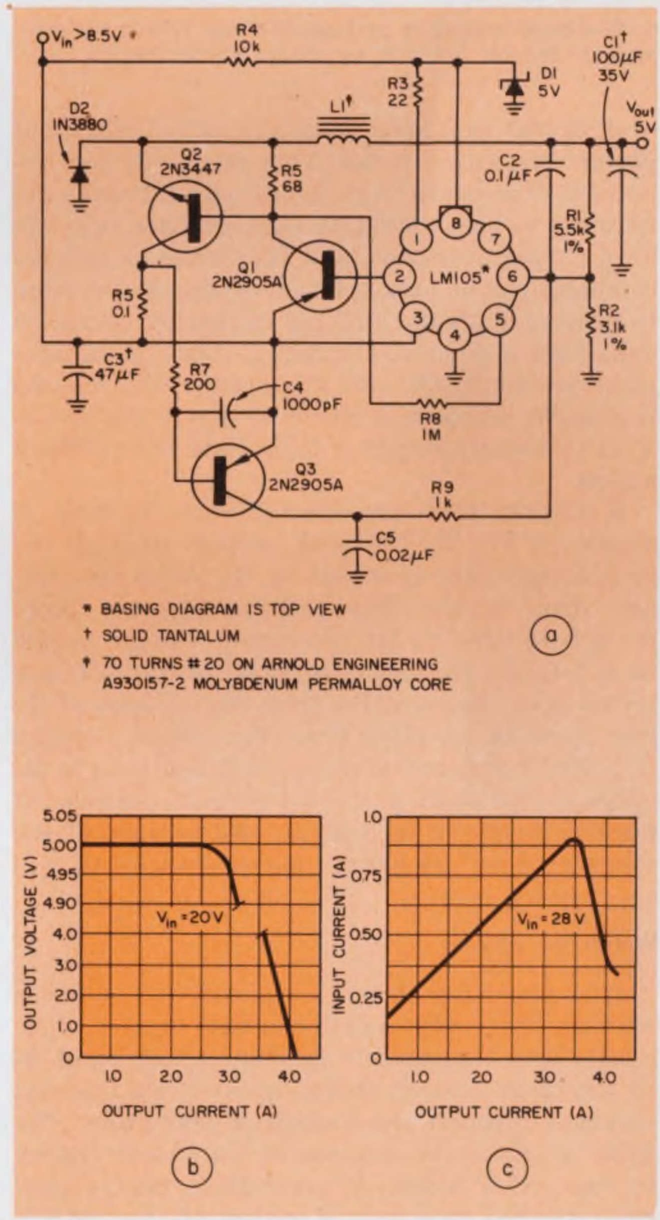
$$2L_1\, \Delta i_L/V_{out}. \quad (12)$$

In the circuits described previously the regulator is not protected from overloads or output shorts. Providing short-circuit protection is no simple problem, since it is necessary to keep the regulator switching when the output is shorted. Otherwise the dissipation will become excessive, even though the current is limited.

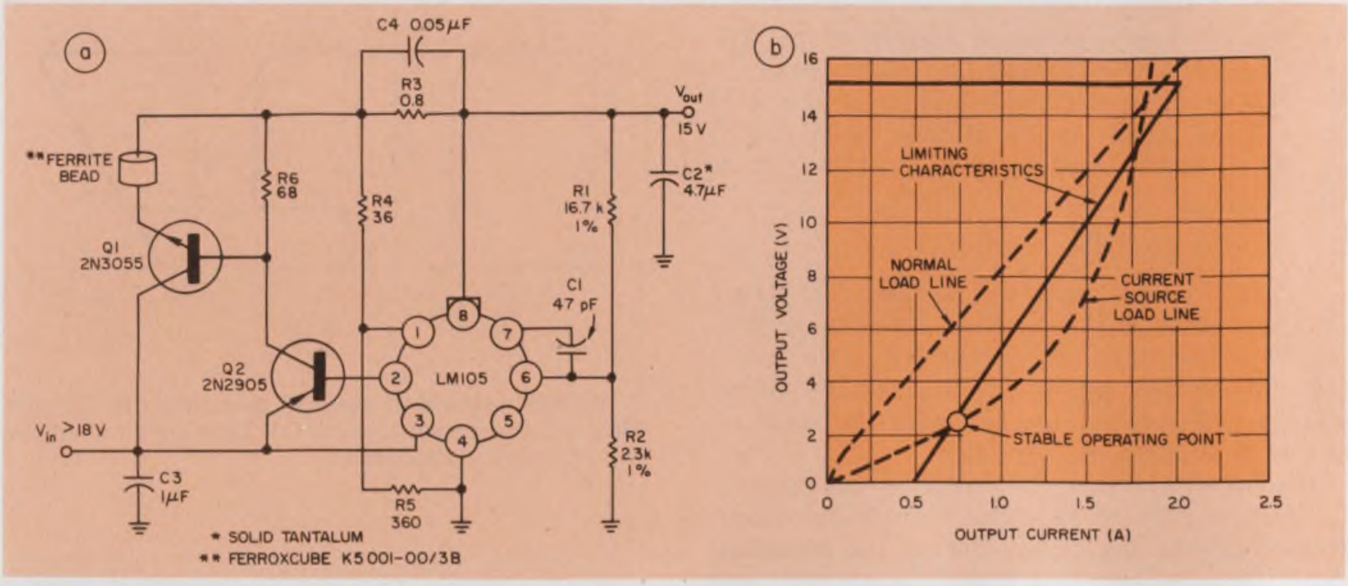
Fig. 4 illustrates the various methods of overload protection. Notice that with current limit or



4. **Various methods of overload protection** can be used. They include current limiting (a), short-circuit shutdown (b) and current foldback (c).



5. **Additional components can be added** externally to an IC regulator to provide current limiting (a). The achieved characteristics are shown in "b." When the circuit goes into limiting, the input current drops (c).



6. **Foldback limiting is perhaps the best choice** for overload protection (a), but as shown in the limiting characteristics, some loads should be avoided (b). Under special conditions, oscillations can occur.

overcurrent shutdown, load current is limited but power dissipation is not. This results in two important drawbacks: (1) Oversized heat sinks are required to keep operating temperatures at a safe level during overloads, and (2) Series or parallel combinations of pass transistors may be required to prevent potential failures caused by operation out of the safe area. Current foldback eliminates these problems. The only drawback of this method is a slight decrease in efficiency due to the 2-to-5-V drop usually required to initiate the foldback action.

A circuit that provides current limiting is shown in Fig. 5. The peak current through the switch transistor is sensed by R_6. When the voltage drop across this resistor becomes large enough to turn on Q_3, the output voltage begins to fall (since current is supplied to the feedback terminal of the regulator from the collector of Q_3, less must be supplied from the output through R_1). Furthermore the circuit will continue to oscillate—even with a shorted output—because of positive feedback through R_6 and because of the relatively long discharge time constant of C_2.

Watch for spikes

It is necessary to put a resistor, R_7, in series with the base of Q_3 to limit the base current. Also, a capacitor, C_4, prevents premature turn on of Q_3 by the large current spike—about twice the load current—through the switching transistor. The spike is caused by removal of the stored charge by the catch diode. A zener-diode bias supply must also be used on the output of the LM105, since current limiting won't work if the voltage at this point drops below about 1 V.

The current-limiting characteristics of this circuit are shown in Fig. 5b, and Fig. 5c shows how the average input current drops as the circuit goes into current limiting. With high-current regulators, the heat sink for the pass transistor must be made quite large—often inconveniently so—to handle the power dissipated under worst-case conditions. This problem can be overcome with foldback limiting, which—under overload conditions—forces the output current to decrease below the full-load value as the output voltage is pulled down. With this technique, the short-circuit current can be made a fraction of the full-load current.

Foldback is the best choice

A high-current regulator using foldback limiting is shown in Fig. 6. A second booster transistor, Q_1, has been added to provide a 2-A output without excessive dissipation in the LM105. The resistor across the emitter-base junction bleeds off any collector base leakage and establishes a minimum collector current for Q_2 to make the circuit easier to stabilize with light loads.

The foldback characteristic is produced with R_4 and R_5. The voltage across R_4 bucks out the voltage dropped across the current sense resistor, R_3. Therefore more voltage must be developed across R_3 before current limiting starts. After the output voltage begins to fall, the bucking voltage—proportional to the output voltage—is reduced. With the output shorted, the current drops to a value determined by the current-limit resistor and the current-limit sense voltage of the LM105.

Load currents up to 2 A are handled by the foldback circuit. Heavier loads will cause the output voltage to drop and reduce the available current. With a short at the output, the current is only 0.5 A. The value of R_3 is given by

$$R_3 = \frac{V_{lim}}{I_{sc}}, \qquad (13)$$

where V_{lim} is the current-limit sense voltage of the LM105 and I_{sc} is the design value of short-circuit current. Resistor R_5 is then obtained from

$$R_5 = \frac{V_{out} + V_{sense}}{I_{bleed} + I_{bias}}, \qquad (14)$$

where V_{out} is the regulated output voltage, V_{sense} is the maximum voltage across the current-limit resistor for 0.1% regulation, I_{bleed} is the preload current at the regulator output provided by R_5, and I_{bias} is the maximum current coming out of pin 1 of the LM105 under full-load conditions. I_{bias} equals 2 mA plus the worst-case base drive for the pnp booster transistor, Q_2. I_{bleed} should be made about 10 times greater than I_{bias}.

Finally, R_4 is given by

$$R_4 = \frac{I_{fl} R_3 - V_{sense}}{I_{bleed}}, \qquad (15)$$

where I_{fl} is the output current of the regulator at full load. It is recommended that a ferrite bead be strung on the emitter of the pass transistor to suppress oscillations under certain conditions (Fig. 6). It is advisable also to include C_4 across the current-limit resistor to prevent damage to the regulator from fast spikes.

In some applications the power dissipated in Q_2 becomes too great for a 2N2905 under worst-case conditions—even when a heat sink is used (as it should be). When dissipation is a problem, the 2N2905 can be replaced with a 2N3740. The ferrite bead and C_4 are not needed then because the 3740 has a lower cutoff frequency.

A further advantage of foldback limiting is that it sharpens the limiting characteristics of the IC. And the maximum output current is less sensitive to variations in the current-limit sense voltage: A 20% change in sense voltage will affect the trip current by only 5%. Also, the temperature sensitivity of the full-load current is reduced by a factor of four (but the short-circuit is not).

Though the voltage dropped across the sense resistor is larger with foldback limiting, the minimum input-output voltage differential is not increased above the 3 V specified for the LM105 —as long as the resistor drop is less than 2 V. The low differential can be traced to the low sense voltage of the IC.

Fig. 6 shows that foldback limiting can be used only with certain loads. When the load is predominantly a current source, the load line can intersect the foldback characteristic at a point at which the regulator can't come up to rated voltage, even without an overload. Fortunately most solid-state loads present no problem. However, the regulator must be designed with the load in mind. ■■


OEM Referral Program

Damper diodes: Do you need them? They serve a usetul purpose, but you might be able to do without them. Here's a test circuit that can help you decide.

Damper diodes. They're considered by some to be useless; by others, a necessary component in CRT horizontal-output circuits. To evaluate the need for this diode, consider these factors in your analysis: drive requirements, dissipation, device rating, efficiency and cost.

You can build a test circuit that can simulate most common horizontal-output sections. This circuit can help you determine when to use the damper diode.

The horizontal output stage of a CRT display provides an almost linear ramp of current through the CRT scan coils during the trace period. This trace is followed by a rapid reversal of current during retrace and a high (retrace) voltage pulse across the collector-emitter terminals of the output transistor.

The use of high-voltage transistors with damper diodes in the horizontal output stage is common today. The inherent problems of switching such transistors, and the circuit techniques to control them, have been described in many papers.[1, 2, 3]

If a damper diode is not used, the transistor operates in an inverted mode to pass the current. During the efficiency period the transistor passes current through a forward-biased collector-base junction; the charge stored contributes to the total collector charge at the end of scan. Thus for optimum circuit operation, the drive conditions to the output device will be different from those needed when the damper diode is used.

In comparison with the total circulating voltamperes in scanning coils, the dissipated energy of the horizontal output circuit is small. The current in the coils has a large ac component. And during the first part of the scan, the current in the coils is negative. When a damper diode is used in the circuit, it passes the negative current until the transistor conducts.

The component values in the test circuit (Fig. 1) are similar to those found in television horizontal-output sections.

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The components L_1, L_2, C_3 and C_4 represent the scanning coils, high-voltage transformer and tuning capacitance. Resistor R_4 represents the total circuit losses during scan. The damper diode, D_1, can be put into the circuit or removed to run the different tests. A pulse generator can be used to evaluate different pulse widths.

How the test circuit works

Transistor Q_1 is switched on by the pulse generator, and the transformer supplies a pulse of current to the base of Q_2. Resistor R_1 limits the average primary current of the transformer, and components R_2 and C_1 damp the collector voltage overswing as Q_1 switches off. This damping shapes the leading edge of the base current in Q_2. The base current produces a negative voltage in series with the secondary voltage of the driver transformer.

The switching action of the high-voltage transistors must be controlled accurately.[2] Inductance L_B, which represents the total secondary circuit inductance and may be all or part of the secondary leakage inductance of the transformer, is included to achieve the control. It does this by slowing the rate of fall of the base current, dI_B/dt, of Q_2.

This control results from the following: At the instant of turn-off of the secondary voltage, inductor L_B presents a high reactance in the base circuit and thus opposes any abrupt change in I_B. The energy stored in L_B during the on period of Q_2 maintains I_B. Inductor L_B has a voltage of $V_{off} + V_{BE(on)}$ across it, which defines the rate of change, dI_B/dt, of I_B.

The base current falls at a constant rate through zero to a value of I_{Boff}, which depends on the type of transistor and its operating conditions. When $I_B = I_{Boff}$ zero current point, the collector current is turned off. The energy stored in I_B (which is equal to $1/2L_B\,I_B{}^2{}_{off}$) causes the base-emitter voltage to swing negative until it is limited by the breakdown voltage, BV_{EBO}, of the device. Inductor L_B now has a voltage $(V_{off} - BV_{EBO})$ across it. This voltage defines a rate of rise of I_B towards zero. When I_B reaches zero, V_{BE} equals

V_{off} and I_B remains at zero.

Let's take a look at how the test circuit operates with the damper diode connected. Typical waveforms (Fig. 2) produced by the circuit simulate those of a TV horizontal output section. Fig. 2a shows the collector-emitter voltage, V_{CE}, of the output transistor, Q_2. You can see that the retrace pulse is 12 μs wide and almost 1000 V in amplitude. The central dip clearly shows the effect of third harmonic tuning.

Using the test circuit

The voltage across the output transistor at the end of the retrace period is clamped at the negative drop across the damper diode during conduction—approximately 1 V. When base current is re-established, the transistor conducts first through the forward-biased collector-base junction. After the collector current passes through zero, the transistor conducts normally in a forward direction as the voltage rises to $V_{CE\,sat}$.

Waveform 2 (Fig. 2b) shows the collector current of output transistor Q_2. This current is negative at the beginning of base drive. The collector current rises to a peak value of 3.5 A—a value defined by L_1, the power supply, dc loading and the scan time. At the start of base-current turn-off, the collector current continues to rise until the decreasing amount of charge stored in the collector can no longer maintain conduction. At that point the current starts to fall, and the collector voltage rises.

The base current of the output transistor (Fig. 2c) reaches a maximum value of 2 A before it falls linearly to −2 A under the control of L_B. The small glitch in both the base and collector currents at the end of retrace is caused by the charging of the stray reactances of the damper diode and output transistor before the diode conducts the scan current.

The base-emitter voltage of the output transistor (Fig. 2d) is approximately 1 V during conduction. When the base current reaches its maximum negative value, $I_{B\,off}$, the voltage V_{BE} reverses and the base-emitter junction goes into breakdown. After the base current has reached zero, the voltage rises to V_{off}. The transient ringing is due to oscillations in the base circuit as the transistor comes out of breakdown.

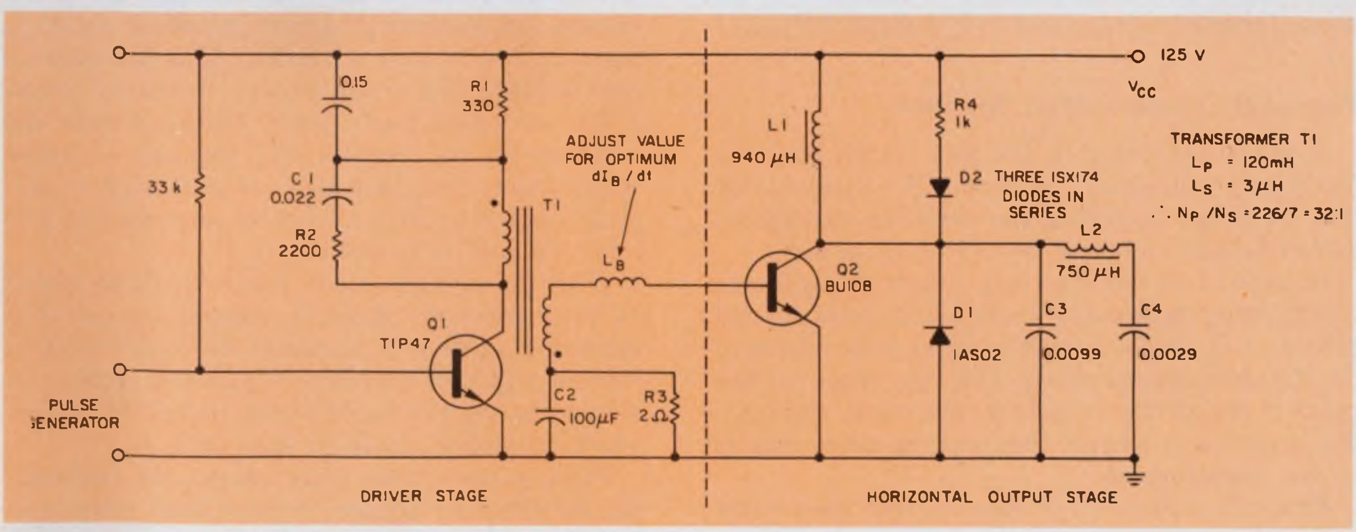
Now let's remove the damping diode and compare the different waveforms. The switching action of the circuit is basically the same, and there is almost no change in the retrace voltage. After retrace, the collector-emitter voltage is not clamped by the damper diode but limited by breakdown voltage of the base-emitter diode, BV_{EBO}.

Typical transistors used for this application include the BU105, BU108, BU308, BUY71 and the TIP550 to TIP553. These have specially designed base-emitter junctions that can operate reliably in breakdown during the efficiency period.

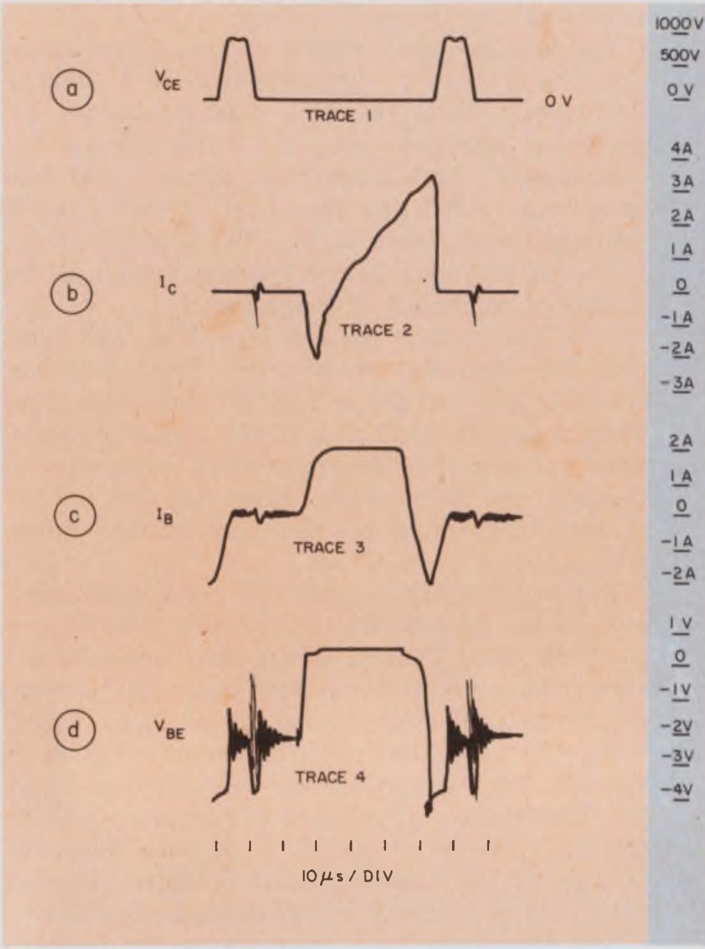
Fig. 3b shows the collector current that flows through the forward-biased collector-base junction immediately after retrace. Just after retrace, the base current (Fig. 3c) is positive, since the voltage at the base terminal is more negative than that of the driver transformer secondary.

The transistor thus operates in an inverted mode with a gain of I_E/I_B. This inverse operation reduces the clamping voltage on the collector-emitter terminals and reduces the power dissipation. For transistors with high inverse gains, the reducing voltage may rise toward $V_{off} + V_f$, where V_f is the base-collector forward voltage.

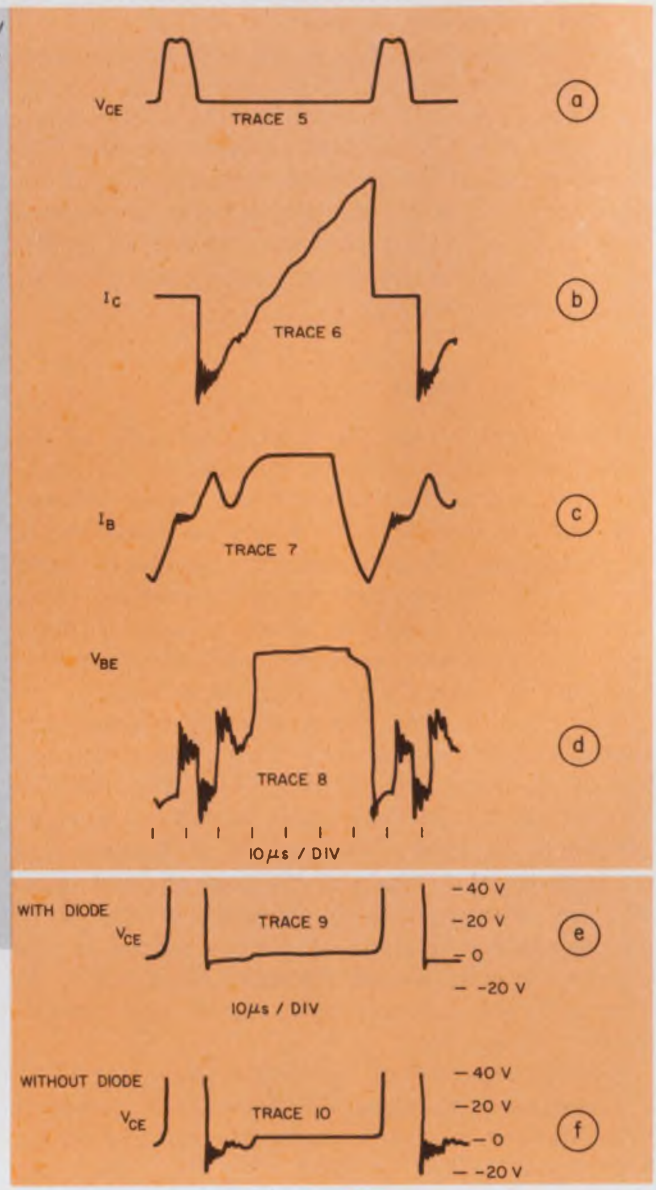
The waveform in Fig. 3d shows the base-emitter voltage that returns to BV_{EBO} after retrace. The voltage then drops in magnitude during the efficiency period. The last two waveforms (Fig.



1. **A test circuit can simulate** the horizontal output stage of most CRT display systems. This can help evaluate the need for a damper diode connected across the horizontal output transistor.



2. **Typical horizontal output traces,** taken at various points in the test circuit, are used as a reference for circuit modifications to optimize performance.



3. **Without the damper diode,** these scope traces (a to d) can be compared with those in Fig. 2. The last two traces (e and f) show the collector-emitter voltages of the circuit with and without the damper diode.

3e, 3f) show the collector-emitter voltage at the end of the retrace with and without the damper diode. In Fig. 3e the voltage is clamped to the diode forward voltage and in Fig. 3f to BV_{EBO}.

Pulse-width changes affect operation

A pulse generator in the test circuit switches the driver transistor. In most CRT displays the line oscillator, locked to the incoming synchronization pulses, switches the driver transistor.

In both cases the inverting action of the driver transformer causes the width of the base-current pulses in Q_2 to decrease when the pulse width of the driver stage increases, and vice versa. As the pulse to the driver transistor increases, the transistor conducts longer, thus storing more energy in the transformer.

The rate of turn-off of base current also varies with changes in drive pulse width to transistor Q_1 and component values.

When a damper diode is used in the circuit, the effect of the driver pulse width on the operation is considerable. As the pulse width of I_B increases, the horizontal output transistor conducts more in the reverse direction. This increase in conduction stores more charge in the collector. Since the amount of stored charge affects the optimum dI_B/dt needed, the increase in pulse width means that the transistor is no longer operating optimally. Also it will be more sensitive to small changes in I_B and dI_B/dt.

With the damper diode removed, there aren't as many problems. Since the output transistor is operating as its own damper, the total scanning current will flow through it, and the amount of stored charge will be constant, except for a few small variations caused by base current.

Thus, without the damper diode, the optimum dI_B/dt will hold almost constant and variations in pulse width will have little effect on the output transistor characteristics.

Once the diode is removed, some of the other circuit parameters will change. Consider device dissipation. The total transistor power dissipation should be a minimum at high temperatures, so that at lower temperatures the power dissipation can increase.[2] Typical power-dissipation curves are shown in Fig. 4a.

A poor choice, for example, would be to optimize the transistor family at the low temperature extreme and operate the devices at the value of dI_B/dt noted in Fig. 4a as point 1. In this example the case temperature would rise because of thermal radiation from other components and the device's dissipation would also rise to point 2. However, if the optimization had taken place at high temperatures, the transistor would operate at the level indicated by point 3.

At low temperatures the device would not dissipate optimum power, but as the case temperature increased, the power dissipation would approach optimum (point 4). This power level is less than the value at point 2; thus the internal runaway problem is practically eliminated.

Optimum-power measurements must allow for a ±20% tolerance to account for variations in voltages and currents. This may also mean that the circuit will work with higher power losses at low temperatures but that the circuit parameters will converge to optimum as the temperature rises.

The variation of dissipation vs. pulse width of the drive current for a typical transistor can be plotted with and without the damper diode (Fig. 4b). In each case dI_B/dt is set to optimum at a particular pulse width. Although dissipation at optimum increases when the damper diode is removed, the variation in P_D with pulse width is much smaller.

The test results compared

Six parameters of the horizontal output transistor can be measured in the test circuit: collector current, base current, rate of change of base current, storage time, fall time and power dissipation. All these are measured first with the damper diode in the circuit and then without. The optimum dI_B/dt is set at a pulse width of 29 μs. Three sets of measurements are taken: First with the circuit optimized and the damper diode in the circuit; second, with the same circuit but with the damper diode removed; and, third, with the dI_B/dt adjusted to optimize power dissipation again in the output transistor with the damper diode removed.

The results of these tests are shown in the table. When the diode is removed and the rest of the circuit unaltered, changes in three parameters can immediately be noticed.

The changes in $I_{B\,(end)}$ and dI_B/dt occur because of the following: Since the efficiency action of the transistor draws forward base current, the average secondary current increases, thus increasing the voltage across C_2 and R_3. This adds to the off voltage and subtracts from the on voltage of V_{BE}, thus increasing dI_B/dt and reducing $I_{B\,(end)}$.

The increase in dissipation comes from the increased efficiency action of the transistor. Some increase is also due to large switching losses caused by deviation from optimum operation.

The third column in the table shows the values of parameters after they have been optimized again for minimum power. To achieve optimum operation, dI_B/dt must be reduced, since larger amounts of charge are stored in the transistor. The dissipation, although less than that in the second column, is 40% higher than when a damper diode is used. However, this increase in dissipation is still acceptable. Let's see why.

If the optimization process for the whole spread of transistors is done at a case temperature of, say, 70 C and the worst-case dissipation is found to be 4 W, reliable operation of the transistor, if it is mounted on a heat sink with a thermal resistance of 4 C/W, will be guaranteed up to an internal board ambient of $70 - (4 \times 4) = 54$ C.

Consequences of circuit changes

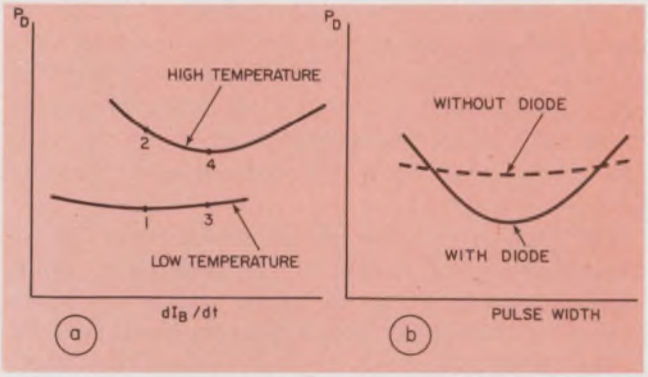
With the same conditions, removal of the damper diode might cause the power dissipation to rise to about 7 W. Now the safe board temperature decreases to $70 - (4 \times 7) = 42$ C. If, because of high external ambients, the limit of the board must be higher, two options are available.

1. Reduce the heat-sink thermal resistance by increasing the heat-sink size. For instance, if thermal resistance drops to 3 C/W, a maximum board temperature of $70 - (3 \times 7) = 49$ C would be permitted.

An approximate formula for the thermal resistance of sheet aluminum is given by $R_\theta = 22/L$, where L (in inches) equals the $\sqrt{\text{surface area}}$. Thus, if the thermal resistance of the heat sink must be reduced by 1 C/W, the surface area of the heat sink must be more than doubled.

2. You can also optimize the transistor again at a higher case temperature. For example, if the new case temperature is 85 C, the device family might have a higher worst-case dissipation of, say, 8.5 W. The maximum safe board temperature (with a 4 C/W thermal resistance) would be $85 - (8.5 \times 4) = 51$ C. A compromise between the two options is also possible—a slight increase in heat-sink size and a lower temperature for optimization again.

The increase in case temperature of the hori-



4. **Power-dissipation curves of the output transistors** are useful in determining safe operating levels for the circuit. Worst-case calculations provide the best guidelines for reliability and stress.

Parameter comparison with and without the damper diode

Parameter	Optimum with diode	Diode removed	Optimum without diode
I_C (A)	3.4	3.4	3.4
$I_{B(end)}$ (A)	2	1.9	2
dI_B/dt (A/μs)	0.46	0.48	0.35
t_s (μs)	8.7	8.8	11.2
t_f (ns)	700	950	800
P_D (W)	3	4.5	4.2

With a pulse width of 33 μs with the diode connected, the device dissipation rose to 3.3 W.

zontal output transistor will have no effect on reliability, provided that the drive conditions to the transistor are optimized for the worst-case dissipation and the board ambient is not allowed to rise above that guaranteed for maximum case temperature.

The linearity of the scanning beam will change when the damper diode is removed. This is because of the difference in voltage across the coils during the efficiency period, when the damper diode is used and when the transistor operates as the diode. The change in voltage is small, and the increase in nonlinearity will be less than 2%. This amount of nonlinearity can be compensated by an adjustment of the CRT linearity coil.

There are also possible cost-reduction benefits when you remove the damper diode. An obvious starting point is the diode itself. To reduce some of the heat problems, you can increase the heat-sink size or use a larger or better designed cabinet for increased air venting. However, with a well-designed output stage an increase in case temperature can be tolerated. ■■

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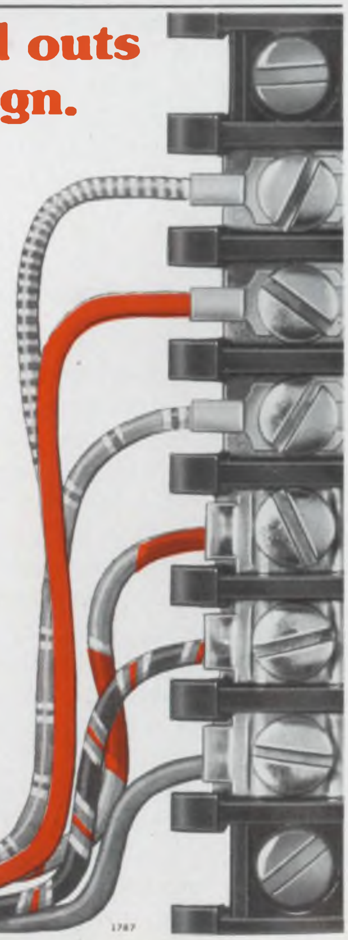

INFORMATION RETRIEVAL NUMBER 36

Beware of CMOS-switch failure modes.

Without extra special care, some analog-switch ICs can latch up even under normal operating conditions.

You've just bought some CMOS analog switches and connected them into your system. Now you turn on the power and observe that the system malfunctions or the new chips burn up. What happened?

Chances are that it wasn't anything you did wrong. Rather, there was little that you could have done right.

Conventional CMOS-switch structures inherently contain parasitic SCRs that can give rise to latch-up conditions in a wide number of cases. To minimize the problem, some manufacturers recommend such remedies as the turning on of power supplies in special sequences, the use of external components, or the avoidance of transients. But for a host of applications—especially industrial and military—these recommendations can't be applied easily.

The ultimate solution lies in improved fabrication techniques that avoid the detrimental parisitics altogether. Fortunately manufacturers are providing the answer with such processes as dielectric isolation (Harris Semiconductor, Melbourne, FL, among others) and floating body (Intersil, Cupertino, CA).

The cause of the problem

A simplified schematic of one channel of a typical CMOS analog switch appears in Fig. 1a. The basic transmission gate consists of an n and p-channel MOSFET. The two are connected in parallel and their gates are driven out of phase by 180°. This technique tends to linearize ON resistance over a wide signal-voltage range. And it makes the resistance virtually constant and only slightly dependent on input-signal amplitude.

In the physical equivalent of the basic gate (Fig. 1b), note that parasitic transistors are inherent in CMOS processing. The n-channel device, for example, has these transistors: a vertical npn, a horizontal npn and the collector part of a lateral pnp.

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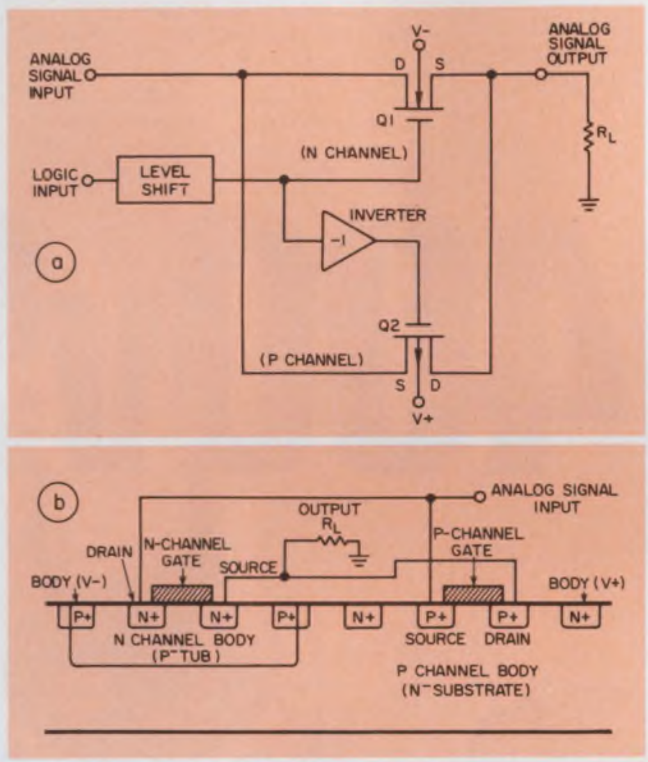


1. **A typical CMOS analog switch** employs an n and p-channel MOSFET in parallel (a). The gate's cross-section (b) contains three parasitic transistors that are inherent in conventional CMOS processing.

The vertical npn results from either a source or drain acting as an emitter. The body acts as a base; and the n-type substrate, as a collector. The horizontal npn comes from either a source or drain acting as an emitter, the p-tub forming a base, and the source or drain providing a collector. Finally the p-type tub acts as a collector of the lateral pnp formed by the proximity of the complementary pair.

Similarly for the p-channel device, a lateral pnp transistor exists in two different directions. In one direction the source or drain acts as an emitter, the n-substrate as a base, and the p-tub as the collector. In another direction there is a horizontal pnp for which a source or drain acts as an emitter, the n-substrate forms a base, and the source or drain provides a collector.

The main culprits causing the latch-up problem are the vertical npn and the lateral pnp (Fig. 2). Note that the base of the lateral pnp is simultaneously the substrate and the collector of the vertical npn; these points are tied electrically. Also the base of the npn, the p-tub, is the collector of the pnp.

This little transistor pair forms an SCR with the characteristics shown in Fig. 2b. It looks like a dual-gate SCR, because either the base of the npn or the pnp can trigger it.

How bad can the problem get?

As long as the plus and minus 15-V supplies are on, no SCR action is possible (Fig. 3). Both emitter-to-base junctions of the npn and the pnp transistors are reverse biased by about 5 V or more.

But let's say you are switching ±10 V—any value above a couple of volts will do—and the 15-V supply is turned off by a glitch, or spike. Since the internal impedance of most references is low, the base of the pnp then looks like a ground. And the pnp becomes forward biased and starts to conduct current.

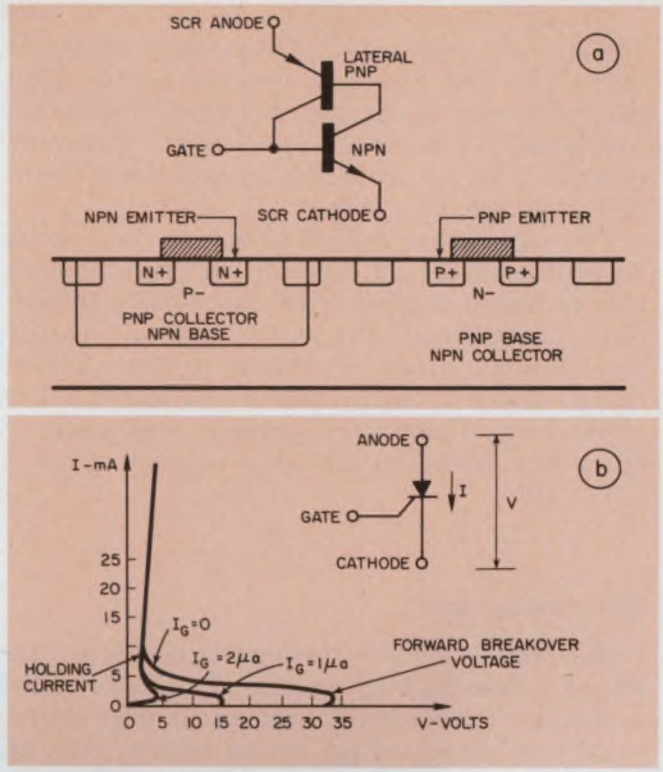
The circuit will latch if the beta product of the npn and pnp devices equals or exceeds 1.0. Then V_{out} will be locked at approximately the signal-input value less 1.5 V—a V_{BE} drop plus a V_{CE} drop. The only limit on the current drawn will be the value of R_L and the current-carrying capacity of the reference analog input.

The only way to unlatch the circuit is to remove the input-signal voltage; you have to reduce the current drawn to a level below the holding current of the SCR. In this case the current is limited by the load resistor and the worst result probably will be a system malfunction. This case doesn't lead to a destructive latch-up.

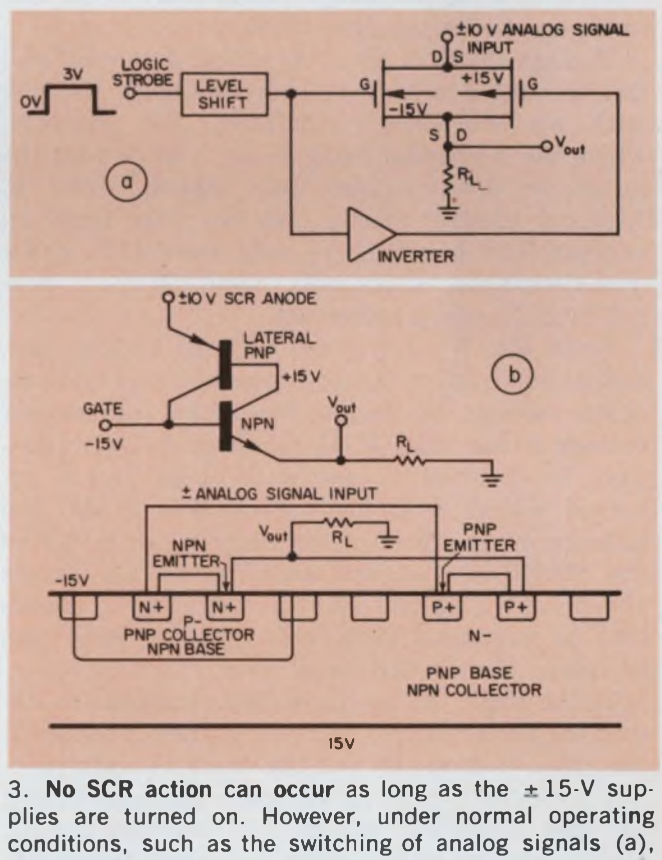
Another nondestructive latch-up can occur even though the 15-V supply is rock steady, never has any glitches and cannot be turned off while an analog signal is present. An overvoltage spike in the signal input can boost the signal level over 15.7 V. Then the pnp becomes forward biased again, and the latch-up returns.

Fortunately the current is limited, so only a malfunction occurs. Suppose, however, that you have a low value of R_L, or you are just driving a capacitive load. Then peak currents, which follow the formula $i = C \times dV/dt$, can become high enough to blow the metal interconnects on the chip for a destructive latch-up.

While the pnp stage has been selected as the trigger for the SCR, you can just as easily reverse the roles and the analog-signal voltage polarity. Now the npn stage becomes the trigger for the action, and the −15 V supply is the key. Here again, an overvoltage spike of −15.7 V can start the SCR action.



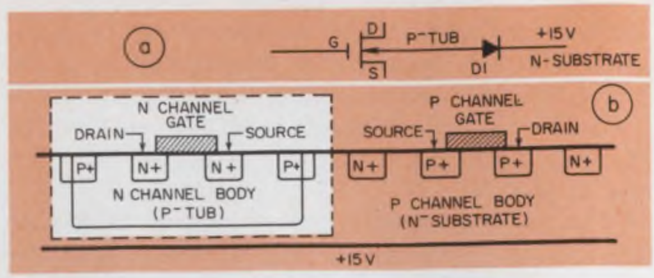
2. **A parasitic SCR results** from the combination of vertical and horizontal npn transistors with a lateral pnp (a). Either the base of the npn or pnp can trigger the dual-gate SCR and the parasitic device has the characteristic curve shown in "b."



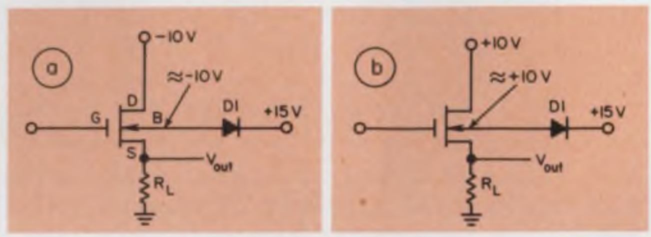
3. **No SCR action can occur** as long as the ±15-V supplies are turned on. However, under normal operating conditions, such as the switching of analog signals (a), the circuit can latch up (b). A sufficiently high load resistance, R_L, can avoid destructively high currents.

A complete elimination of the parasitic SCR action—by a reduction of the npn-pnp beta product to less than 1.0—runs into this hurdle. Typical npn betas run in the 100-to-1000 range, and pnp betas run in the 0.1-to-2.0 range. Hence the product is in the 10-to-2000 range—ideal for an SCR, but not for a gate.

The pnp lateral beta depends on the spacing between emitter and collector; increased separation of the p-channel from the n-channel helps reduce beta. Practically, with 2-to-5-mil spacing, the lateral pnp can be reduced to the 0.1-to-0.5 range. The real stopper has to be the reduction of the vertical npn beta; a maximum of about 1.5 must be obtained to achieve a product of $0.5 \times 1.5 = 0.75$.



4. **The floating-body technique eliminates the parasitic SCR.** The technique uses back-to-back diodes that electrically float the body. The diode in series with the n-channel MOSFET body results automatically by use of the p-tub-to-substrate junction (b).



5. **The back-to-back diodes don't significantly affect** body-to-source or body-to-drain voltage, even though the analog input may be −10 V (a) or +10 V (b). For both cases the voltages referenced to body are both about 0 V.

Why floating body?

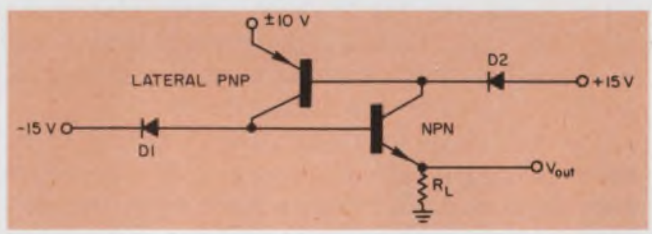
One way to achieve these goals is through the use of a floating-body process. The name refers to the fact that MOSFET bodies can float electrically, so no direct voltage can be applied (Fig. 4). Instead, the body voltage comes through a back-to-back diode voltage divider.

Diode D_1 comes from the junction formed by the p-tub and n-substrate. It results automatically, if no connection is made to the body of the n-channel device. A back-to-back-diode structure forms because of source-to-body or drain-to-body junctions of the MOSFET. Thus there is no way to forward-bias the MOSFET.

Though the SCR action is killed, one could still zap the drain-to-body or source-to-body junction with an overvoltage condition. For example, when the n-channel body is at −15 V and the source or drain voltage goes beyond −15.7 V, forward biasing starts, and the only limit on current flow is substrate body resistance. Since this resistance equals only about 50 Ω, it does not provide much protection.

From Fig. 5 you can see why the back-to-back diodes don't affect the body-to-source or body-to-drain voltage. As long as the drain (or source) voltage is less than 15 V, the drain-to-body junction is forward biased and diode D_1 is reversed biased. Since the current flow is only the leakage of D_1, there is virtually no drop across the MOSFET junction and V_{BD} or V_{BS} equals about 0 V. This condition is particularly important to n-channel MOSFETs, because body bias increases circuit threshold.

If the drain or source voltage happens to exceed the power supply (an overvoltage condition), the roles of diode D_1 and the drain-to-body junction reverse. Diode D_1 becomes forward biased and the MOSFET junction is reversed biased. No harmful condition results as long as the breakdown of the MOSFET junction is not exceeded.



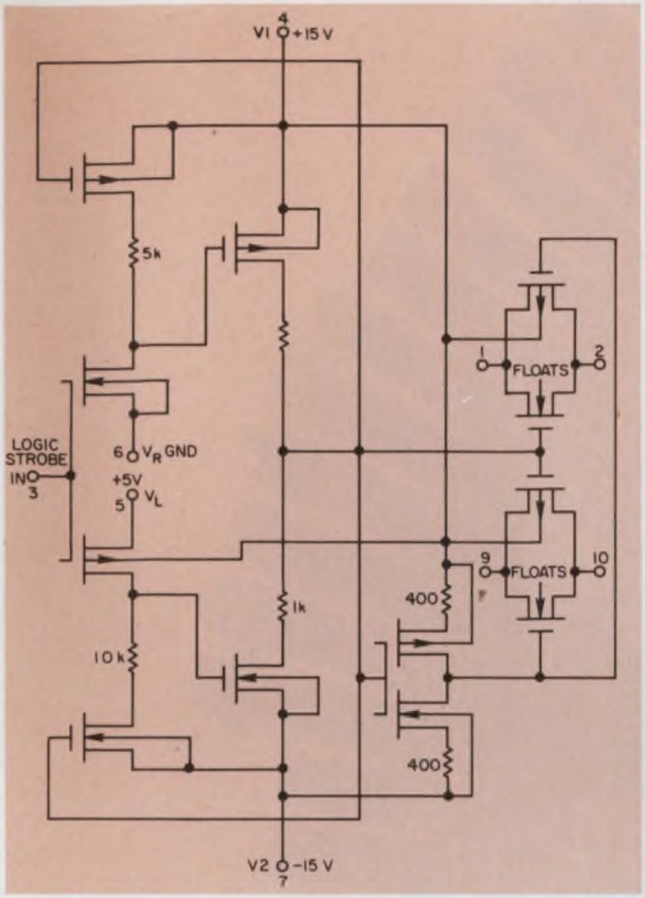
6. **The diodes introduced by the floating-body technique** allow either the positive or negative 15-V supply to be turned off without latch up.

The back-to-back diode structure provides complete circuit protection up to plus and minus 25-V overvoltage.

In addition, if either the plus or minus 15-V supply turns off for any reason, no forward-bias condition can exist (Fig. 6). Diodes D_1 and D_2 form back-to-back combinations with respective emitter-to-base diodes.

The first products to use the floating-body process are Intersil's IH5040 family of analog gates. The family consists of spst, spdt, dpst, dpdt, 4pst, and dual versions of each. Maximum ON resistance is 75 Ω for any input signal between −11 and +11 V. Also the entire line is TTL as well as CMOS compatible.

A typical schematic—for an spdt switch—in the IH5040 series appears in Fig. 7. The driver part of the schematic is always the same for all members of the family; only the output connection differs from unit to unit.



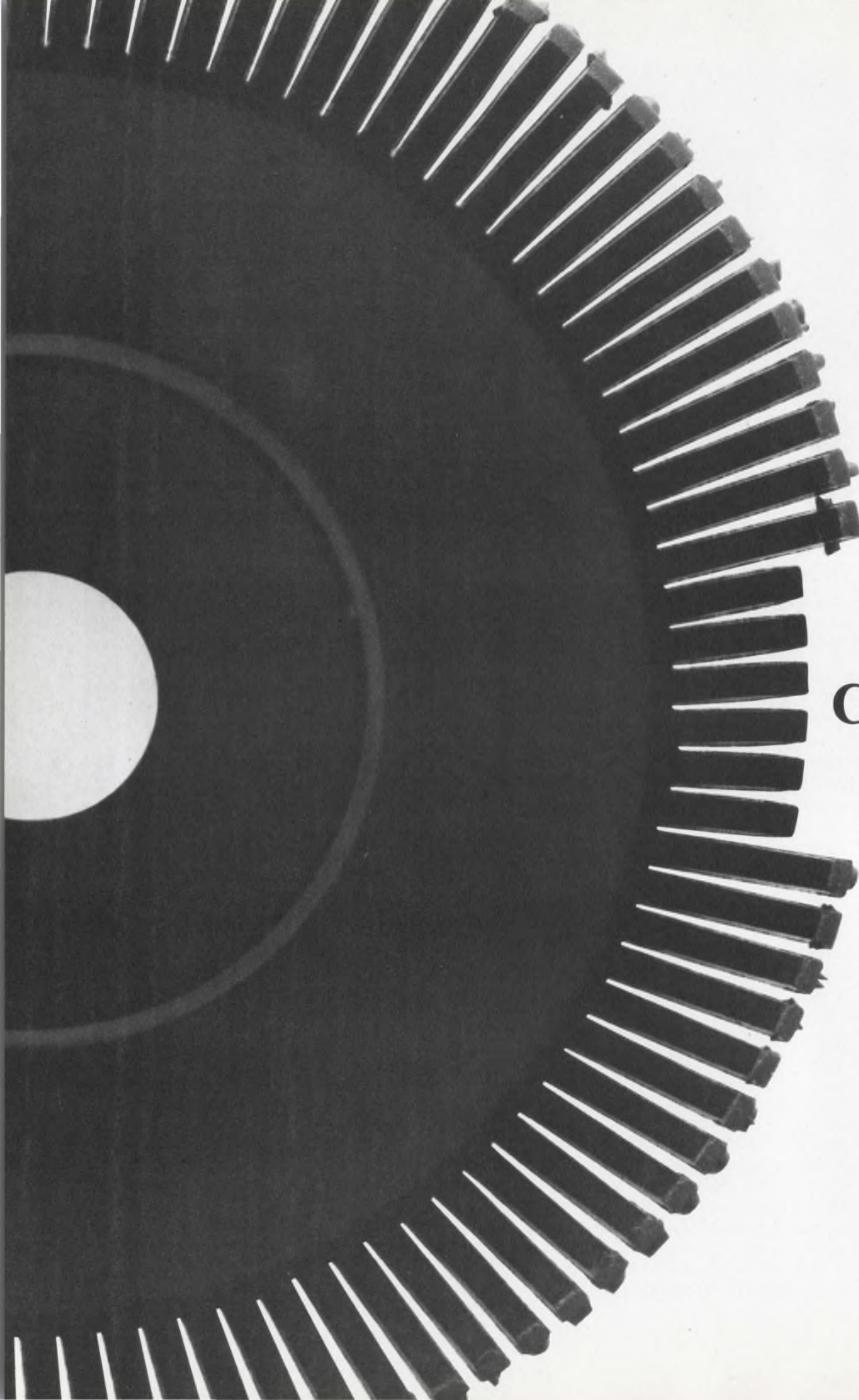
7. **A typical driver gate using floating body,** Intersil's IH5042, employs standard 0-to-3-V TTL levels to change the switch state.

All circuits have a beta product (for the vertical npn and the lateral pnp) that doesn't exceed 0.1; typically, it's 0.01. Therefore no latch up is possible. The signal can be present while any power supply is turned off in any sequence. Also you can exceed the signal-input level up to ±25-V overvoltage with 15-V supplies.

The tradeoffs

Of course, increased reliability has required some sacrifice in other areas. One disadvantage of the process is that OFF leakage currents are higher than in a conventional CMOS process. They are spec'd at 5 nA max, compared with typical values of 1 to 2 nA in conventional circuits.

Another disadvantage is that the overvoltage protection scheme limits the pk-pk voltage that the switch can handle. CMOS can usually switch an input signal that reaches the power-supply value. In applications of the IH5040 family where each side of the switch goes to the opposite polarities, pk-pk handling capability is spec'd at 22-V pk-pk minimum, and at about 26-V pk-pk typical. Thus you cannot switch 30-V pk-pk with ±15-V supplies, as you can with other CMOS versions. ■■



Carousel:

Test that SCR turn-off time if you would forestall circuit burnout. Doing the job yourself will guarantee that the device is fast enough.

If you are designing silicon controlled rectifiers into power-control circuits that operate above 400 Hz, make sure the SCRs turn off fast enough. If the turn-off time is too long, circuits may fail.

What you need is a good, easy way to test the SCRs for turn-off time. This testing can be done by the device manufacturer—but you'll pay for it. Turn-off time is one of the most difficult parameters to measure routinely. A fairly complex test circuit and a thorough understanding of electrical and thermal measurement techniques are required.

Most SCR manufacturers provide detailed turn-off test circuits in their handbooks or application notes. You can build your own from one of these.

SCRs are easy to use in equipment like series inverters, parallel inverters and choppers. They can be turned on by their control element—the gate—at any time. Unlike transistors, though, they can't be turned off just by removal of the voltage from the gate, as you turn off a transistor by removing the voltage at the base. SCRs need special turn-off circuitry. Without this, they lose their ability to act as control elements.

What is SCR turn-off?

The turn-off time of an SCR, t_q, is defined as the minimum time (in microseconds) following the end of forward current and until the SCR can again block a reapplied forward voltage. Initially an SCR blocks a forward voltage, V_{DRM}, at an operating junction temperature T_j (Fig. 1). A gate signal to the device starts the forward current flow. This current increases at a rate di_f/dt (amps/microsecond) until it reaches a peak of I_{TM}.

The peak current is maintained until it is forced to decrease at a rate of di_r/dt. Turn-off time is measured from the point at which the forward current flow drops through zero. After the current passes through zero, it continues its negative flow until it reaches a value $I_{RM\ (REC)}$. Then it goes back to zero during the period known as reverse recovery (t_{rr}).

This reverse-voltage period lets the SCR regain its internal charge equilibrium. The equilibrium is necessary, of course, for successful turn-off. At the end of the reverse-voltage period, the forward voltage, V_{DRM}, can be reapplied.

The SCR turn-off waveforms under test conditions are seldom the same as when the devices are operating in practical circuits. Here are common reasons why this is so:

- Increased di_f/dt and/or I_{TM} causes higher operating junction temperatures and thus longer turn-off times.
- Increased di_r/dt causes larger $I_{RM\ (REC)}$ losses and thus longer turn-off times.
- Increased reapplied dv/dt causes longer turn-off times.
- Reduced reverse voltages (such as when SCRs are clamped with inverse diodes) also cause longer turn-off times.
- Reduced operating temperatures can help shorten the SCR turn-off time.

Measuring the turn-off time

Let's simplify a manufacturer's test circuit to ease understanding of what turn-off time is and how it affects intended circuit performance (Fig. 2a). Section 1 supplies the forward current to the SCR under test. This current provides an independently controlled di_f/dt and I_{TM}. When the SCR triggers at time t_1, the forward current flow, I_{TM}, starts.

In Section 2 the triggering of SCR_2 at time t_2 starts the di_r/dt portion of the forward current. The reverse voltage to the test SCR is supplied by supply V_2. Diode D_1 in Section 3 is the most critical component in the test circuit. Its function is to isolate the forward current and reverse voltage supplies from the reapplied dv/dt supply (Section 4). Poor selection of this diode will produce improper voltage waveforms. This includes reducing the rate of the reapplied dv/dt as time t_3 decreases or the reverse voltage mag-

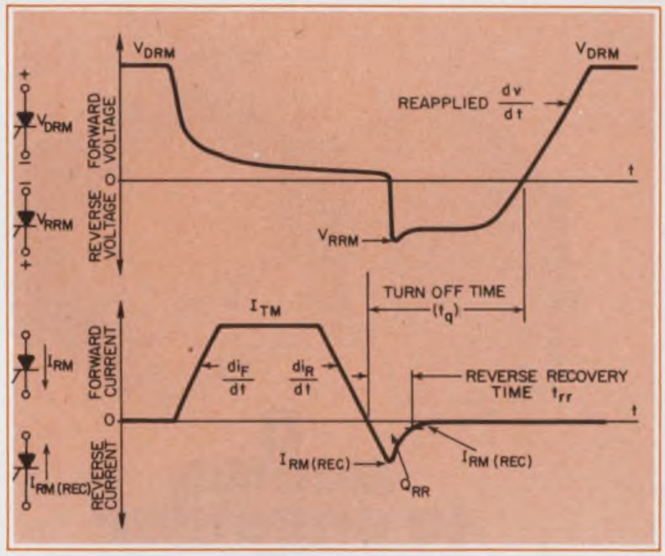
Julian Rydeski, Sr. Quality Control Engineer, Semiconductor Div., Westinghouse Electric Corp., Youngwood, PA 15697.

nitude decreases.

Section 4 is the reapplied dv/dt supply. When SCR_1 is triggered at time t_3, linear charging of capacitor C takes place. Thus the forward voltage is applied to the SCR under test at the reapplied dv/dt rate.

The actual value of turn-off time can be observed on an oscilloscope (Fig. 2b). If you decrease the time interval between t_3 and t_2, you can see that the turn-off time also decreases until the SCR under test cannot support the reapplied dv/dt.

This dv/dt turn-on is nondestructive if the rate of current rise, di_f/dt is limited to rated values for two-terminal SCR turn-on. The turn-off time, as defined earlier, is the minimum value of observed time for which the device will support reapplied forward voltage.



1. **Voltage and current waveforms for an SCR** start changing as soon as a gate signal is applied to the device. When the current waveform passes through zero, it starts the turn-off time period of the SCR.

Testing can create problems

But even when you use a test jig, you can run into the following problems:

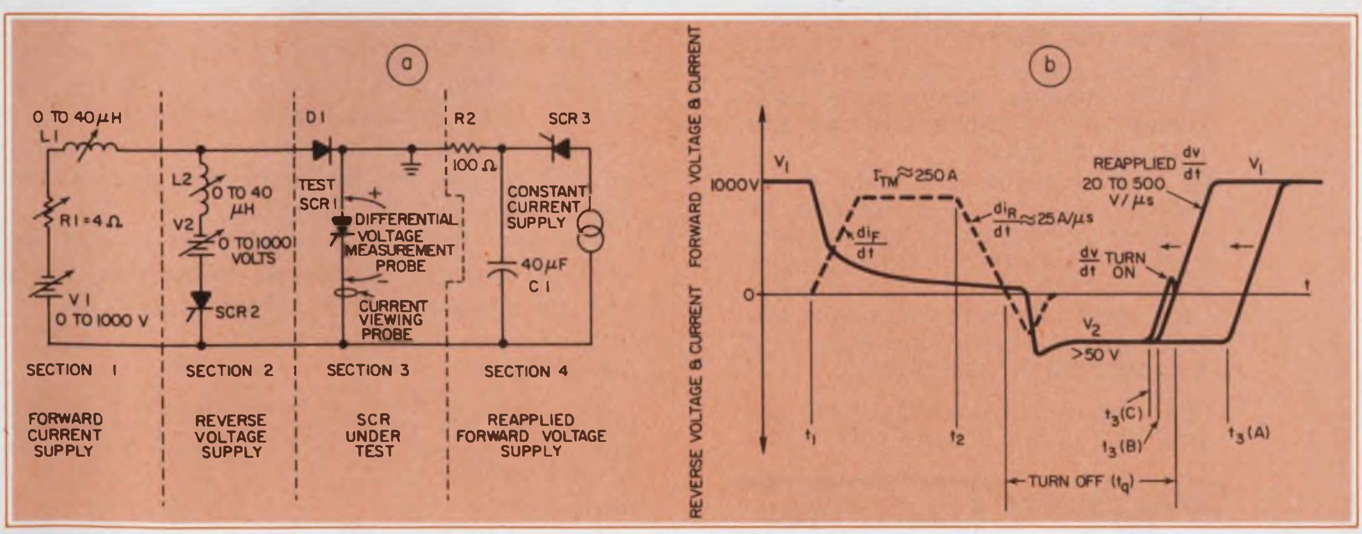
- Temperature stability. Maintaining the junction temperature of the SCR under test is important. Variations can alter the measured value of t_q.
- Poor selection of D_1. This diode isolates the forward-current and reverse-voltage supplies from the reapplied dv/dt. Poor isolation can lead to changes in t_q.
- Soft commutation turn-off time testing. If the test SCR has an inverse diode in parallel, as specified in some inverter diode designs, tests cannot be performed with this circuit to give useful results.

SCRs with fast turn-off capabilities are found in power-inverter circuits and can be used in phase-control circuits, but they do not always offer any performance improvements over slower SCR types.

Turning off the SCRs in power-control circuits requires special care. In the case of the series-inverter circuit (Fig. 3a) a capacitor may be used in series with the load. A gate pulse to SCR_1 charges the capacitor to the dc supply voltage. When this happens, SCR_1 turns off because the charged capacitor limits further current flow. When SCR_2 is gated on, it discharges the capacitor and turn-off is thus attained.

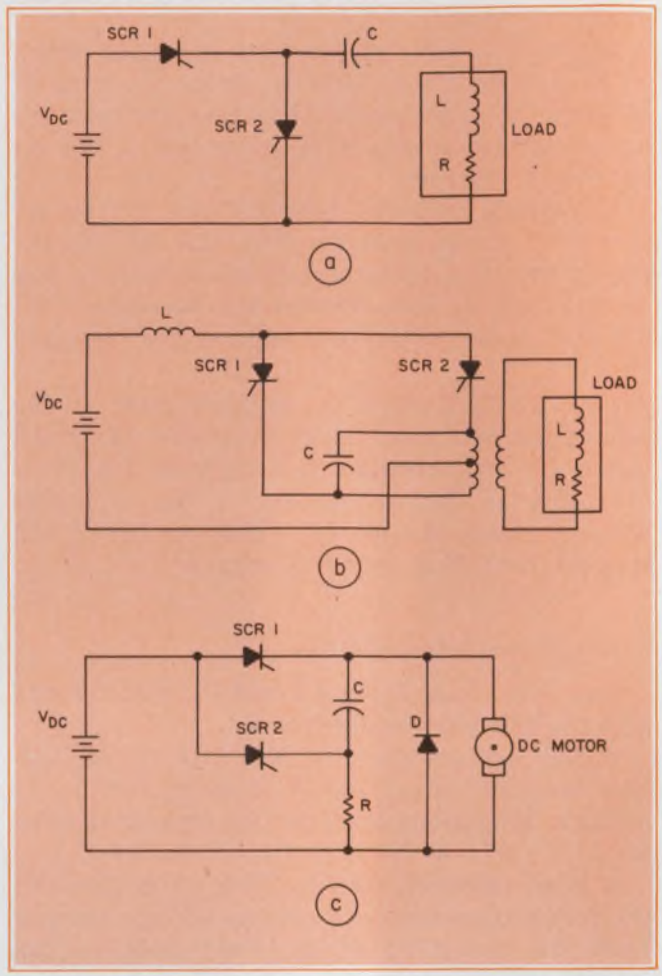
If SCR_1 and SCR_2 are alternately fired, load-dependent, half-sine waves of current can be generated. Short-circuit currents and damaging overloads result if one SCR fails to turn off before the other is turned on.

The parallel inverter circuit (Fig. 3b) has a capacitor in parallel with the load. As with the series inverter, circuit operation is load dependent. Current through the SCR does not auto-



2. **Simplified version of a typical SCR test circuit** (a) can test for turn-off time as well as many other parameters.

Superimposed waveforms (b) show the interdependence of forward voltage and reverse current.



3. **Some typical turn-off circuits** for a series inverter (a), a parallel inverter (b) and a dc motor controller (c) don't require much additional circuitry.

matically decrease to zero to achieve turn-off. Alternate SCR gating causes the commutating capacitor to reverse-bias the conducting SCR, resulting in turn-off. Again, should one of the SCRs fail to turn off properly, short-circuit current can cause device failure.

A dc motor controller (Fig. 3c) supplies varying dc current to a motor for adjustable periods of time. When SCR_1 is gated on, it allows current to flow through the motor until SCR_2 is gated. And, when SCR_2 is gated, it causes capacitor C to reverse-bias SCR_1 and thus induce turn-off as in the parallel inverter.

For this circuit, failure of SCR_1 to turn off will not result in component destruction, but it will cause loss of motor-current control. ■■

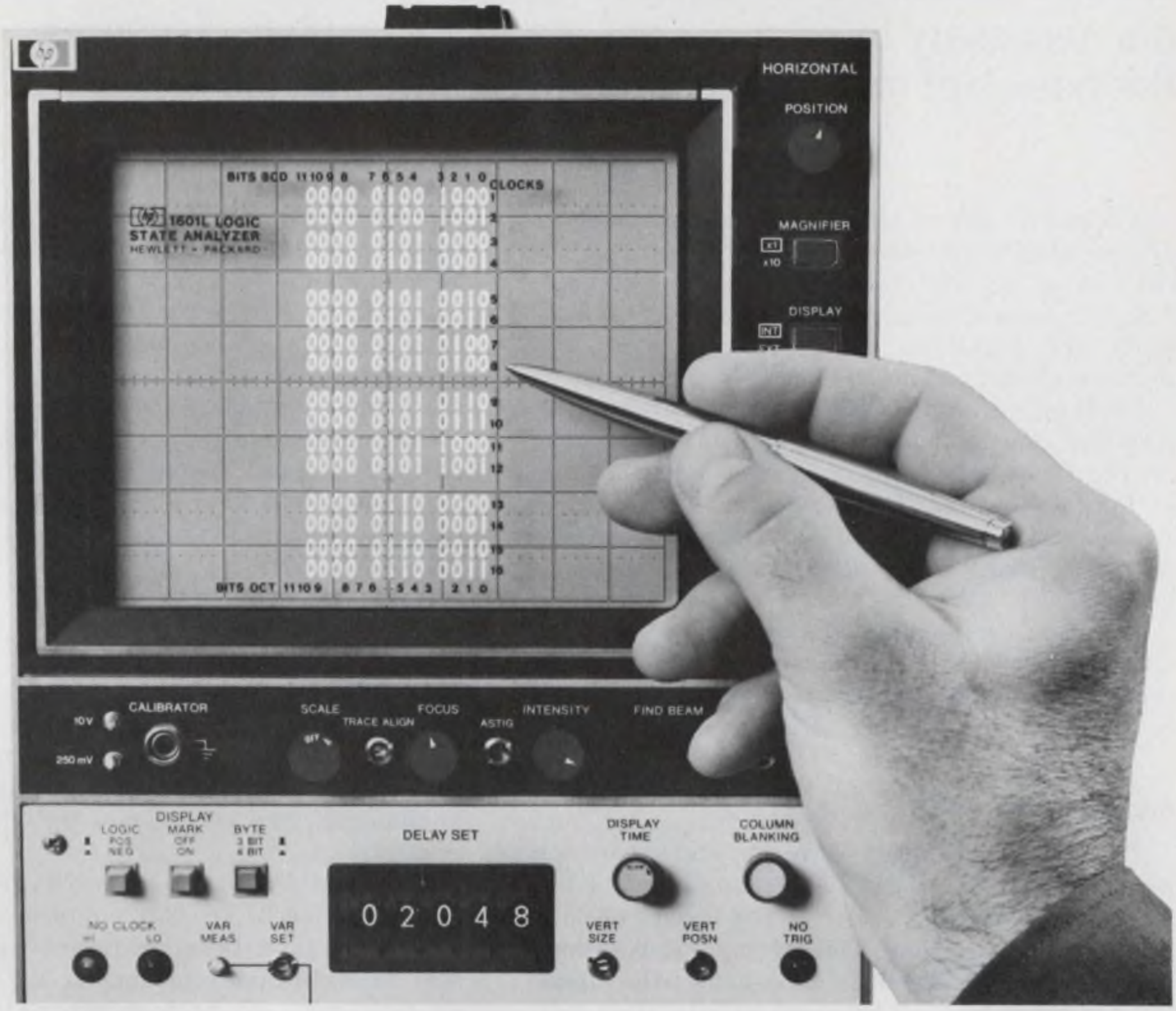
Acknowledgment

Many thanks to Messrs. J. Dennis Balenovich and William H. Karstaedt, applications engineers for high-power SCRs, Semiconductor Div. of Westinghouse, for their advice and comments.

Reference

1. "Thyristor Design Tradeoffs in Turn-off Specifications," *Application Note AD 54-580*, Westinghouse Electric Corp., Youngwood, PA 15697.

Can you spot this counter problem?



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Level with your staff, especially when it's necessary to kill a project. An IBM executive discusses the basics of motivating (and placating) engineers.

Engineers and managers everywhere almost always have to decide the fate of a project without having all the facts. I try to do it successfully by establishing a reputation for creditability and frankness among the engineers and managers who report to me.

I had an argument with an executive once who said that you can't make decisions until you have all the facts. I told him that I thought that one of the talents I was being paid for as a manager was to make decisions on less than all the facts and then make those decisions turn out to be right.

When do we terminate or redirect a project? Usually when the requirements change or we've misinterpreted the requirements. A project is rarely killed because the engineering solution is bad.

Appeasing the losers

This poses a problem. Projects started by top management have a difficult time making it unless there's a spear carrier in the lower echelons to help push it along. One of my most serious management problems is appeasing the spear carrier whose project has been killed. Often he'll have difficulty accepting it. He has sold a lot of people on the project and suddenly he realizes that he's been doing the wrong thing.

Another problem in a company our size is competing projects—two engineers running around on white chargers with spears. The problems these two engineers started with were similar, but not exactly the same. As time evolves there'll be a partial overlap of the two products they're working on, and this may spread until eventually these two products are competing to fill the same product requirements.

The manager of these two engineers has to review the requirements of each project and decide which will give the company a better solution. The tough part of that decision is that the staff of the doomed project can't accept the fact that the reason their program was killed had nothing to do with how good a job they were doing. It's a very hard thing to accept. If that happened to me, I couldn't help but think that if I'd worked harder and smarter, I'd have been the winner instead of the loser.

Occasionally we'll have a case where one group is doing a much better technical job than the other, and we'll level with them. But usually we redirect one of the projects strictly for business reasons.

As a rule engineering groups are technically equal; the IQ level of most people in one group will equal the IQ level of most of those in the other. If we had one-man programs, there might be a great variance in performance, but when you have 20 to 30 people in each group, I've found that each group approaches a problem intelligently, and each comes up with acceptable solutions.

There are cases where we'll give the same product problem to two engineers, so we can look at two or three different approaches on how to solve that problem. Or we'll "blue sky" it; we'll pit two project groups against each other. But they'll know that's the game from the beginning. The decision of which project to stop will be based on cost and performance.

Making yourself credible

The only way I know to convince the engineer of a losing project that it wasn't his fault is to establish credibility with him at the outset. No matter how much he believes you, though, if an engineer has done three projects in a row that have been killed, he's going to be very low emotionally. That leads to another management challenge: Recognize a sure project winner for that man and get him on it quickly.

I try to be very open as a manager—open with my problems and open with my successes. It's rare that there's a reason to withhold anything from my subordinates. I don't post news of a confidential nature on the bulletin board, but I

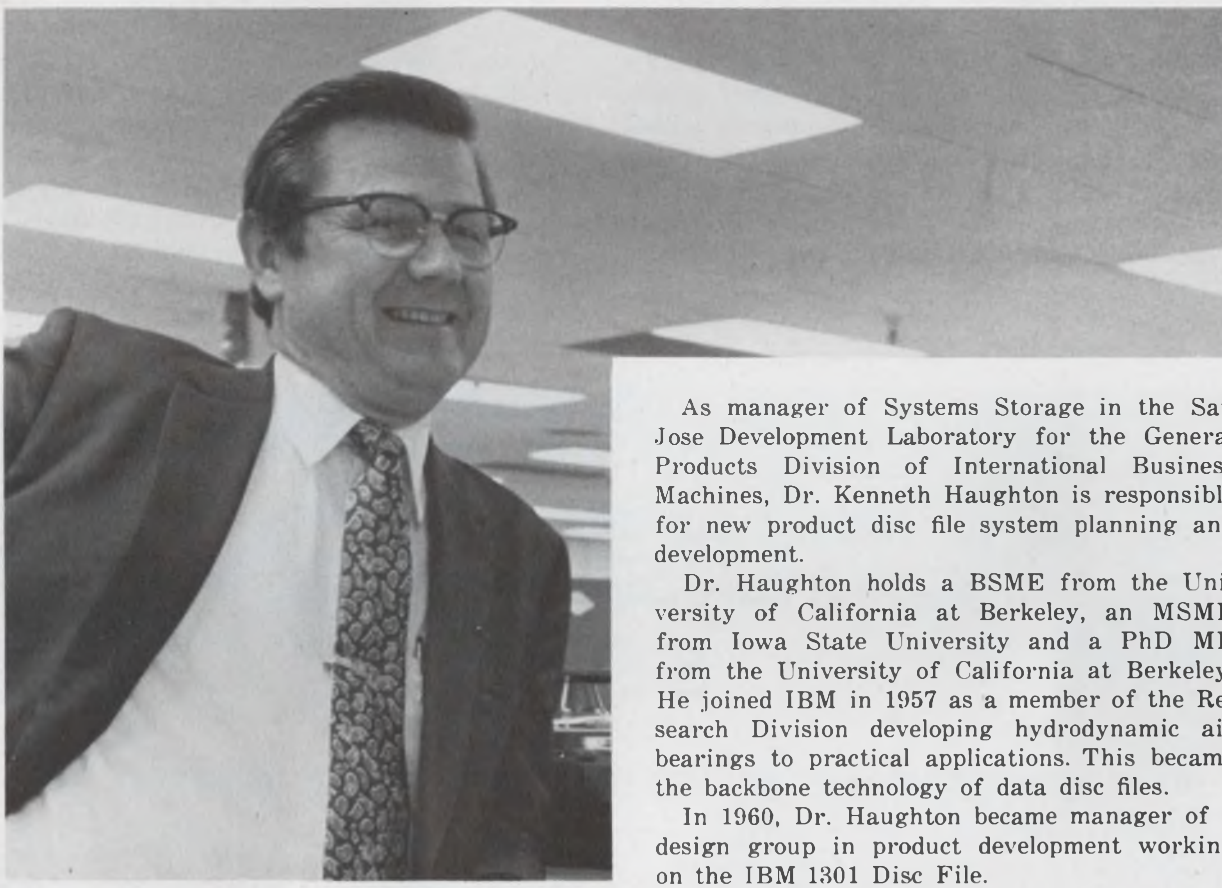
Dr. Kenneth Haughton, Manager of Systems Storage, General Products Div., IBM, San Jose, CA 95114.

don't hesitate to discuss things of a confidential nature with the individual affected. When I'm in trouble, I tell them. I also tell them what's bothering me, and I try to find out what's bothering them.

There's a tendency in our business to destroy credibility by playing games with one another. When I want a man to do something, I don't aim in that general direction and hope that he'll do it accidentally; I tell him exactly what I want.

To have a successful project, you must have engineers who are enthusiastic about what

Dr. Kenneth E. Haughton and IBM



As manager of Systems Storage in the San Jose Development Laboratory for the General Products Division of International Business Machines, Dr. Kenneth Haughton is responsible for new product disc file system planning and development.

Dr. Haughton holds a BSME from the University of California at Berkeley, an MSME from Iowa State University and a PhD ME from the University of California at Berkeley. He joined IBM in 1957 as a member of the Research Division developing hydrodynamic air bearings to practical applications. This became the backbone technology of data disc files.

In 1960, Dr. Haughton became manager of a design group in product development working on the IBM 1301 Disc File.

After using an IBM Fellowship to complete his PhD in 1964, he subsequently assumed prime responsibility in the development of the IBM 1360 Photodigital Data File. In this capacity, he managed a group that developed an electron beam recorder for this file. After delivery of this system, he managed a magnetic recording technology group until he was promoted to his present position.

In addition to his IBM career, Dr. Haughton has taught various subjects at Iowa State University, Cornell University, and the University of California at San Jose, including Engineering Graphics, Engineering Mechanics, and Thermodynamics.

they're doing and who understand what you're doing. Every product organization is interested in developing vitality in its people.

We condition people to look for the usual goals, like raises and promotions, but these are not the total definition of success. A man is a success if he finds his work constructive, creative and enjoyable. It's not a job; it's part of his life.

I've learned that the most successful projects are those that start in the ranks. An engineer will come up with an idea to solve a problem in the company, and he or his manager or someone else will try to convince everyone of the validity of the solution. Those projects are successful because the men believe in them and know what they're doing.

Here in San Jose we make storage products. When we start a new project, we define the requirements first. For example, we may specify the characteristics for a disc file product, including speed, size, performance and cost. That project will start with a small nucleus of people, including an individual who is heavily committed to an approach he wants to sell. More often than not, he sells his idea to the group while the entire team enlarges the concept until a satisfactory solution to the project requirements is at hand.

We continually review our product objectives, to make sure we don't drift off the target. Engineers like to solve tough technical problems, and if they can really see the target, they'll steer around rocks in the road.

One of the talents I look for in people is the ability to recognize when they've met the requirements for the project. They have to know if the next refinement they're planning is worth the man-hours and development effort they'd be putting into it. A big problem for engineers is knowing when to stop developing a product. Development leads to better and better ideas, which makes the average engineer want to keep trying new approaches. That's why you'll see nearly identical products on the marketplace, with the newest one just a little bit better than the older one.

In developing a product over a period of years, an engineer will see another way to do it. And he'll be convinced that the new way should be pursued especially since he doesn't have as much data about this new way as he has about the old. The management problem is to keep the engineer acquainted with his objectives and ensure that he always has his eye on the goal. If he doesn't, he can keep spinning around the development loop forever. ■■

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Circuits & Circuit Theory

Department key

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NEWS	News
PF	Product Feature
SR	Special Report

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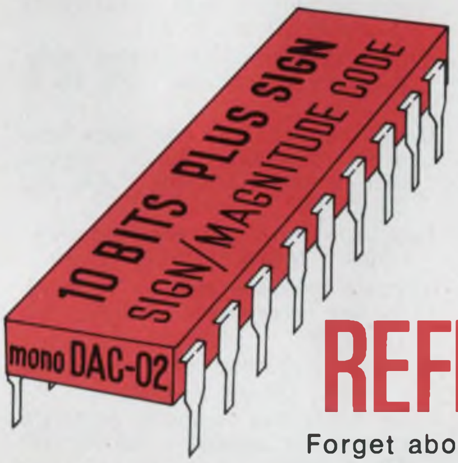

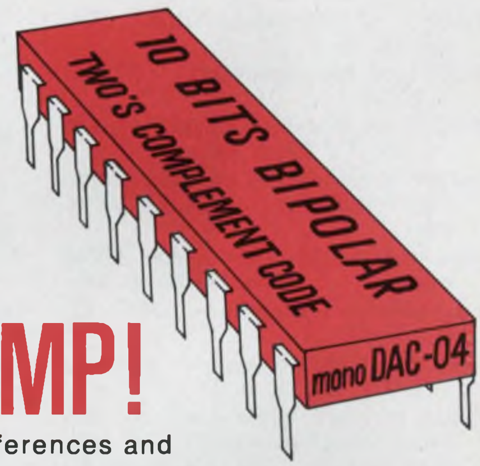

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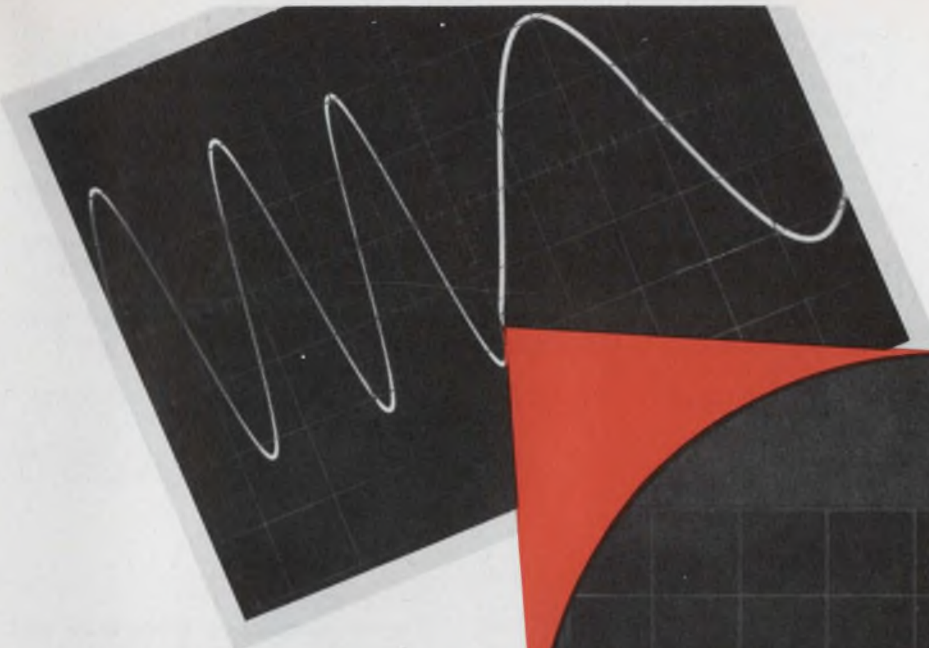

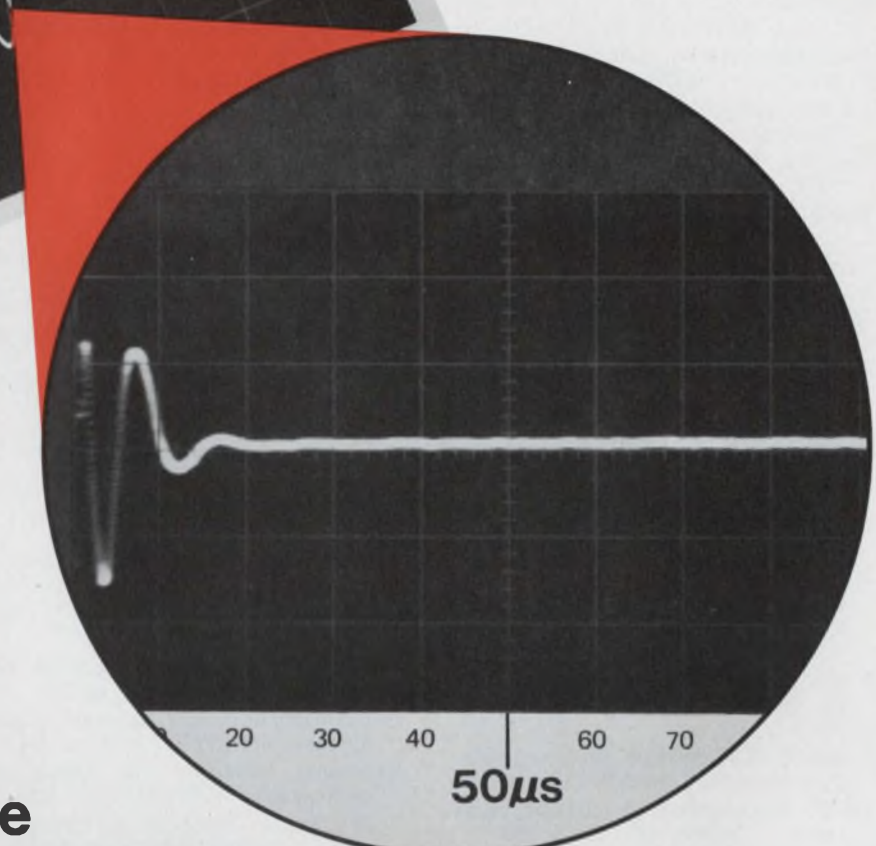

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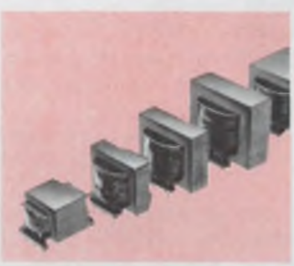

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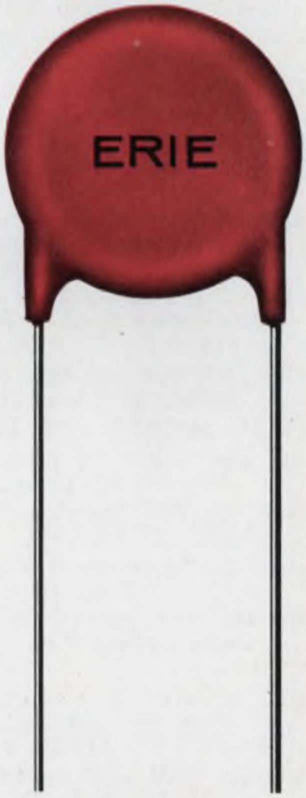

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Test and Measuring

INFORMATION RETRIEVAL NUMBER 48

ideas for design

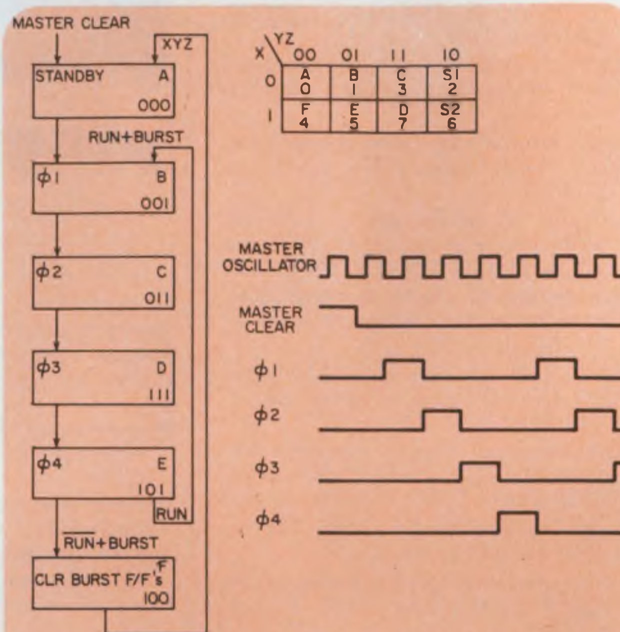
Build a multiphase clock that never loses its sequence

A multiphase clock that always returns to its normal sequence, even if a random-noise pulse temporarily throws it off, can make a logic system more reliable (Figs. 1 and 2). In addition a built-in single-burst mode enhances its use for trouble-shooting.

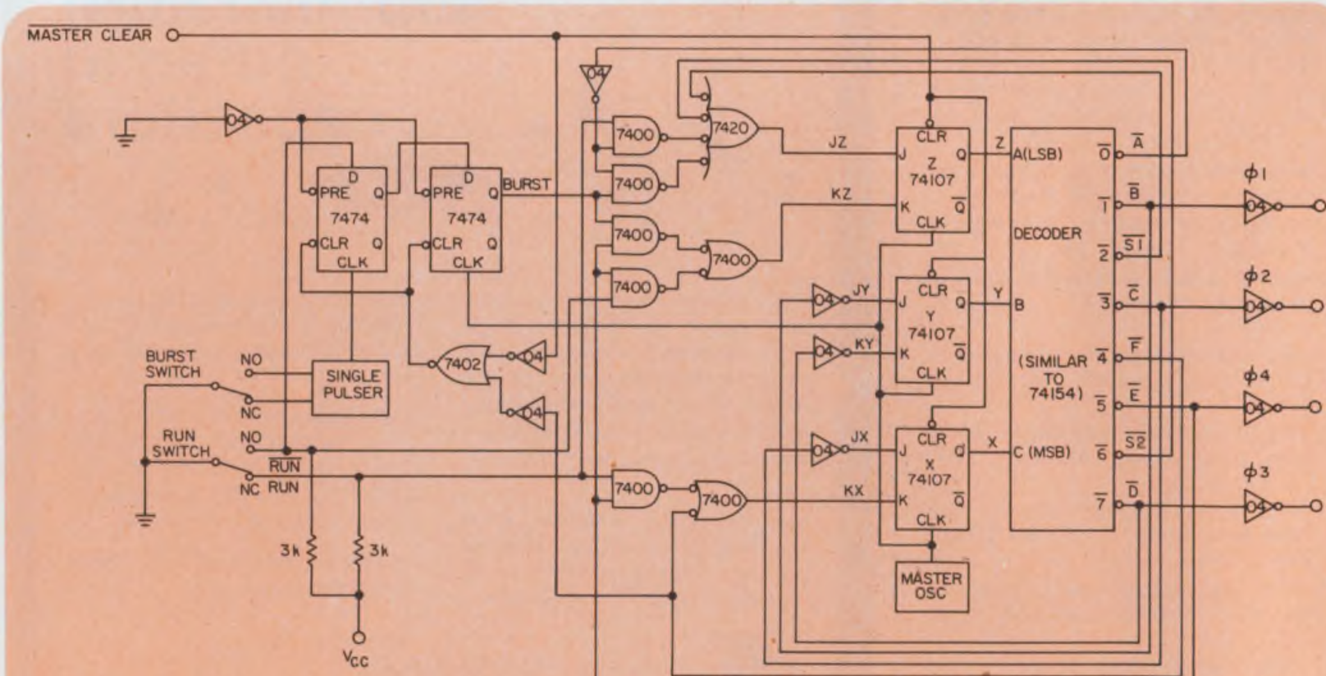
Many designers use a simple Johnson counter to generate a multiphase nonoverlapped clock. But this works well only in a noise-free environment. Noise spikes can put such a circuit out of sequence; the output phases never return to normal unless a clear pulse is issued.

Fig. 1 shows the timing sequence, phase states and Karnaugh map for the design of a four-phase clock. The technique is based upon an article previously published in ELECTRONIC DESIGN.[1] Any even number of phases can be generated by this method, but four phases are sufficient to illustrate the design procedure. If the number of phases equals 2^n-2, the simplest circuits are obtained, because there are no unused states in the circuit's Karnaugh map.

Each phase is nonoverlapped and equal to one full period of the master oscillator. For TTL



1. **A timing diagram, state chart and Karnaugh map for a four-phase clock system** illustrate a technique for designing a self-clearing mutiphase clock with an even number of phases.



2. **A multiphase clock should automatically resume its normal sequence** even if temporarily thrown off by noise pulses. Other clock circuits with a lower parts count may not have this self-reset feature.

logic, the upper frequency limit of the master oscillator is approximately 20 MHz.

The circuit uses a run switch, a burst switch and a master-clear signal (Fig. 2). The master-clear signal forces the system to the standby state. When the run switch is turned on, the sequencer leaves the standby state and cycles through the phases until the run switch is turned off. Each phase follows the preceding one in sequence. If a noise spike causes the sequencer to jump some states, the circuit continues to cycle properly from that point on. If an unused state is entered, the next clock pulse forces the sequencer to the adjacent used state and back into the mainstream again.

If a single four-phase burst is desired, the momentary burst switch is activated. The run switch must be in the OFF position.[2] This action sets the first 7474 of the burst flip-flop pair. The second stage of the pair thereafter sets on the rising edge of the next master-clock pulse and synchronizes the burst request with the sequencer. The burst flip-flops are automatically cleared after the four phases are generated, and the sequencer returns to a standby condition.

The input equations for the sequence control flip-flops to implement the control loop and Karnaugh map are:

$$JX = C$$
$$KX = E \cdot RUN + F$$
$$JY = B$$
$$KY = D$$
$$JZ = A \cdot (RUN + BURST) + S1 + S2$$
$$KZ = E \cdot (\overline{RUN} + BURST)$$

Though this technique may require more parts than some other multiphase clock designs, this disadvantage is offset by high operational reliability.

References

1. Bentley, James H., "The Foolproof Way to Sequencer Design," *Electronic Design*, No. 10, May 10, 1973, pp. 76-80.

2. Laurino, A. J., "Single IC Pulser Eliminates Contact Bounce," *Electronics*, Nov. 9, 1970, p. 79.

James H. Bentley, Principal Development Engineer, Government & Aeronautical Products Div., Honeywell Inc., 1625 Zarthan Ave., St. Louis Park, MN 55416.

CIRCLE No. 311

Flat, flexible TV antenna offers high gain

Better than the simple indoor TV "rabbit ears," but not as good as a complex, multi-element outdoor antenna, a flexible PC antenna is limited to the reception of single-direction vhf and uhf broadcasting.

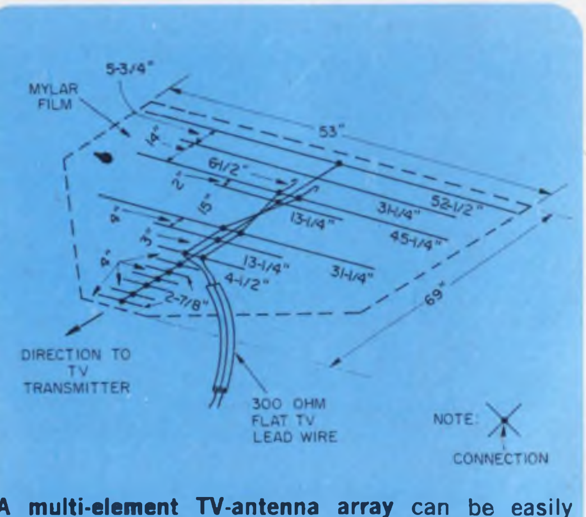
The design uses the configuration of a multi-element outdoor antenna, but in a flexible printed-circuit form. It can bring the advantages of high gain and directivity into a den or living room, and avoid the problems of the outdoor environment.

All the user needs to do is orientate the flat antenna under the rug, in close proximity to the TV, and connect it to the set's 300-Ω input with flat, twin-lead wire. However, expect some loss in range compared with a roof installation, because of the lower elevation.

The design in the figure has 13 elements. In theory, there is very little restriction on the maximum number of elements that you can use. A flexible plastic sheet can be pieced together from Mylar velum. Other necessary materials include 1/8-in.-wide adhesive copper tape, 1/4-in.-wide adhesive copper doughnuts and Mylar insulating tape for crossovers. The copper materials are solderable, but avoid overheating them.

Marshall K. Kessie, Bechtel Corp., P.O. Box 60860, Term. Annex, Los Angeles, CA 90060.

CIRCLE No. 312



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2A15-.5A	12V - 0.5A 15V - 0.5A	$24.95	2C15-2.8A	12V - 3.0A 15V - 2.8A	$54.00	2D15-6A	12V - 6.5A 15V - 6.0A	$ 87.00
2A24-.4A	18V - 0.4A 20V - 0.4A 24V - 0.4A	$24.95	2C24-2.3A	18V - 2.0A 20V - 2.3A 24V - 2.3A	$54.00	2D24-5A	18V - 4.5A 20V - 5.0A 24V - 5.0A	$ 87.00
2B5-3A	5V - 3.0A 6V - 2.5A	$32.00	2CC5-9A	5V - 9.0A 6V - 7.5A	$67.00	2DD5-18A	5V - 18.0A 6V - 16.0A	$109.00
2B15-1.3A	12V - 1.5A 15V - 1.3A	$32.00	2CC15-4.4A	12V - 4.8A 15V - 4.4A	$67.00	2DD15-9A	12V - 10.0A 15V - 9.0A	$109.00
2B24-1A	18V - 1.0A 20V - 1.0A 24V - 1.0A	$32.00	2CC24-3.7A	18V - 3.3A 20V - 3.7A 24V - 3.7A	$67.00	2DD24-7.5A	18V - 6.8A 20V - 7.5A 24V - 7.5A	$109.00

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INFORMATION RETRIEVAL NUMBER 53

Convert your pocket calculator into a programmable counter

A pocket calculator can do the job of a counter, if you bring out the contacts of the [=] key switch (or the [+] switch on some models) and use a reed switch or photodiode to make a circuit closure. The built-in-constant feature of most of today's low-cost calculators is also used.

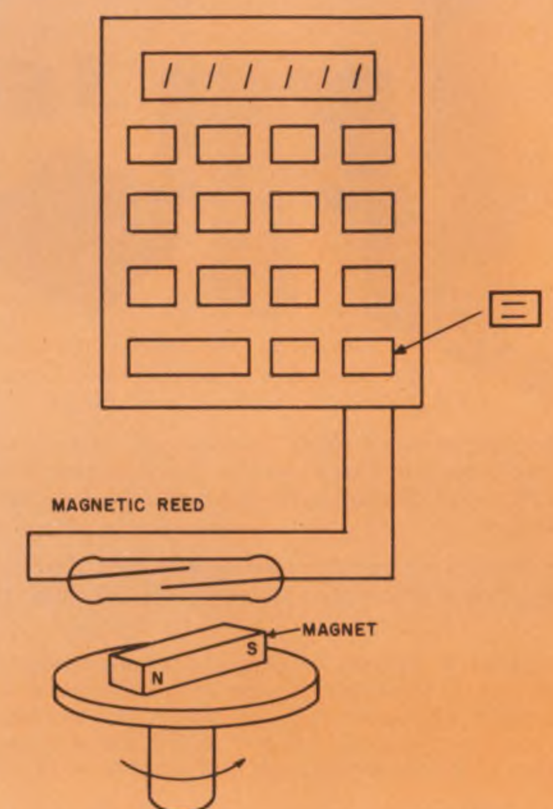
If you enter 0 [+] 1 [=] into the calculator, every time you press the [=] button thereafter, you will add one to the sum. Consequently if you use the external contacts, the calculator counts the number of times the contacts close, and the display shows one count more than the number of closures.

If you use a magnetic-reed switch as the external contact, a small magnet attached to a rotating, or moving part of a device can operate the reed switch. A photodiode requires a light source and a moving light shield or reflective surface.

You can program the calculator to count up or down by entering either [+] or [−] . And you can start with a number other than one, and the calculator will count in multiples of this number. For example, the revolutions of a capstan can be converted to inches if a number equal to the capstan's circumference is entered.

But calculators are not very fast, so don't attempt to use one for high-speed counting. However, for most chores around the lab, you can't beat it.

George Alexandrovich Sr., Vice President Engineering, Robins/Fairchild, 75 Austin Blvd., Commack, NY 11725. CIRCLE NO. 313



A pocket calculator can be used as a counter. It can count in multiples of any number within its range.

IFD Winner of November 8, 1974

Jack Althouse, Palomar Engineers, P.O. Box 455, Escondido, CA 92025. His idea "IC Timer, Stabilized by Crystal, Can Provide Subharmonic Frequencies" has been voted the Most Valuable of Issue Award.

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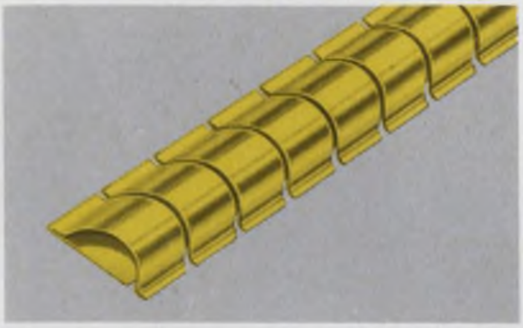

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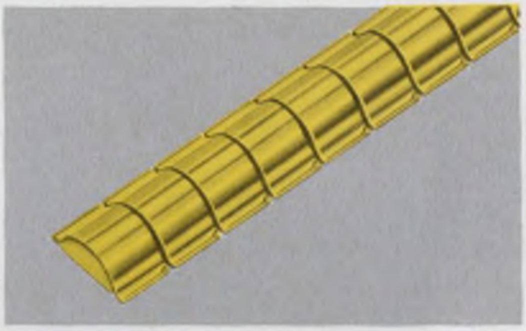

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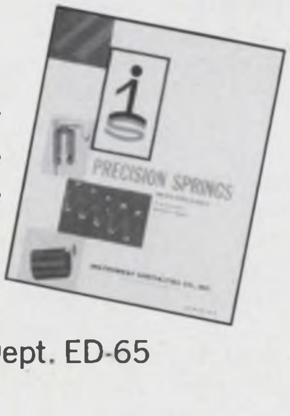

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INFORMATION RETRIEVAL NUMBER 54

international technology

New image tube moves into 8-to-14-μm region

An image tube based on the electron-mirror principle and using a pyroelectric target has been developed for operation in the 8-to-14-μm wavelength region.

Designed at the Services Electronics Research Laboratory in Baldock, England, the tube has sufficient sensitivity to detect temperature differences of 1 K.

A time-varying thermal scene, focused onto a triglycine sulphate pyroelectric element by wide-aperture germanium optics, produces voltages on the order of millivolts for image temperature differences of a few degrees K. Because the spatial frequencies in a 10-to-20-mm diameter image can easily be a few line-pairs per millimeter, the thermal image produces pyroelectric fields of over 10 V/m.

In the tube, electrons are reflected from the target, which is held close to the potential of the electron-gun cathode. The reflected electrons, after acceleration to 3 to 6 keV, strike a fluorescent screen. The thermal image is reproduced there with sufficient detail to give recognizable images of human faces or hands.

Many tubes have a sensitivity comparable to that of a pyroelectric Vidicon. But the electron-mirror tube's power consumption is considerably less. The electron reflection process in the mirror tube allows the use of thicker targets without loss of sensitivity. Thus spatial definition in the new tube will probably exceed that of the Vidicon. The mirror tube can also be expected to be less microphonic.

Bandwidth improved in optical fibers

The transmission bandwidth of optical fibers has been improved at the Siemens Laboratories in Munich, West Germany, by control of the mode coupling. The control was achieved by application of tension to an optical fiber.

In experiments, a 1-km-long fiber was wound onto a 38-cm-diam drum of expanded polystyrene. When the drum and fiber were heated from 0 to 50 C, expansion of the drum—which was greater than that of the fiber—stressed the fiber. The researchers report that temperature rise alone does not affect the fiber properties.

Pulses of infrared energy from a gallium-arsenide laser were sent into one end of the fiber. At the other end of the fiber, a p-i-n diode and a sampling oscilloscope detected and displayed the output. The mode coupling increased with mechanical tension, and the output pulses became smaller, but more symmetrical, in shape. The pulse shape is independent of the input conditions when the fiber is under moderate tension. With excess tension, losses increase in the fiber and the output pulses become very small.

The Siemens researchers determined that light originally transmitted in a mode of certain velocity does not remain in this mode throughout the length of the fiber. Instead the energy is randomly coupled to modes of different velocities, and the fiber output is a mixture of lower and faster light components.

Video recorder offers long playing times

BASF, one of the largest European chemical concerns and a pioneer in the manufacture of magnetic tape, is planning to enter the consumer electronics market with a Longitudinal Video Recording (LVR) cassette system.

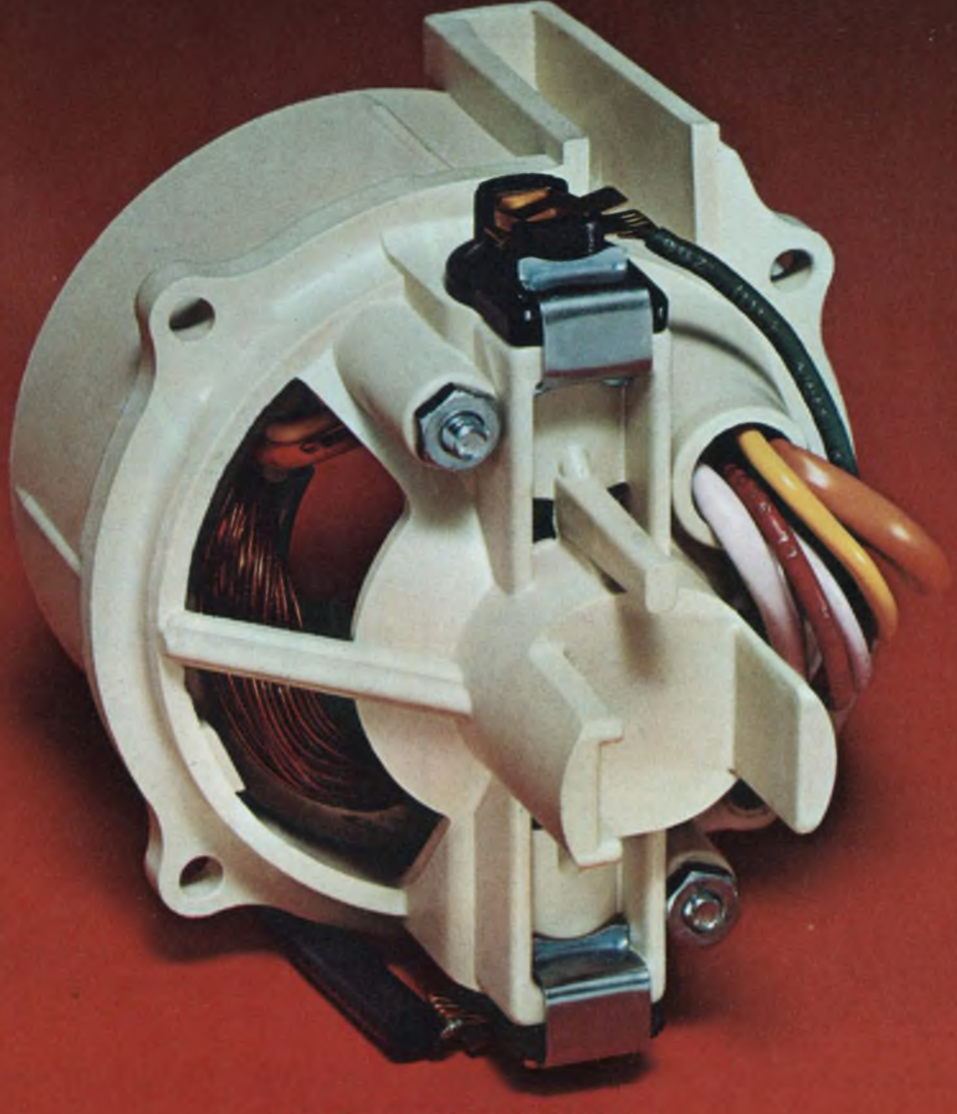
The LVR system uses a 4.4 × 4.4 × 0.06-in. cassette and a chromium dioxide (CrO_2) tape, for extremely high signal-packing density. The 1/4-in.- wide tape can be used for color and black-and-white recording. It is said to offer 90 or 120 min of playing time, depending on the thickness of the tape used.

The machine uses a fixed head, and recording is done longitudinally, in contrast with the usual helical recording techniques. The LVR system contains a contact-pressure tape transport that is driven by a motor. The tape is pressed against the rotating transport drum from the moment it leaves the spool. It passes the head assembly, still in contact with the transport drum, and leaves it at the point where the take-up spool is pressed against the drum.

This feature allows the use of very thin tapes—9 μm for 90 min of playing time and 6 μm for 120 min. The tape speed is 3 meters/s, which equals about 118 in./s. Another unusual feature is that there are 28 parallel, tightly spaced tracks on the quarter-inch tape. This makes switching between tracks necessary. BASF does the trick in track-to-track switching time of 80 ms.

Tiny transmitter sends body data from animals

Unlike traditional designs, a new miniaturized radiotelemetry transmitter can telemeter dc outputs from temperature, heat-flow, pressure and other transducers. Developed at the Cambridge Institute of Animal Physiology in England, the transmitter has been used for telemetering biological data from animals without hindering their movement.



The HOWARD LIFETIME GUARANTEE fan vs. "the other fan"

The new Howard Cyclohm fan matches the "other fan" in every way. It delivers the same volume of air in the same quiet way—even costs about the same as the "other" fan you are now using. But Howard includes a LIFETIME GUARANTEE with every fan. (See why we call the comparison "unfair"?)

In all fairness we admit this new Howard fan is exactly the same size as "the other fan". They're interchangeable. And available "air away" and "air over" motor.

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Howard will replace any Cyclohm fan that fails in normal service **for the life of your product.** Accidents or intentional damage are not included.

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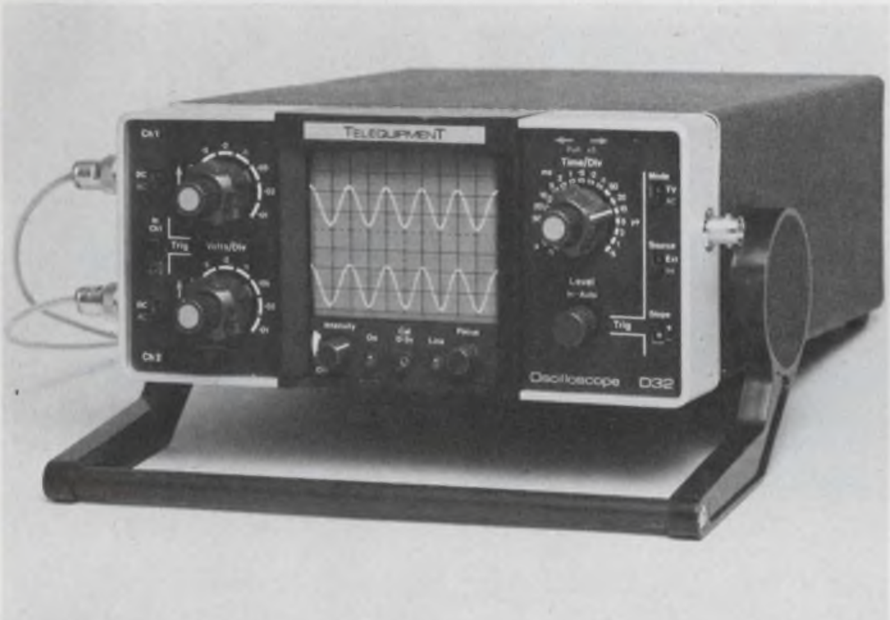
INFORMATION RETRIEVAL NUMBER 56

new products

Dual-trace battery-powered scope weighs 10 lb and operates to 10 MHz



Telequipment Div. of Tektronix, P.O. Box 500, Beaverton, OR 97077. (503) 644-0161. P&A: See text.

A dual-trace portable scope, the D32, developed by the Telequipment Div. of Tektronix, weighs 10 lb. and has a 3-dB bandwidth of 10 MHz. The scope uses rechargeable D-cell batteries that provide up to four hours of continuous use.

The screen of the CRT has an 8 × 10 division graticule, with each division 0.7 cm on a side. The CRT uses a standard p31 phosphor and has a 3-kV accelerating voltage. The package dimensions, only 4 in. high × 9 in. wide × 11 in. deep, include all projections except for three female BNC input connectors on the scope sides.

Among the D32 features are vertical sensitivity from 10 mV/div to 5 V/div in nine steps; 19 sweep speeds from 500 ns/div to 500 ms/div (extended to 100 ns/div with a ×5 magnifier); auto selection of TV line frame displays; auto selection of chopped or alternate mode display; and triggering level control.

A built-in charger circuit permits either trickle charging while the scope is operating or overnight charging when the unit is off. The power source is six D cells at 1.25 V each, or 100 to 250 V ac, 50 to 400 Hz. When operated from ac, the unit consumes 14 VA; under battery power, dissipation drops to 7 VA.

A front-panel ac output of 0.3 V pk-pk, permits simple field calibration of input voltage. Front-panel indicator lamps show when the instrument is on and when the ac line in use.

The time-measuring accuracy of the scope on the ×1 scale is ±5%. On the ×5 scale, from 200 ns/div to 100 ms/div, accuracy is ±7%, and on the 100-ns range, ±10%. The trigger level can be adjusted over the full eight-division display (for positive and negative slopes). In the absence of a trigger signal, a bright line automatically appears on the screen.

Included as standard equipment in the $1000 price are the rechargeable battery pack, two ×10 passive probes with 3.5-ft cables, BNC connector and spring-loaded probe sheath; and a molded front-panel cover to protect the scope during transportation and storage. An optional feature is a shoulder-strap carrying case.

The D32 is available in 16 wk.

CIRCLE NO. 305

Meter locks on signals with 3 mHz equivalent bw

Evans Associates, P. O. Box 5055, Berkeley, CA 94705. (415) 848-6839. $1350; 4 wks.

Model 4103A digital lock-on-voltmeter measures incoming periodic signal amplitudes over the frequency range of 1 Hz to 100 kHz, with an equivalent filter bandwidth selectable down to less than 2 mHz. Tracking is automatic—less than four periods are required to lock onto any desired frequency. A variable phase control permits measurement of vector component values.

CIRCLE NO. 320

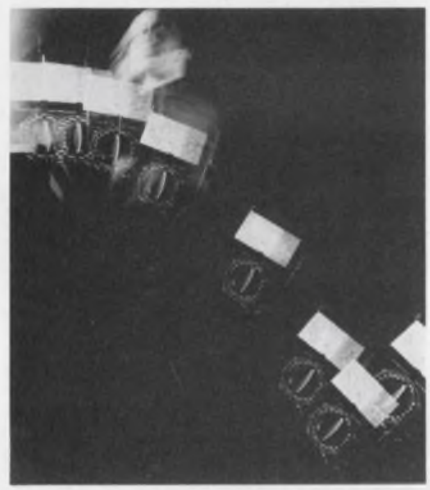
New DPM family includes 3-3/4-digit models

Gralex Industries, 155 Marine St., Farmingdale, NY 11735. (516) 694-3607. Start at $80 (100); 4-6 wks.

A new family of DPMs is highlighted by its 3-3/4-digit models. Features include Beckman planar gas-discharge displays, ac line or 5-V-dc powered versions, full-scale voltage ranges of 399.9 mV, 3.999 V and 39.99 V, and an accuracy of ±0.1% of reading ±1 digit. Space and supply voltages are provided to permit the user to incorporate his own circuitry within the meter.

CIRCLE NO. 321

Extra-safe VOM provides self-test



Triplett Corp., 286 Harmon Rd., Bluffton, OH 45817. (419) 358-5015. $90; stock.

Drop a new VOM from a 5-foot height and what happens? Nothing. Check a fuse on the ×1-ohm range, then try to measure line voltage without changing range and function. And what happens? You may blow one or two of the meter's three fuses. But you don't blow the meter and you don't even wrap the pointer around the peg.

But you're nervous. In that first millisecond after you realize that you forgot to switch to a voltage range, you figure "there goes a $90 meter," or "there goes 30 days and a $25 repair bill," or "if this survives, it's because I've been living right, but I'll have to send it to the cal lab to find out." Not so. After you replace any blown fuses (there are two spares in the meter), you can check out the Triplett "Extra Chance" Model 60 in about 30 seconds.

You set the mechanical zero adjust, switch to the ×10k ohms position, short the leads and adjust the ohms control for a zero reading. Then, with the leads still shorted, you switch to "Test." If the needle lands in a mid-scale red bar, you can relax.

In short, Triplett has made it difficult to damage this meter electrically or mechanically, and easy to find out if some fiendish accident has spoiled the specified accuracy—2% of full-scale on dc ranges, 3% on ac ranges.

If the accuracy isn't good enough for you, Triplett has the $100 60A, a mirror-backed version with 1.5% dc accuracy.

Both versions have input impedance of 20,000 ohms per volt dc and 5000 ohms per volt ac. Each has 23 ranges for dc voltage and current, ac voltage and resistance, and a decibel scale.

A wide range of accessories includes a $28.50 clip-on ammeter that provides six ac ranges from 6 to 300 A.

The Extra Chance is designed to be extra safe for humans as well as for itself. It has, for example, no exposed metal parts. Connections from the four-foot test leads to the meter are through insulated banana jacks on the leads to recessed banana plugs in the meter. At the other end, the pin-tip probes can accept slip-on, boot-protected alligator clips.

CIRCLE NO. 304

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INFORMATION RETRIEVAL NUMBER 58

Synthesizers work at low end of frequency scale

Philips Test & Measuring Instruments Inc., 400 Crossways Park Dr., Woodbury, NY 11797. (516) 921-8880.

These 100-kHz and 1-MHz synthesizers, designated the PM 5141 and PM 5142, respectively, offer optional programmable operation. Outputs are sines and square waves. The frequency is set by four thumbwheel switches and five pushbuttons, which determine the range. Out-of-range is indicated by a warning light. The amplitude is 10-V open circuit, 5 V into 600 Ω. Pushbutton attenuation provides two 10-dB and one 20-dB steps, with an additional continuous attenuation of 20 dB for a total of −60 dB. No price is available at press time.

CIRCLE NO. 322

Counter retains data for more than 1000 h

OKI Electronics of America, P.O. Box 24260, Fort Lauderdale, FL 33307. $150

Model DC-401, a four-digit electronic digital counter, has all-solid-state electronic circuitry controlled by a CMOS IC and includes a built-in battery that allows data retention for more than 1000 h in case of power failure. Including the 12-pin connector, the unit is only 4-in. long and 2-in. wide. Weight is about 4 oz. The counter uses 5 V dc, is shock resistant and has a 4-digit, 7-segment LED display with character height of 1/8 in. Counting speed is 300 pps.

CIRCLE NO. 323

INSTRUMENTATION

Low-cost counter/timer has 100-MHz range

Data Precision, Audubon Rd., Wakefield, MA 01880. (617) 246-1600. $295; stock.

A seven-digit, 100-MHz frequency counter, Model 5740, also measures period, period average, elapsed time and total events. The counter costs only $295 in unit quantity and uses a 0.5-in. high LED display.

The measurement capabilities of the counter/timer include: frequency from 5 Hz to 100 MHz; single-period time (sine wave) from 1 μs to 0.2 s; period average with 1-ns resolution to 99,999.99 μs; event counting (totalizing) from 0 to 9,999,999; and time interval (stop watch) from 0 to 99,999.99 s (27.8 hr). Over a frequency range of 5 Hz to 20 MHz, the sensitivity is 10 mV rms, but as frequency increases to 100 MHz, the sensitivity drops to 50 mV rms.

Decimal-point placement is automatic, and an adjustable trigger-level control on the front panel allows odd-shaped waveforms to be measured. The trigger-level control, in conjunction with a 20:1 attenuator switch, extends the voltage range to $\pm$250 V.

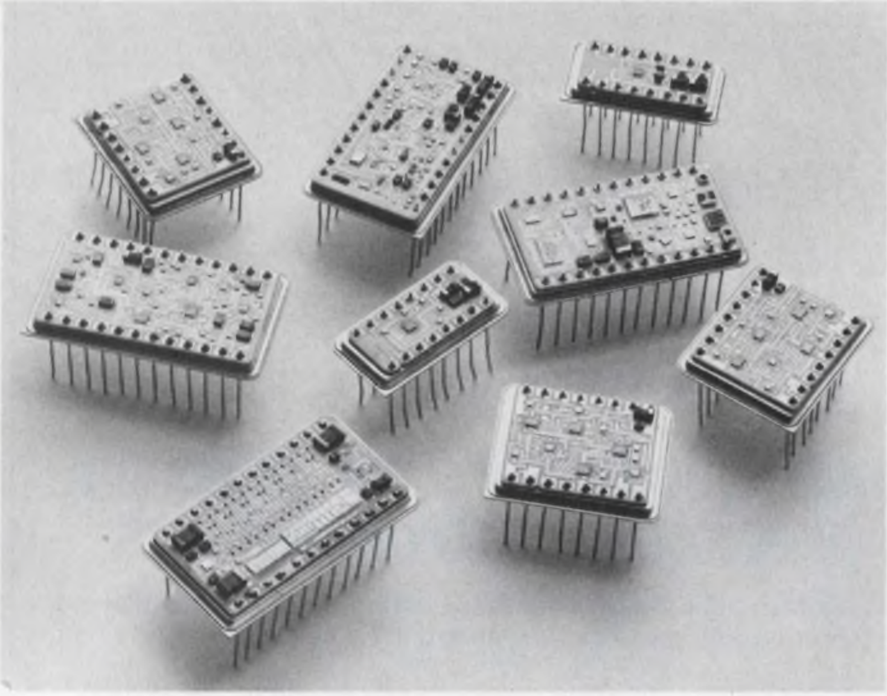
The input impedance of the counter is 1 MΩ shunted by a 25-pF capacitance, although a 50-Ω input impedance termination is optional. A special feature of the counter is its ability to count and resolve random pulses. It can, for instance, count pulses as close together as 15 ns.

Four separate gate times can be switched by a front-panel control to take full advantage of the seven-digit resolution. The control covers gate times of 10, 1, 0.1 and 0.01 s for frequency resolutions of 0.1, 1, 10 and 100 Hz, respectively. The same switch, when used with a mode slide switch, allows single period time or average measurement over 10, 100 or 1000 periods.

CIRCLE NO. 302

INFORMATION RETRIEVAL NUMBER 60

Hybrid IC converter series gives high speed at low cost



ILC Data Devices Corp., Airport International Plaza, Bohemia, NY 11716. (516) 567-5600. P&A: See text.

The ADH-10/1 series analog-to-digital converters, made by ILC Data Devices, have integral track-and-hold amplifiers and can convert an analog signal into 10 bits in under 1 μs.

The a/d converters use the company's new ADH-030 hybrid digital-to-analog converter and the new ADH-050 hybrid track-and-hold amplifier (which are also available separately) to form an 8 or 10-bit hybrid module a/d that fits on a 5.25 × 5.38 × 0.375 in. printed-circuit card.

The ADH-10/1 a/d converter comes in four different versions: the 8/1-3, 8/1-1, 10/1-3 and 10/1-1. Throughput word rate for the two ADH-8 versions is 1.6 MHz since they are accurate to only 8 bits. The ADH-10 units, though, are accurate to 10 bits and have a 1-MHz throughput.

Both the d/a converter and t/h amplifier are housed in hermetic DIPs that measure 1.4 × 0.8 × 0.2 in., not including pin height. There are two versions of the ADH-30 d/a available: the 030-8, with a current output linearity of 0.2%; and the 030-10, with a linearity of 0.05%.

Either d/a has a resolution of 12 bits and settles to within 0.01% of final value in 50 ns. The converters have current output capabilities of 0 to −16 mA or ±8 mA and a tempco of ±25 ppm/°C. Glitch height for the converters is ±40 mV with a duration of approx 6 ns per peak.

The ADH-050 t/h amplifier, which has a 500-ps aperture time and 120-ns acquisition time, also comes in two versions: the 050 and 051.

The 051 has a longer acquisition time (600 ns) because it uses a larger internal holding capacitor. The larger capacitor also reduces the slew rate from 200 V/μs for the 050 to 40 V/μs typical, and it drops the signal bandwidth from 5 MHz to 1 MHz. It improves the drift,

(continued on page 114)

INFORMATION RETRIEVAL NUMBER 63

(continued from page 112)
however, from 1 mV/μs to 0.2 mV/μs. Both t/h amplifiers handle ±5-V signals and have linearity of 0.0125%.

You pay for the high speed—and not only in dollars—since these units use ECL circuits. Power consumption is a high 9 W maximum for the a/d, 2.275 W for the t/h and 1.5 W for the d/a.

Prices for the modules in unit quantities follows: ADH-8/1-3, $675; 8/1-1, $845; 10/1-3, $725; 10/1-1, $895; ADH-050 or 051, $275; ADH-030-8, $250; and 030-10, $295.

All units are available with delivery times of 2 to 6 weeks and operate over a temperature range of −55 to +85 C. Processing to MIL-STD-883, level C, is standard, and level B processing is available at slightly extra cost.

CIRCLE NO. 301

Adjustable timers have dpdt output contacts

Syracuse Electronics, P.O. Box 566, Syracuse, NY 13201. (315) 488-4915. From $16; 8 wk.

The TNR series timer has a repeat accuracy of ±2% (typical) and 10-million-operation reliability. The TNR is a dpdt timer. It is plug-in, adjustable and comes in a wide range of delay intervals and input voltages. Plug-in timers are available over standard operating ranges of 0.1 to 480 s. Within each range, the timer is locally or remotely adjustable, and will accept variable input voltages from 12 to 115 V ac and from 24 to 230 V dc. Maximum output is 2 W. Reset time is 100 ms during and after timing. The timer will operate according to specs at temperatures ranging from −10 to +60 C.

CIRCLE NO. 324

Scanning sequencer made for thermocouples

Omega Engineering, Box 4047, Stamford, CT 06907. (203) 359-1660. $329; stock.

The Model 1695 thermocouple scanning sequencer automatically samples up to 24 thermocouples. It has a continuously variable channel dwell capability and can be set from 5 s to 1 min to reach each thermocouple. To change the amount of dwell-time for a particular thermocouple reading, rotate the dwell-time indicator a few degrees. The sequencer can be used with any thermocouple calibration. The unit is designed to operate from 110 V ac and consumes only 10 to 40 W during scanning. In addition to continually scanning up to 24 thermocouples, the 1695 can be operated manually as a 24-position thermocouple selector switch or anywhere sampling of various signals is desired.

CIRCLE NO. 325

14-bit d/a converter has 15 μs settling time

Analogic, Audubon Rd., Wakefield, MA 01880. (617) 246-0300. $129; stock to 2 wk.

The MP1814 digital-to-analog converter provides 14-bit resolution. The unit also includes a high speed voltage amplifier that slews at 10 V/μs. It has a throughput settling time of less than 15 μs for conversion to within ±0.005% of a full 20-V step. The MP1814 has pin-selectable analog output ranges of ±10, ±5, 0 to 10 and 0 to +5 V.

CIRCLE NO. 326

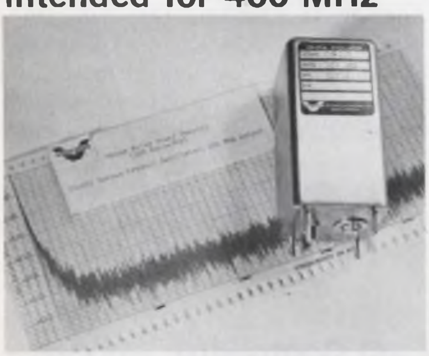
Monopulse comparator has 0.1 to 50 MHz range

Olektron, 6 Chase Ave., Dudley, MA 01570. (617) 943-7440. $185.

The Model P-MC-50 monopulse comparator has four antenna inputs and provides reference, elevation, and azimuth. When used with a four-sector antenna array the comparator network provides boresight axis information for directing the array. Basic specifications of the comparator are as follows: frequency range, 100 kHz to 50 MHz; impedance, 50 Ω (all ports); VSWR 1.2 to 1 (all ports); isolation, 30 dB min between antenna ports; insertion loss, 0.5 dB (max); amplitude and phase balance, 0.25 dB and 3°, respectively; and boresight null depth, 35 dB on azimuth and elevation. The comparator measures 1.23 × 1.109 × 0.5 in.

CIRCLE NO. 327

Vhf crystal oscillators intended for 400 MHz



Vectron Laboratories, 121 Water St., Norwalk, CT 06854. (203) 853-4433. From $325 (unit qty.); 1 to 4 mo.

Model CO-224 vhf crystal oscillator is available at any fixed frequency in the 25 to 400 MHz range. It provides an output level of 20 mW (+13 dBm) up to 200 MHz and 7 mW (+5 dBm) up to 400 MHz. The signal-to-noise ratio is 130 dB/Hz, 1 kHz from carrier. Aging is lower than 1×10^{-8} per day and temperature stability of $\pm 5 \times 10^{-8}$ over 0 to 50 C is achieved by housing the oscillator in a proportionally controlled oven. Options include operation over the −55 to +85 C temperature range and voltage frequency control to permit phase locking on to an external reference or for remote frequency control.

CIRCLE NO. 328

CRT terminal enhanced by microprocessor

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. (415) 493-1501. From $2640 (qty 6); Stock.

First in a series of new microprogrammed computer terminals, the Model 2640A CRT Terminal operates in either a page mode or a character mode. Among the benefits of microprocessing are a smart memory that can store over 400 lines of data (that can be viewed 24 lines at a time) up to four plug-in character sets, off-line data preparation and editing capability, and easy expandability. The user can verify and correct data before transmission to the CPU. The Model 2640A transmits one character or a block of characters at a time. Asynchronous data transmission of ASCII characters is RS-232-C compatible and selectable rates up to 2400 baud. The Model 2640A can be equipped with up to 14 powered slots of memory or peripheral interface.

CIRCLE NO. 329

Fast floppy-disc system boasts long life

Fort Communications, 710 North Central, Richardson, TX 75080. (214) 690-0050. $3500; 60 days.

A flexible disc system with hard disc longevity is available for CAI computers and PDP-11s. The controller fits on a half board, and handles up to eight drives. Each disc has a 2.16 M user bit capacity with a 17.26 M bit capacity for an eight drive system. Track-to-track seeks take 100 ms with 300 ms for 63 tracks. Data are transferred at 2.5 Mbit/s in DMA or regular I/O modes.

CIRCLE NO. 330

When "off the shelf" won't do, call us!

If you're talking precision pots, then talk to Duncan. For the past 15 years, Duncan's crack engineering team has designed literally thousands of 'specials.' We're proud to have some of the nation's finest technical minds to help solve your engineering problems. And a short step away is Duncan's modern production and testing facilities. Since 'specials' are a major part of our regular business, you'll be equally impressed by our competitive prices and unusually quick delivery schedules.

Duncan is keeping up and ahead of our times to meet your growing requirements for better more reliable products; including non-wirewound Resolon® Conductive Plastic elements and single-turn or multi-turn precision wirewound pots, both available with linear or non-linear functions. Call us for design assistance or write today for technical literature.

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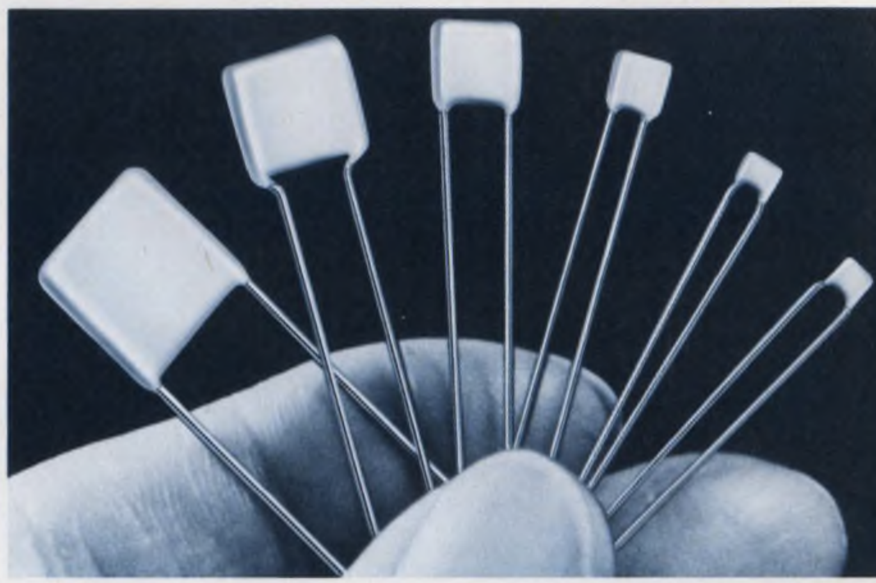
INFORMATION RETRIEVAL NUMBER 74

QUALITY IN VOLUME

When you achieve it, you can offer true competitive value. That's just what we're doing at USCC/Centralab for 1975. MONO-KAP™ radial, and MONO-GLASS axial monolithic ceramic capacitors are now available to volume users *from stock* to eight weeks. Our investment and "learning curves" last year guarantee competitive responsiveness – USCC will welcome your specials and non-stock orders. Here's an offer you haven't heard lately – your money is going to buy more at USCC. Cash in on the best values in monolithic ceramic capacitors.

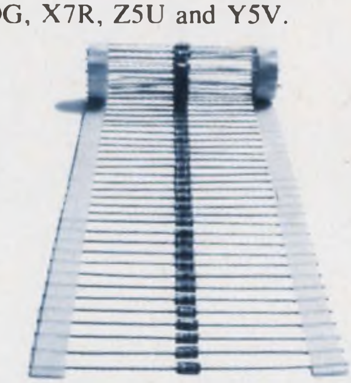


DISCRETE ASSEMBLY

MONO-KAP™ radial-leaded epoxy coated capacitors are reliable performers; they're rugged enough to work in MIL environments. 4.7 pF to 10 Mfd., 50 to 200 WVDC in 4 dielectrics, including Z5U, in a variety of case sizes featuring meniscus control to 0.032 inches. Large quantity orders from stock.

AUTOMATIC INSERTION

MONO-GLASS axials are glass encapsulated, designed for automatic PCB insertion; furnished reel-packed for high volume applications. They're available in 50 and 100 WVDC from 1 pF to 1.0 Mfd.; four dielectrics: COG, X7R, Z5U and Y5V.



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INFORMATION RETRIEVAL NUMBER 75

Printer/plotter offers 200 dot/in. resolution

Gould, Inc., Instrument Div., 20 Ossipee Rd., Newton, MA 02164. (617) 969-6510. $9700; stock.

An electrostatic printer/plotter with a resolution of 200 dots/in., the Model 5200, provides 0.2% accuracy for graphic plots. When printing, the unit generates 132 characters per line at 650 line/min. with fixed character spacing on 11-in. wide paper. The 5200 also has the ability to generate variable spacing between characters. Printing and plotting software packages and on-line/off-line hardware packages are available for most computer systems.

CIRCLE NO. 331

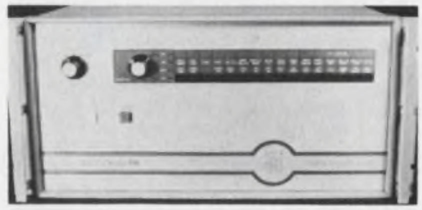
Modem does 9600 bit/s on unconditioned lines

Intertel, 6 Vine Brook Park, Burlington, MA 01803. (617) 273-0950. $9700; 30 days.

The MCS9600 is said to be the first 9600-bit/s modem to operate over unconditioned private telephone lines. Normally C2 or D1 line conditioning is required in order to improve leased telephone lines for use with conventional modems. The MCS9600 can also be multiplexed to mix 2400, 4800, and 7200 bps data rates. A switched carrier control capability allows multiplexing in multipoint networks without any hardware or software modification to the central computer or front-end equipment.

CIRCLE NO. 332

Minis linked to maxi over 1-mile coax cable



Systems Associates, 55 Park St., Troy, MI 48084. (313) 585-7995. See text; 90 days.

Any mini can communicate to an IBM System/360 or 370 at 277 kbyte/s. The LLA 400 (long-line adapter) uses a single coax wire up to a mile in length. In addition the LLA 400 can communicate with up to 64 computers even in industrial environments. The protocol used is that of IBM's mini-oriented Sensor Based Control Unit. A complete unit with mini interface and single coax driver sells for $4500.

CIRCLE NO. 333

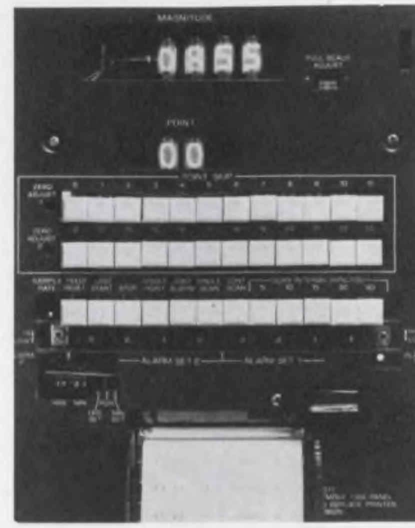
Line controller handles up to eight channels

Stritec, 5352 Sterling Center Dr., Westlake Village, CA 91361. (213) 889-3540. From $3508; 8 wks.

A flexible data line controller interfaces most RS-232-C comaptible devices with Honeywell minicomputers. Model S100 Asynchronous Interface unit is designed for use with H316, DDP416 and DDP-516 minicomputers and allows interface with line printers, CRTs, Modems and TTYs. They are provided with one to eight channels. Baud rate, data word length, parity mode and number of stop bits are independently programmable. Selectable baud rates (at time of order) range from 75 to 9600 baud with simultaneous reception and transmission capability.

CIRCLE NO. 334

Recorder has time printout and dual alarms



Doric Scientific Corp., 3883 Ruffin Rd., San Diego, CA 92123. (714) 565-4415. From $2195; stock to 5 wks.

Designed for industrial environments, the ruggedized Digitrend 200 will scan, display, log and produce alarm outputs from thermocouples, transducers, transmitters, strain gauges or other millivolt sources. An optional digital clock automatically adds the time-of-day to the recording and provides a continuous display in hours and minutes. If the power is interrupted for longer than 500 ms, the time display will flash on and off upon resumption of power and the time printout will be disabled until reset. A new feature is the dual alarm option—two separate alarm circuits that are common to all set-points to provide High/Higher, High/Low, and Low/Lower alarm setting capability.

CIRCLE NO. 335

Versatile matrix printer available as a plug-in

Practical Automation, Trap Falls Rd., Shelton, CT 06484. (203) 929-1495. $195; 4 wks.

An 18 column printer now exists as a plug-in module that measures only 3 × 3.5-in. on the panel. At 100 char/sec. the DMTP-3 prints 7 × 5 dot-matrix characters at a rate of 2.3 line/s. Interfaces to the printer can be serial, parallel or RS-232C.

CIRCLE NO. 336

Can't Tell A .015" PC Tape Width From A .020"?

Now You Can . . . AT A GLANCE . . . With Bishop's Exclusive New Color Core Coding!

No more "miking", guessing or measuring PC artwork tape widths . . . with Bishop tapes you *know*. New *color coded cores* tell you *instantly* . . . **and only Bishop has it!** You even get a full-color chart that identifies the color core with tape size. Affix it to your light table, drafting machine . . . anywhere it's handy. Think of the valuable time you'll save!

New Bishop FLAT Packaging

All Bishop PC Precision Slit Artwork tape now comes in a brand-new, flat package called the FLATPAK™. This reusable package keeps tapes clean, fresh and safe . . . prolongs shelf life.

Another Bishop Exclusive!

Each FLATPAK™ has dated labeling which not only gives tolerances, size, order no. and quantity . . . but shows "use before" dates for your protection . . . **and only Bishop has it!**

FREE Bulletin Tells All

New full-color Bishop Technical Bulletin No. 1019 tells the whole story. Call your local Bishop dealer for a copy and to order, or contact us direct.

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INFORMATION RETRIEVAL NUMBER 78

The New Brush 2400: the best performing, most versatile wide channel recorder you can buy.

It is available in 2, 3 and 4 channel configurations utilizing combinations of 50 mm and 100 mm channels totalling 200 mm. It has a 99.65% linearity over the full 100 mm channel. Its frequency response is an outstanding 30 Hz at 100 mm, 50 Hz at 50 mm and up to 125 Hz at reduced amplitude. It has a full range of plug-in signal conditioners for just about any industrial-scientific-medical application.

For full details on why the new Gould 2400 is the best performing direct writing recorder you can buy, write Gould Inc., Instrument Systems Division, 3631 Perkins Avenue, Cleveland, Ohio 44114. Or Kouterveldstraat 13, B 1920 Diegem, Belgium.

GOULD

INFORMATION RETRIEVAL NUMBER 79

Now... AC MEASUREMENTS GO DIGITAL!

- True RMS Volts
- True RMS Current
- AC Watts

. . . all in YEW's new 2504 AC DMM!

The new 2504 digital AC instrument offers unexcelled accuracy and versatility for the measurement of sinusoidal and non-sinusoidal waveforms and for measurements at low power factors. Flexible design allows optional purchase of just the measuring functions required while push-button controls provide ease of operation.

The YEW 2504 is **the** AC DMM. Its 0.25% accuracy and 0.01% resolution, standard analog output, and low cost (Prices start at $1,590.) make it the ideal instrument for quality control, lab, field maintenance, and instrument calibration applications. Write for details.

Standard ranges (Multirange Model):
30V/60V/100V/150V/300V,
0.5A/1A/2A/5A/10A (15W to 3,000W)
Frequency range: 25 Hz to 1 kHz

YEW® Yokogawa Electric

YEWTEC CORPORATION
1995 Palmer Avenue
Larchmont, N.Y. 10538
Telephone: 914-834-3550

60 Years of Measuring and Recording Instrumentation

INFORMATION RETRIEVAL NUMBER 80

POWER SOURCES

500-W switching supply weighs in at just 14 lb

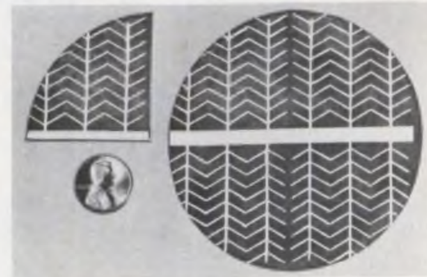
Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. (415) 493-1501. $650; 6 wks.

This 500-W, 5-V switching-regulated (20 kHz) modular power supply, Model 62605M, reduces heat-sink requirements and permits greater freedom in mounting. Integral forced-air cooling in many cases eliminates other in-cabinet cooling. Inherent efficiency is approx. 70%. Size is 5 × 8 × 11-1/2 in. and weight is 14 lbs. Regulation is to 0.1% with ripple and noise of 20 mV rms, 40 mV pk-pk (20 Hz to 20 MHz).

CIRCLE NO. 337

INFORMATION RETRIEVAL NUMBER 81

Silicon solar cell delivers 1 A



Edmund Scientific, 380 Edscorp Bldg., Barrington, NJ 08007. (609) 547-3488. $19.95; stock.

A new 3-in.-diameter silicon solar cell will deliver over 1 A at 0.5 V dc, or 1/2 W. It is said to be five times more efficient per unit cost than any cell previously offered. For higher current requirements, multiple cells can be hooked up in parallel. Or the cells can be used in series for higher voltage applications. Since the new cell uses no plastic lenses to increase its efficiency, it is extremely flat—only one mil thick; and the cell is complete with tab leads for any circuit.

CIRCLE NO. 338

Switcher line covers 150 to 750 W

ACDC Electronics, Oceanside Industrial Center, Oceanside, CA 92054. (714) 757-1880. About $275 (150-W unit); 2 to 4 wks.

Six new high-efficiency, switching-type power supplies have been added to the company's JP series. The additions include a 750-W and five 150-W units. This brings the JP Series to a total of 16 models, ranging from 150 to 750 W. These 20-kHz inaudible switchers operate from a selectable input of 115/230 V ac (100 V ac also available), 47 to 63 Hz, with 70 to 80% efficiency and 0.1% regulation. Overvoltage and overload protection are standard and radiated and conducted EMI is minimized by shielding and filtering.

CIRCLE NO. 339

TEC LITE

LOW-COST LED DIGITAL READOUTS IN RED, ORANGE, YELLOW OR GREEN

Solid State Modules Come Ready to Install and Operate – Include Decoder/Driver and all Circuitry Needed to Hook up to Your System

- **Standard 0-9 plus overflow, with character heights of 0.30" and 0.40" – and both sizes at the same low price!**
- **Accept BCD input code**
- **Compatible with TTL**
- **Optional bezel with choice of 5 filters**

And Immediate Delivery!

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Century Aero Corp., So. California	*(213) 772-1166*
Peerless Radio Corp., Florida	*(305) 566-5966*
Ratel Electronics, No. California	*(415) 965-2010*

0.30" High: MDA-6151 (green), MDA-6171 (red), MDA-6181 (yellow), MDA-6191 (orange)
0.40" High: MDA-7151 (green), MDA-7171 (red), MDA-7181 (yellow), MDA-7191 (orange)

TEC, Incorporated • 9800 NORTH ORACLE ROAD • TUCSON, AZ USA 85704 • (602) 297-1111 • TWX 910-952-1377

INFORMATION RETRIEVAL NUMBER 82

PREMIUM QUALITY COMPONENTS

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FIRST QUALITY ONLY

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	1–9	10 up
4000AE	.48	.45
4001AE	.48	.40
4002AE	.48	.40
4004AE	5.85	5.85
4006AE	3.50	3.30
4007AE	.48	.42
4008AE	2.90	2.70
4009AE	.87	.86
4010AE	.55	.54
4011AE	.48	.45
4012AE	.48	.45
4013AE	.95	.85
4014AE	2.80	2.50
4015AE	2.80	2.50
4016AE	1.00	.90
4017AE	2.60	2.50
4018AE	2.80	2.60
4019AE	.95	.85
4020AE	2.80	2.60
4021AE	2.70	2.50
4022AE	2.70	2.50
4023AE	.48	.45
4024AE	1.80	1.60
4025AE	.48	.45
4026AE	8.40	7.90
4027AE	1.20	1.00
4028AE	2.20	2.00
4029AE	4.00	2.90
4030AE	1.00	.90
4033AE	3.40	2.90
4035AE	2.80	2.75
4040AE	2.80	2.60
4041AE	1.20	.90
4042AE	2.80	2.60
4043AE	2.80	2.60
4044AE	2.80	2.60
4047AE	3.10	3.00
4048AE	1.45	1.35
4049AE	1.10	.90
4050AE	1.10	.90
4051AE	3.35	2.90
4052AE	2.15	2.05
4053AE	2.90	2.80
4055AE	2.70	2.60
4056AE	3.45	3.41
4060AE	3.30	3.00
4066AE	1.80	1.60
4069AE	.80	.70
4071AE	.50	.45
4076AE	2.70	2.50
4081AE	.48	.42
4508AE	3.90	3.50
4510AE	2.70	2.50
4516AE	2.90	2.80
4518AE	3.30	3.00
4520AE	3.30	3.00
4901AE	.48	.42
4911AE	.45	.42

TWO-PHASE MOS CLOCK DRIVER
MH0026CN
$5.50

74LS

74LS00	.58	74LS76	.92
74LS01	.58	74LS78	.92
74LS02	.58	74LS107	.92
74LS03	.58	74LS109	.92
74LS04	.63	74LS112	.92
74LS05	.63	74LS113	.92
74LS08	.58	74LS114	.92
74LS09	.58	74LS138	2.38
74LS10	.58	74LS139	2.38
74LS11	.58	74LS151	2.10
74LS15	.58	74LS153	2.38
74LS20	.58	74LS157	2.10
74LS21	.58	74LS158	2.40
74LS22	.58	74LS160	2.70
74LS27	.64	74LS161	2.70
74LS30	.58	74LS170	5.92
74LS32	.64	74LS174	3.02
74LS51	.58	74LS175	2.90
74LS54	.58	74LS181	3.72
74LS55	.58	74LS251	2.55
74LS73	.92	74LS253	3.05
74LS74	.92	74LS260	.58

Microprocessors $79.95

8 Bit Parallel CPU on a single chip • complete instruction decoding and control • TTL compatible (Inputs, Outputs and Clocks) • Address or retrieve 16K x 8 bits of memory (RAM, ROM or SR) • DIP package. Build your own micro-computer with one CPU, one added ROM and 20 added TTL interface devices. **Type 8008: $79.95 - Type P2102 Static RAM: $8.00**

MOS-LSI

P1101A	6.90	C2102-2	8.00
P1101A1	8.50	P2102-2	6.00
1402AN	5.40	2505K	3.30
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C2102	8.00	MM5055N	5.50
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P2102-1	6.00	MM5058N	5.50

TERMS: Check or M.O. (no C.O.D.) minimum order $10.00 (add $1 to cover postage & handling) California residents add 6% sales tax.

SPECIFICATION SHEETS: $.25 ea.

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ANCRONA CORP.
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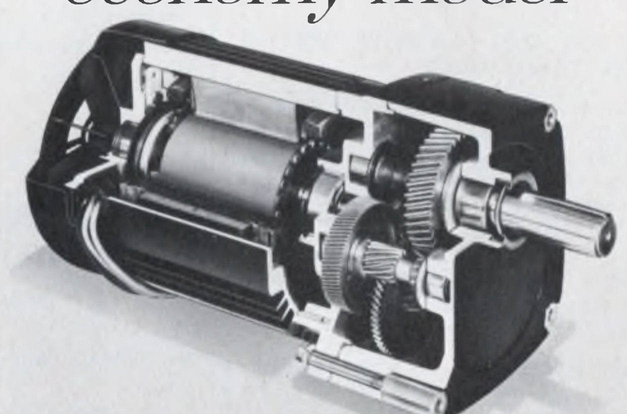
INFORMATION RETRIEVAL NUMBER 83

economy model



Bodine makes quality fhp motors and drive systems. Some may cost a little more. Initially. But, in the long run they cost less to use.

After Delivery Economies (ADE) are the reason. You get fewer rejects. Consistent quality, motor to motor, lot to lot. Less profit robbing service and downtime problems. Bodine motors perform. Reliably. Run stronger and last longer. Help protect your reputation and profit.

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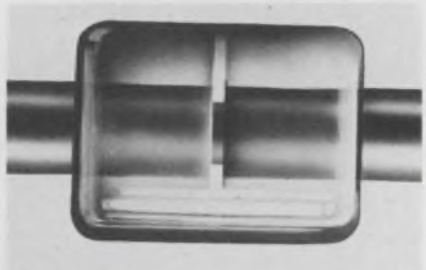
Bodine Electric Company, 2528 W. Bradley Place, Chicago, IL 60618

INFORMATION RETRIEVAL NUMBER 84

Varactor tuning diodes have low inductance



MSI Electronics, 34-32 57 St., Woodside, NY 11377. (212) 672-6500. $5.50 (100-up); 2 wk.

The G801A to G522A varactor tuning diodes have the silicon chip in butt contact with the DO-35 case leads. This eliminates whiskers or ribbons that contribute to series inductance. The resulting packages have a 1.5-nH inductance, which, with a 0.1-pF capacitance make the tuning diodes suitable for operation in the uhf and low microwave ranges. The 4-V capacitance values range from 1.8 to 22 pF and Qs from 800 for the low capacitance diodes to 500 for the higher capacitance diodes at 50 MHz. These capacitor diodes have less than 0.5 μA of leakage current at 20-V reverse voltage and exhibit capacitance ratios of 2:1 from 2 to 20 V.

CIRCLE NO. 340

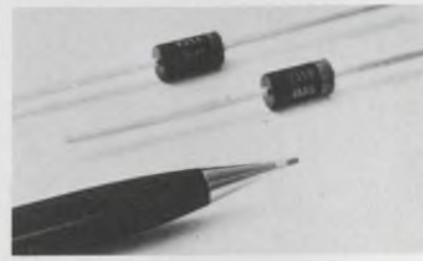
High voltage rectifiers handle up to 15 kV

Electronic Devices, 21 Gray Oaks Ave., Yonkers, NY 10710. (914) 965-4400. $0.50 (100,000 pcs); stock.

The SR-15 high stress silicon diode can handle 15,000 V PRV repetitive and 18,000 V nonrepetitive. The diode is designed specifically for use in 35-kV dc multiplier applications. Special construction and diffused junctions that have avalanche characteristics provide high surge capability, low leakage, and recovery time of 150 ns typical and 300 ns maximum. Diode diameter is 0.16 in. and body length is 0.6 in. Leads are a minimum of 0.5 in. long and have diameters of 0.02 in.

CIRCLE NO. 341

Silicon rectifier series has 200-A surge ratings



Varo Semiconductor, P.O. Box 676, 1000 N. Shiloh, Garland, TX 75040. (214) 272-4551. From $0.22.

A line of 32 rectifiers includes a controlled avalanche series with 250, 450, 650 and 850 V min. avalanche ratings, a noncontrolled avalanche series with 50 to 1000 V ratings (V_{RRM}), and a fast recovery time series with 200-ns reverse recovery time (t_{rr}). The devices are rated at 3 A (I_o) at $T_A = 40$ C, for both 100 and 200-A peak surge. The fast recovery series has a 75 and 150-A surge rating. Operating temperature range is -50 to $+150$ C. Part number designations for the 100 A surge line are V322, 4, 6, 8 (controlled avalanche), V330, 1, 2, 4, 6, 8, 10 (noncontrolled avalanche) and V330X, 1X, 2X, 4X and 6X (fast recovery).

CIRCLE NO. 342

LED lighted switches come in three colors

Dialight, 203 Harrison Pl., Brooklyn, NY 11237. (212) 371-8800. From $2.59 (1000-up); 3 to 4 wk.

The series 913 miniature, momentary action switches are available with red, green or yellow LEDs. The LED in the switch operates from a 5-V-dc supply. The switch is available in either a normally-open, normally-closed, or two-circuit version. A long cylindrical lens cap has an internal fresnel ring for uniform light distribution.

CIRCLE NO. 343

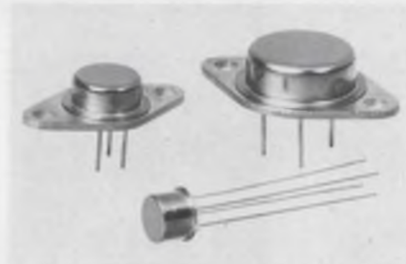
Schottky mixer diodes have high dynamic range

Alpha Industries, 20 Sylvan Rd., Woburn, MA 01801. (617) 935-5150. $8.25 (1000-up); 10 to 30 day.

The D4007 Schottky barrier silicon diodes provide low intermodulation distortion performance in local oscillator/mixer high-drive level applications. These diodes have beam-lead construction and are mounted in a quad configuration to achieve minimum size and optimum uniformity. The diodes are available for use through the X-band frequency range. Typical turn-on voltages are 600 mV at a 1 mA current level. The mixer quads are mounted on the company's 132-002 four lead ceramic substrate package. Max junction capacitance at $V_R = 0$ V is 0.6 pF, total resistance at $I_F = 10$ mA is 12 Ω, and the storage and operating temperature range is −65 to +150 C.

CIRCLE NO. 344

High-voltage Darlingtons handle up to 300 V

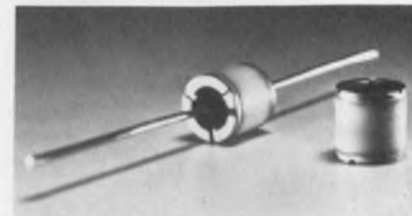


Unitrode, 580 Pleasant St., Watertown, MA 02172. (617) 926-0404. From $3.40 (100-up); 2 to 3 wk.

The U2T700 and U2T800 series high voltage Darlington transistors are available in hermetic TO-5, TO-66 and TO-3 packages. They are rated up to 300 V BV_{CEO} and can handle dc currents to 5 A or pulse currents to 10 A. Gains are typically 2000 at rated dc currents, thus making it possible to switch high power dc loads directly from low level logic. All types in both the 2 A, 700 series and 5 A, 800 series have provision for external biasing of both input and output transistors.

CIRCLE NO. 345

Surge arresters handle voltage spikes of 230 V



Cerberus AG, CH-8708 Mannedorf, Switzerland.

The Cerberus surge arresters are compact metal/ceramic devices that have a fast and accurate response, a very high shunt capacity and consistent performance, even after loading. All arresters maintain their tolerances and meet the CCITT and VDE 0845 requirements. Some of the surge arrester specs include: static sparkover voltage of 230 V ±10%, dynamic sparkover voltage (at dU/dt of 2 kV/μs) of 600 V, impulse discharge current (Form 8/20) of 25 kA and an ac discharge current (1 s, 50 cycles) of 20 A. Case dimensions are 8 mm long and 8 mm in diameter.

CIRCLE NO. 346

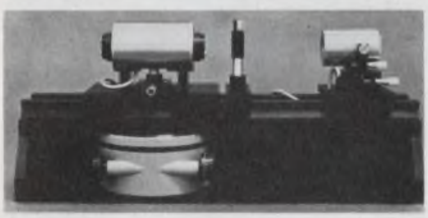
System monitors noise and gain

International Microwave Corp., 33 River Rd., Cos Cob, CT 06807. (203) 661-6277.

The NTM-0260R system for noise and gain monitoring consists of compact solid-state modules, which readily integrate into earth stations or radar equipment. Rf range extends from 300 MHz to 18 GHz, depending on the noise source used, and i-f range is 30 to 100 MHz. The system has a noise-temperature spec of 200 to 9000 K, and a gain range of ±3 dB. Accuracies are ±6% for noise temperature and ±0.25 dB for gain.

CIRCLE NO. 347

Tunable laser emits visible-to-IR spectrum



Interactive Radiation Inc., 406 Paulding Ave., Northvale, NJ 07647. (201) 767-1910.

With a new tunable laser, output wavelengths can be continuously tuned over the spectral range from 415 to 2100 nm. A 20-J ruby-pump input yields an optical-parametric-oscillator output of 3 to 20 kW per pulse unfocused. The pulse width is 5 ns and the line width is 0.01 nm in blue, increasing to 0.3 nm at 630 nm. The beam divergence is 2 mr at 470 nm in the TEM_{00} mode.

CIRCLE NO. 348

New vendor takes over plug-in line

Optimax Inc., P.O. Box 105, Advance Lane, Colmar, PA 18915. (215) 822-1311.

Filling the market void created by Fairchild's recent withdrawal from the hybrid amplifier and attenuator business, the company is now offering the equivalents to the Fairchild FMA Series of modular plug-in components in TO-3, TO-8 an DIP packages.

CIRCLE NO. 349

Transmitter tests noise loading

The Model 4641 baseband noise transmitter provides band-limited white noise for noise-loading microwave-radio relay systems. The transmitter features selectable band limiting and band-stop filters for two separate radio loads, simulating up to 2100 channels of voice traffic. Output power is 0 to −29 dBm adjustable in 1-dB steps. Band-stop filters provide noise discrimination greater than 70 dB over 3-kHz bandwidth.

Scientific-Atlanta, Inc., 3845 Pleasantdale Rd., Atlanta, GA 30340. (404) 449-2000. Under $1900; 8-10 wks.

CIRCLE NO. 350

Synthesizer spans 0.5-to-18-GHz range

Watkins-Johnson Co., 3333 Hillview Ave., Palo Alto, CA 94304. (415) 493-4141.

With new components for the company's WJ-1250 Modular Synthesizer System, automatic coverage is obtained over the full 0.5-to-18-GHz frequency range. The new WJ-1253A Multisource Chassis houses up to three WJ-1251 Series rf sources. These are automatically interfaced with the WJ-1250 microwave frequency synthesizer mainframe via the WJ-1253B Interface Module. By stacking two Multisource Chassis, up to six rf sources can be accommodated. Two new double-band rf sources, employing fundamental YIG-tuned oscillators, have also been introduced. The WJ-1251-7 provides 5 mW (min) output power from 8 to 18 GHz, while the WJ-1251-8 supplies 20 mW (min) over the 1-to-4-GHz band. With the present WJ-1250 system, 5 mW, 10 mW or higher minimum output power can be provided, and 100-kHz resolution and 3 parts per 10^9/day long-term stability are standard.

CIRCLE NO. 351

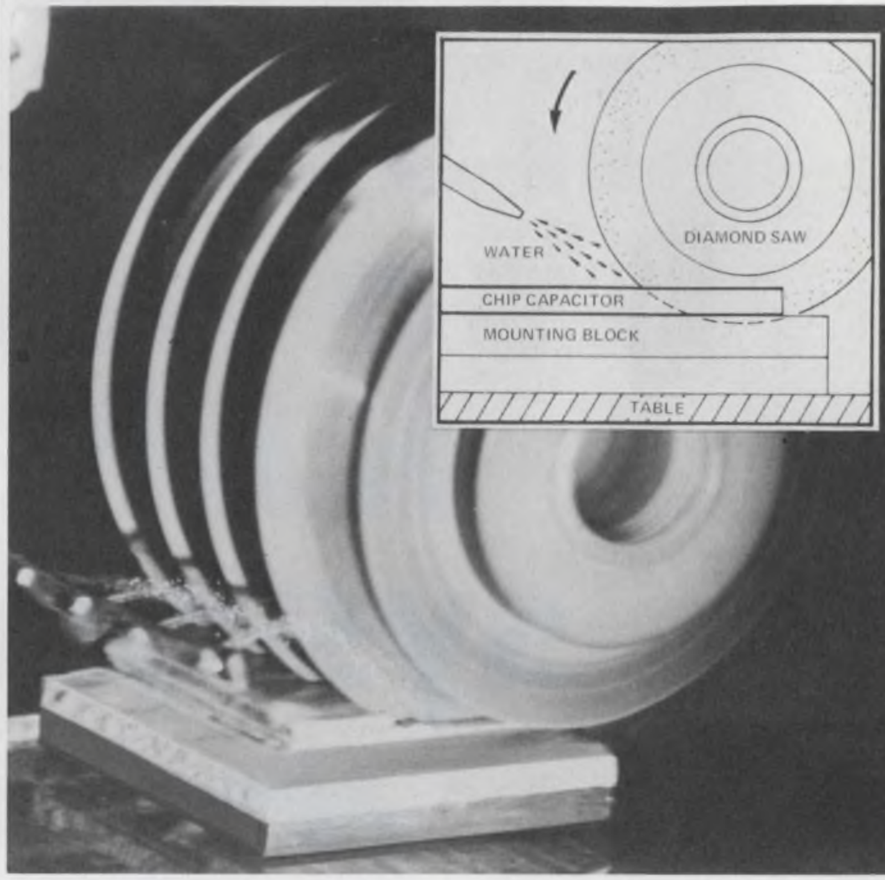
8-GHz TWTs output 500 W

Varian, 611 Hansen Way, Palo Alto, CA 94303. (415) 493-4000.

Traveling wave tubes are offered for use in ground-based cw satellite transmitters. The VTX-6281H3 operates from 7.9 to 8.4 GHz, and it delivers a saturation output of at least 500 W. A control anode permits pulse modulation. The VTX-6281H3 has a minimum gain of 37 dB at 500-W output, maximum noise figure of 35 dB and load VSWR of 1.15:1. It weighs only 12 lb. A 250-W version—the VTX-6281H2—is also available.

CIRCLE NO. 352

High-voltage chip capacitor? Cut your own from a slab



Semtech Corp., 652 Mitchell Rd., Newbury Park, CA 91320. (805) 498-2111. See text; stock to 4 wk.

A major bottleneck in the design and prototyping of high-voltage circuits is the lack of a large variety of capacitance values for high-voltage chip capacitors. Along comes the Semtech Corp., and it says, in effect: "If you need a high-voltage chip capacitor of a particular value, cut it yourself."

Available from the company are high-voltage slab capacitors, Series SC6000, that can be cut either by diamond saw or laser to custom capacitances and shapes. Once the prototype has been determined. Semtech can provide the required size and shape in large quantities.

Each slab is a single layer of barium titanate ceramic, with either silver or palladium silver terminations for contact to the circuit. Slabs come in various sizes—from 0.6 × 0.6 in. to 1.8 × 1.8 in., and in capacitance values up to 23,000 pF.

Voltage ratings of 2, 3, 4, 7.5, 10, 15, and 20 kV are standard. Up to 70-kV slabs can be provided, with low-capacitance values on special order.

Semtech guarantees that all slabs are corona free within the voltage rating and are of uniform dielectric strength and value throughout. Capacitance tolerance can be specified as +10%, +20% or +100%, −0%.

Insulation resistance is 100 kΩ or 1000 MΩ-μF, whichever is less at 25 C and 500 V dc. A maximum dissipation factor of 2.5% and a ±15% max temperature characteristic for the X7R ceramic (ΔC between −55 and +125 C) are standard.

(continued on page 134)

We make deliveries

FMC 40C Thyristors are available for off-shelf delivery and immediate installation. Designed in a T065 case, this power semiconductor replaces bulky T094 and T083 packages and upgrades 35 amp devices to 40 amp.

The FMC 40C Thyristor is equivalent to IR-40RCS and GE-C147 and operates at a higher case temperature of 95°C.

For detailed information, contact:
FMC Corporation
Semiconductor Products Operation
Homer City, Pa. 15748
(412) 479-8011

FMC Special Products

INFORMATION RETRIEVAL NUMBER 93

COMPONENTS

(continued from page 132)

Since the edges of these chip capacitors are unfinished after cutting, they must be used in circuits that are to be potted before use.

In 1-to-10 quantities the slabs cost from 66 cents to $10 apiece, depending upon size and value. At the 100-quantity level, the price dips to 45 cents to $7. Large quantities of a single capacitor cut to order cost about 50% less than the 1 to 10 quantity price of an uncut slab of similar value.

CIRCLE NO. 306

Solid tantalum caps are plastic encapsulated

Arco Electronics, Community Dr., Great Neck, NY 11022. (516) 487-0500. $0.16 to $0.90 (1000 up); stock.

Miniature, plastic-encapsulated, dipped, tantalum capacitors, type ART, are designed with a solid electrolyte plus a highly stable oxide layer and finished with an epoxy coating. The tantalums have a capacitance range from 0.1 to 680 μF and tolerances of ±20% or ±10%. The working voltage range is 3 to 50 V dc. Straight leads are standard, crimped, formed, leads are optional.

CIRCLE NO. 353

Set time digitally in delay relay

International Microtronics Corp., 4016 E. Tennessee St., Tucson, AZ 85714. (602) 795-9440. $16 to $34.95 (unit qty).

A digitally controlled time-delay relay, the 276 series, uses a frequency-division technique to generate time delays. The desired time delay is selected by setting binary-coded miniature switches. The delays have 0.5% accuracy and repeatability, and a zero-crossing switching circuit is used. The standard time range is 1 s to 4-1/4 min. Other models from 16 ms to over 29 h and accuracy to ±0.05% are also available.

CIRCLE NO. 354

This is not a semiconductor memory.

But then, semiconductor memory isn't always the answer. What you're looking at is our new 16K X 20 core memory board. It's the newest addition to our fine family of compatible memory products. (We reduced it just to get your attention).

We call this board the Harris 3800. You'll call it reliable. Reliable because they meet the exacting demands of our own computer systems. And, they'll meet the unpredictable demands of your unpredictable needs.

Harris memories. Another source when you need economy in quantity purchases. When you need field proven memories. When you need custom design. Or when you expect reliability.

- 250 ns access time
- Size: 11½ X 13¾
- Power required: +15 vdc, +5 vdc
- cycle time 650 ns
- random access
- no field adjustments

Write for the newest in 16K memory boards... the newest non-semiconductor that is. But if your need is semiconductor... we'll be pleased to discuss pin compatible HARRIS semiconductor memory systems.

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1200 Gateway Drive, Fort Lauderdale, Florida 33309 (305) 974-1700

INFORMATION RETRIEVAL NUMBER 100

COMPONENTS

Single in-line package houses resistor network

Beckman Instruments Inc., 2500 Harbor Blvd., Fullerton, CA 92634. (714) 871-4848. 784-1: $0.65; 784-3: $0.60; (1-99).

Single in-line packaged resistor network, Series 784-1, contains seven equal resistors with a common termination at pin 1. Series 784-3 contains four equal, but isolated resistors. Resistor tolerance is ±2%. Each of these eight-pin networks comes in 15 different resistance versions from 100 Ω to 22 kΩ. Other resistance values or configurations can be special ordered on an OEM basis. The total package dissipation rating is 2 W at 25 C. Individual resistors are rated at 0.3 W for the 784-1 and 0.5 W for the 784-3. Maximum recommended operating temperature is 125 C.

CIRCLE NO. 355

INFORMATION RETRIEVAL NUMBER 101

Tiny rotary switch provides coded output

Janco Corp., 3111 Winona Ave., Burbank, CA 91504. (213) 845-7473.

A new miniature rotary switch for circuit board applications, the Janco Mini Code switch, is similar to a thumbwheel, but it occupies much less space. The unit measures 3/8-in. high and is less than 9/10 in. in diameter so that it can be used with card racks on 1/2-in. centers. The unit can be produced to provide decimal, octal, hexadecimal and most other common digital codes. Markings can be parallel to any axis and in any of six colors. Also the switch can be lighted internally. Seals, rotational stops and accessories to gang units for panel mounting are available. The basic switch is designed to meet the environmental requirements of MIL-S-22710.

CIRCLE NO. 356

Fiber-optic display gives high brightness

Industrial Electronic Engineers, Inc., 7720-40 Lemona Ave., Van Nuys, CA 91405. (213) 787-0311. $28.35: Numeric (250 up); 4-6 wks.

Special for avionics and cockpit applications, IEEE-Hellios high-intensity fiber-optic displays provide both high-density packaging and extreme brightness. The units are available in either seven-segment numerical or 16-segment alpha-numerical models with 1/4-in. high characters. They conform to MIL-E-5400 requirements, have a low power demand of 20 mA per segment at 5 V dc and standard modules are offered in from one to six digits. The units operate from −40 through 80 C and feature both easy readability in direct sunlight and controlled brightness for night vision. Average life expectancy for the subminiature incandescent lamps is 10,000 h at 5 V.

CIRCLE NO. 357

OEM Buyers take note:
CONTROL DATA® Storage Module Drives Models 9760 and 9762.

40 and 80 megabyte capacities. Removable media.

9760—now being delivered in production quantities.

Features:

- Offers substantial lower cost per megabyte than current competitive products of equivalent capacity.
- Basic unit consists of a spindle and associated drive motor; voice-coil head positioner and servo systems; read/write, fault, transmitter/receiver electronics; and air filtration system.
- Options available include:
  - 5 power supply options for versatility.
  - phase-lock oscillator data separator and NRZ to MFM data encoder simplify interface design.
  - daisy-chaining for system expandability.
  - rack-mount package.
  - base cabinet for stand-alone configuration.
  - hysterisis brake to reduce pack stop time to 18 sec.
  - variable sector length for flexibility.
- Specifications
  Capacity - 40 MB - Model 9760/80 MB - Model 9762
  Average Access Time — 30 MS
  Bit Transfer Rate — 9.67 MHz @ 3600 RPM
  (Optional) — 6.45 MHz @ 2400 RPM
  Tracks per Inch — 192-9760/384-9762
  Bits per Inch — 6038
  Number of Disks — 5 (3 recording, 2 protective)
  Usable Surfaces — 6 (5 read/write, 1 servo)
- Deck and logic chassis hinged for easy access to all components.
- Compact size — 10.5" H x 17.25" W x 30" D.
- Field test exerciser with head alignment feature is available.

40 and 80 MEGABYTE STORAGE MODULE DRIVES . . . add a whole new dimension to meeting medium to large capacity storage needs in a package less than half the size of other drives; use CDC® 9876 or 9877 removable disk packs; pack has 5 disks (3 for data and head positioning, 2 for data protection); rack-mount package or optional base cabinet; daisy-chain interface; average access time 30 ms.; data rate 9.67 MHz (6.45 MHz optional); MODELS 9760 AND 9762 RESPECTIVELY.

Control Data Corporation
Ray Crowder, OEM Marketing Manager
Normandale Operations,
7801 Computer Ave. So.
Dept. ED-35 Minneapolis, MN 55435

CONTROL DATA
CORPORATION

Name

Title

Company

Address | Phone

City | State | Zip

☐ I want to see a demonstration of the Control Data Models 9760 and 9762 Storage Module Drive. Have my Representatvie call.

INFORMATION RETREIVAL NUMBER 102

CMOS MSI line expands with 2 ICs

Motorola Semiconductor, P.O. Box 20924, Phoenix, AZ 85036. (602) 244-3466.

The company's line of 14500 Series CMOS MSI circuits now includes an adder (MC14560) and 9's complementer (MC14561). The MC14560 can add two 4-bit natural binary-coded decimal (NBCD or 8-4-2-1 code) words. Consisting of a 4-bit binary full adder, the MC14560 operates with a typical quiescent power dissipation of 0.1 μW. The MC14561 is a 9's complementer consisting of a 4-bit binary adder and inverting logic on a single chip. When a BCD number (8-4-2-1 code) is applied to the data inputs, that number, or its 9's complement, appears at the outputs. Propagation delay is, typically, 130 ns, and all inputs are buffered.

CIRCLE NO. 358

MOS chips form terminal xmtr/rcvr

Nitron Corp., 10420 Bubb Rd., Cupertino, CA 95014. (408) 255-7550. $9 (100); stock.

The NC2257, 59 and 60 terminal transmitter/receiver MOS circuits provide the required interface for data systems using a serial communications link. All circuits are direct replacements for like-numbered Motorola ICs. The NC2257/NC2260 transmitters transform parallel binary data, in the form of characters, to serial data, with internally generated parity—even, odd, or none. Other features include externally selectable character length of 5, 6, 7 or 8 bits; 1 or 2 stop bits externally selectable for asynchronous mode; input clock frequency of 64, 16 or 1 times bit rate, and up to 200 bits per second. The NC2260 also provides internal clock and word-complete outputs. The NC2259 receiver accepts serial digital data from a modem or other source, organizes the data into fixed word lengths corresponding to characters and transfers these characters to a buffer register from which the character may be accessed in parallel form.

CIRCLE NO. 359

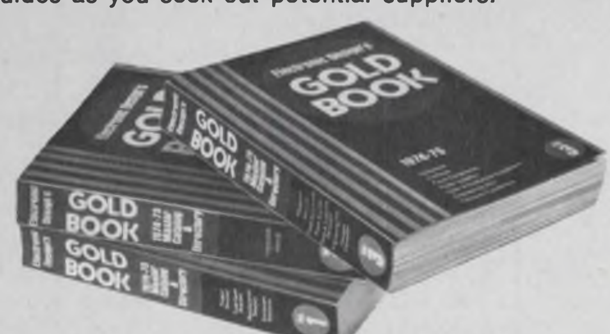
THIS SYMBOL "■" HAS A MESSAGE FOR YOU

Look at the listings magnified above. They're from the PRODUCT DIRECTORY of *Electronic Design's* GOLD BOOK. Note that each product classification begins with boldface listings. **These manufacturers have provided catalog pages for that product in vols. 2 or 3 of the GOLD BOOK.**

But what about the other companies shown? Do they really make the product or would they merely *like* to make the product if your order is big enough? A printer's bullet (■) in front of its name means that the company has submitted printed literature on that product to the editors of the GOLD BOOK. It's reasonable to assume that these suppliers actually make the product, for its not likely that a supplier would prepare literature for a product he can't ship. The bullet ■ gives you a measure of verification.

Manufacturers listed in boldface in the second sub-group have provided catalog pages, but not for the specific product heading the list.

In a constantly moving industry, these measures of verification are of course subject to change. Yet they can be helpful guides as you seek out potential suppliers.



Electronic Design's

GOLD BOOK

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INTEGRATED CIRCUITS

Low power Schottky-TTL aims for MIL uses

Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. (408) 739-7700.

Military-temperature range low-power Schottky-TTL circuits—the 54LS series—are offered by the company. Circuits operate at a toggle rate of 35 MHz. Power dissipation is 2 mW per gate and propagation delay is 8 ns. The 54LS series has a speed-power product of 15 pJ, or five times better than standard 5400-TTL circuits.

INQUIRE DIRECT

1-k shift register uses 5-V supply

Intersil Inc., 10900 N. Tantau Ave., Cupertino, CA 95014. (408) 257-5450. $9.90 to $16.80 (100-999); stock.

A static 1024-bit shift register —the IM7733—uses silicon-gate, n-channel MOS enhancement-mode technology. It has a 1024 × 1-bit organization, features TTL/DTL compatibility, uses a single 5-V supply and requires no external pull-up components. Clock to output data delay is typically 100 ns. An on-chip generator yields the three clock phases used in the static register cells. The push-pull output buffer provides a fanout of two TTL loads. The IM7733 is pin-for-pin compatible with the Signetics and AMD 2533, National's MM5058 and Texas Instruments' TMS 3133.

CIRCLE NO. 360

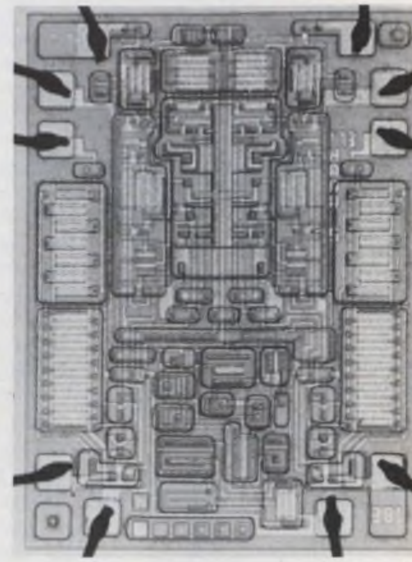
1-k static RAM has 500-ns access

SGS-ATES Componenti Elettronici SpA, Via C. Olivetti 1, 20041 Agrate (Milano), Italy

A 1024-bit static RAM, using n-channel silicon-gate MOS technology, operates from a single 5-V supply and doesn't require clocks or refresh. The output of the M 330 is read nondestructively, with the same polarity as the input data. Three versions are offered for these maximum access times: 500 ns (suffix C); 650 ns (suffix B), and 1000 ns (suffix A).

CIRCLE NO. 361

CMOS switch handles ±15-V signals



Harris Semiconductor, Melbourne, FL 32901. (305) 727-5407.

A dual SPST CMOS analog switch—the HI-200—is pin-for-pin and function-for-function replaceable with the DG-200 from Siliconix. (Within the next two months, Harris expects to alternate source the entire Siliconix CMOS analog-switch family.) The new switch has an analog signal range of ±15 V. Other features include DTL/TTL and CMOS compatibility, switch current of 80 mA at 25 C, power dissipation of 15 nW and typical ON-resistance of less than 60 Ω.

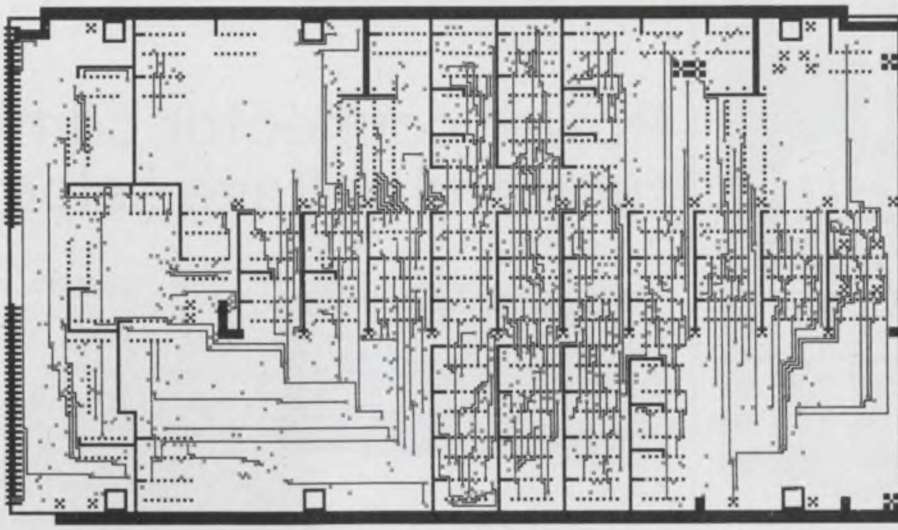
CIRCLE NO. 362

ECL family offers 1-GHz rates

Fairchild, Integrated Circuits Group, 464 Ellis St., Mountain View, CA 94042. (415) 962-3816. $2.05 to $54.95 (1000).

An ECL family—the F11C00 series—for instrumentation and communication applications kicks off with five circuits, featuring the 11C05, a 1-GHz divide-by-four counter which operates from standard ECL or TTL power supplies; and the 11C06, a 750-MHz D flip-flop. Both prescalers employ the company's Isoplanar II technology. The 11C44 phase/frequency detector can be used in synchronization applications. The 11C24 and 11C58 voltage-controlled multivibrators are intended for clock generators and as variable frequency elements.

CIRCLE NO. 363



By the time your drum plotter turns this out, a Gould printer/plotter can turn it out 400 times.

If what you're looking for is higher plotting speed and lower plotting cost, we've got something that can give you both. And something else besides.

A Gould electrostatic printer/plotter. The one that makes your old drum plotter remarkably underproductive. The one that gives you a useful printing capability in the bargain. A Gould plotter is so fast, it can turn out this plot in only 2 seconds – versus an average 13½ minutes for your old drum plotter.

And what gives that Gould plotter its blinding speed is its direct on-line operation to your computer. Whether it's the PDP-8/E, PDP-9, PDP-11, PDP-15, HP2100, Nova/Supernova, H316/516, Raytheon 704, UNIVAC 1108, IBM 360/370, CDC 3000/6000, Interdata 70 and more.

In addition to output speeds up to 400 times faster, a Gould printer/plotter gives you a lower unit cost, as well as lower paper cost. Better-looking output, since there's no ink to smudge, clog or run out of. Few moving parts for quiet operation, high reliability. Software that's upward compatible with the leading drum plotter. Without any sacrifice in mainframe CPU time.

And, in addition to everything else, it gives you an alphanumeric printing capability that also lets you compile management reports at speeds up to 3000 lines per minute.

Users will tell you that a Gould electrostatic printer/plotter makes their computer-aided design system truly interactive since output of modified data for verification can be quickly obtained. And by producing hardcopy output in a matter of seconds – instead of the many minutes it can take with older methods – time savings are maximized.

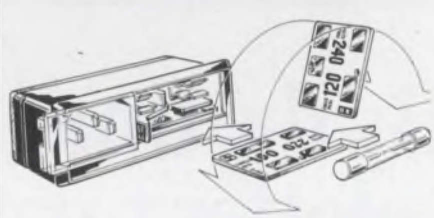
This all adds up to the best printing/plotting hardware and software available anywhere. And it's backed by Gould's own factory trained service technicians.

To learn more about Gould electrostatic printer/plotters – get in touch with Gould Inc., Instrument Systems Division, 3631 Perkins Ave., Cleveland, Ohio 44114 U.S.A., or Kouterveldstraat 13, B 1920, Diegem, Belgium.

GOULD

INFORMATION RETRIEVAL NUMBER 107

Power connector combines fuse and voltage selection



Corcom, Inc., 2635 N. Kildare Ave., Chicago, IL 60639. (312) 384-7400. $4.95: 6J1; $9.75: 6J4 (100-2499).

Corcom's Type 6J1 voltage-selecting and fused (VS & F) connector combines a power voltage-selection system with a fused connector. This type of connector was formerly made only by instrument manufacturers for their own use. Now Corcom has been licensed to market it as a separate component.

The unit allows the user to change the line-power voltage to his equipment safely and to select 100, 120, 220 or 240 V at 50 to 400 Hz. Voltage selection is made with a replaceable selector card. The maximum current rating is 6 A, and the replaceable fuse is a 3-AG type.

Only one rectangular cutout is needed for snap-in mounting. And spring-actuated mounting tabs eliminate the need for mounting hardware, regardless of panel thickness. The housing is made of UL-approved, SE-01 fire-retardant polyester. The connector also complies with International Electrotechnical Commission (IEC) requirements.

The fuse and the voltage-selector card are behind a see-through cover, which cannot be removed until the power cord is detached from the equipment. This ensures safety when a fuse is changed or a new operating voltage is selected.

The VS & F connector is available with an RFI powerline filter, Type 6J4, which also meets both UL and IEC safety and reliability requirements for industrial equipment.

CIRCLE NO. 303

Ceramic-fiber gaskets are asbestos free

Cotronics Corp., 37 W. 39th St., New York, NY 10018. (212) 531-9376.

Cotronics asbestos-free ceramic-fiber gaskets are fabricated from high-purity refractory fibers with a melting point of 3200 F and a continuous-use temperature in excess of 2300 F. This ceramic fiber product offers high-temperature stability, resistance to most chemicals and solvents and it meets OSHA requirements. The gaskets are produced by a low-cost die-cutting process from ceramic paper, blanket or board.

CIRCLE NO. 364

GGG crystals available as wafers or boules

Deltronic Crystal Industries, Inc., P.O. Box 323, Denville, NJ 07834. (201) 361-2222.

Gadolinium-gallium-garnet crystals of uniformly high quality are available as wafer blanks and boule sections for use primarily in thin-film growth of magnetic rare-earth garnets. Crystals are strain and core free, with dislocation counts less than 3/cm^2—and often zero—over the entire surface area. Lattice constant is 12.383 Å; standard orientation is (111). Sizes available range from 3/4 to 1-1/2 in. dia.

CIRCLE NO. 365

FOR INFORMATION, CIRCLE 151 FOR DEMONSTRATION, CIRCLE 152

INFORMATION RETRIEVAL NUMBER 115

INFORMATION RETRIEVAL NUMBER 116

bulletin board

Digital Equipment has introduced **a series of PDP-15 hardware configurations** priced 6 to 11% below previously available configurations. Called the PDP-15/78 and PDP-15/76-C systems, they are priced from $35,000, with deliveries scheduled for March, 1975.

CIRCLE NO. 366

Silicon Transistor has announced the immediate availability of **JAN silicon power transistor types 2N1485, 86, 89 and 90 and 2N3715 and 16.** The JAN 2N1485, 86, 89 and 90 are single diffused types supplied in TO-8 and TO-3 packages. The JAN 2N3715 and 16 are epitaxial base, high power types capable of dissipating 150 W in the TO-3 package.

CIRCLE NO. 367

NCR Corp. has raised rental and maintenance charges on most **Century Series computer systems.** The rental increases range from 1 to 8%. Century 50 rental charges have increased 6% and Century 101 charges 8%, while the larger 200 and 201 models will increase only 2% and 1%, respectively.

CIRCLE NO. 368

Monsanto has announced a series of **opto-isolators with JEDEC registration.** The new units, 4N25 to 4N28, are optically coupled phototransistors.

CIRCLE NO. 369

Price reductions

RCA has reduced gate prices more than 30% and MSI prices more than 20% for **standard CD4000 series devices** in 100 to 999 quantities.

CIRCLE NO. 370

Kinetic Technology has announced an average 15% across-the-board price reduction on all standard **thick-film hybrid active filter modules.**

CIRCLE NO. 371

FOR PEOPLE WHO WANT TO READ ALL ABOUT IT!

We have nothing less than a fully illustrated, systematic, easy-to-use survey of the entire field of data management as it exists today. It covers it all, from A to Z, so it's for everybody. The programmer tightening up his files. The analyst working out a workable timesharing program. Top management needing industry-wide perspective on competitive system designs.

It's a rare publication that takes a unique "blueprint approach" to current know-how. Beginning with the single data item as the first building block in total system design. And progressing through specific techniques for data structures, streams, files . . . total hardware and operating system control . . . the latest advances in timesharing and multiprogramming . . . system modeling and simulation . . . complete designs for various types of commercial accounting and document-oriented storage and retrieval systems. It all adds up to a vast and impressive "top to bottom" view.

And it does it all in fresh, jargon-free language, with scores of illustrations and diagrams for a rapid, visual grasp.

Whether you use it as an on-the-job manual, as a desk-top reference, or as a conference room companion with all the answers, it's an indispensable tool guaranteed to broaden your perspective and practical skill in a field that knows no limits to growth and progress. And generally give you the professional confidence that comes from knowing just about everything that's going on.

#5100-X, 6 x 9, 300 pages, cloth $14.95

To Order:
Circle the **Information Retrieval Number** to order your 15-day free examination copy of **Data Management for On-Line Systems by David Lefkovitz.** At the end of that time please remit payment or return the book with no further obligation.

Hayden Book Company, Inc., 50 Essex Street, Rochelle Park, N. J. 07662

TO ORDER, CIRCLE 94

new literature

Rotary switches

A 40-page rotary switch catalog is complete with a quick-reference chart, dimensional drawings, general, electrical and mechanical specifications and distributor cross-reference. Included is a specification sheet and ordering information. Centralab, Milwaukee, WI

CIRCLE NO. 372

Tube commemorative

"Fifty Years of Innovation," a 20-page illustrated publication, traces the company's history, starting with the first production of Sylvania radio tubes in 1924. GTE Sylvania, Waltham, MA

CIRCLE NO. 373

Hand-held DMM

Model 21 hand-held digital multimeter is described in a four-page brochure. Features, illustrations and a comparison of the Model 21 with similar HP and Dana DMMs are included. Data Technology, Santa Ana, CA

CIRCLE NO. 374

Test equipment

A 230-page catalog is complete with product descriptions and applications on frequency synthesizers, pulse echo test sets, level meters, noise loading test sets and return loss measuring sets. The units are manufactured by Anritsu, Tokyo. Tau-Tron, North Billerica, MA

CIRCLE NO. 375

Integrated circuits

A 96-page book tells the designer the ground rules for using the SL600 series integrated circuits. Typical circuit connections are presented, with clear and comprehensive discussions of alternative connections and their relative advantages and disadvantages. Plessey Semiconductor, Santa Ana, CA

CIRCLE NO. 376

Photomultipliers

A 12-page selection guide of photomultiplier tubes, electron multipliers and gas-filled and vacuum photodiodes allows a quick comparison of the characteristics of the different RCA devices to facilitate initial selection. RCA, Harrison, NJ

CIRCLE NO. 377

Inductive devices

A 20-page brochure details inductive devices and custom networks for military, computer and industrial applications. Specifications, dimensional data, MIL-Spec numbers and application information are included. Vanguard Electronics, Inglewood, CA

CIRCLE NO. 378

Crystals

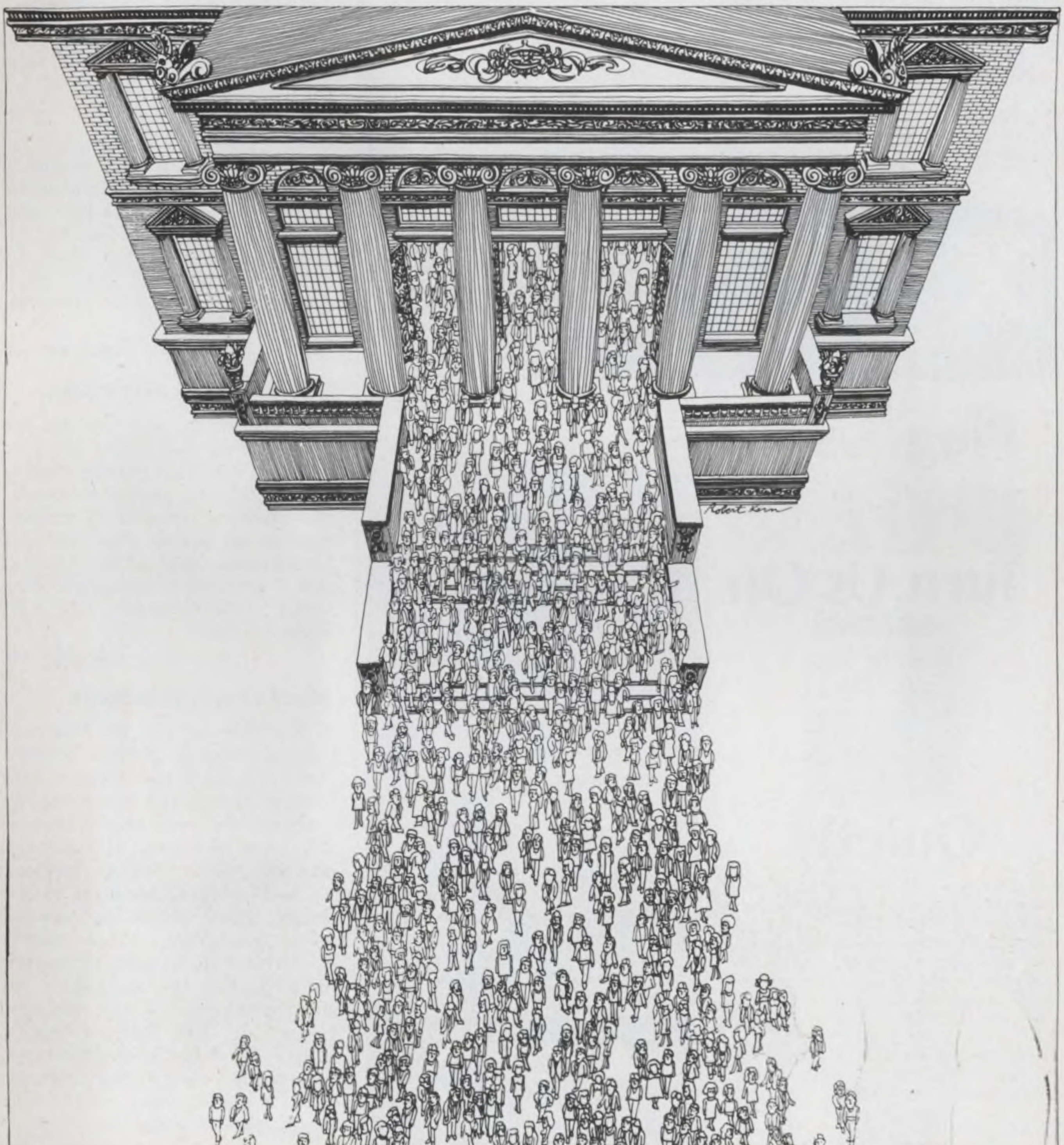
Low and medium-frequency crystals, crystal ovens, plug-in transistor oscillators and accessories and frequency meters are described in a 28-page catalog. How-to-order information is included. International Crystal Manufacturing, Oklahoma City, OK

CIRCLE NO. 379

Modular motor system

A 32-page catalog describes a major innovation in motor design. Unlike conventional motors, new synchronous H4 motors are assembled from modular components. Detailed graphs and application information tell the key facts about performance. General Time, Industrial Controls Div., Thomaston, CT

CIRCLE NO. 380



NEW LITERATURE

Datel Digest

The Datel Digest is a quarterly publication featuring interesting summaries of significant new products. The stories features descriptions, specifications, block diagrams, photographs and other useful information. Datel Systems, Canton, MA

CIRCLE NO. 381

Hybrid power assemblies

Specifications and ratings for hybrid power assemblies are provided in an eight-page brochure. In addition to circuit diagrams, the brochure contains 11 graphs, dimensional outline drawings and photographs. Application information is provided. International Rectifier, Semiconductor Div., El Segundo, CA

CIRCLE NO. 382

Measuring instruments

Available in any of four languages—English, French, German and Japanese—the Philips 1975 catalog of test and measuring instruments is sure to give browsing pleasure as you flip through the 288 pages (English version) of oscilloscopes, recorders, multimeters, signal sources, counters and other equipment. Clear photos, comparison charts and engineering data will help you select the right instrument, too. For your own copy, write to: Test and Measuring Dept., TQ. 3-4, Philips Industries, Eindhoven, the Netherlands. Be sure to specify which of the four languages you'd like.

INQUIRE DIRECT

Digital instruments

A four-page brochure provides a quick look at features of digital instruments for any type of physical measurement. Doric Scientific, San Diego, CA

CIRCLE NO. 383

Vacuum capacitors

A vacuum capacitor catalog includes information on the variable and fixed types, which are available in glass or ceramic versions. The catalog includes individual data sheets, applications, OEM prices and cross-reference information. As new data sheets become available, they will be added to the catalog via a monthly mailing to qualified recipients. Amperex Electronic, Hicksville, NY

CIRCLE NO. 384

'See-through' control

Features and applications of a "see-through" photoelectric control are given in a bulletin. Micro Switch, Freeport, IL

CIRCLE NO. 385

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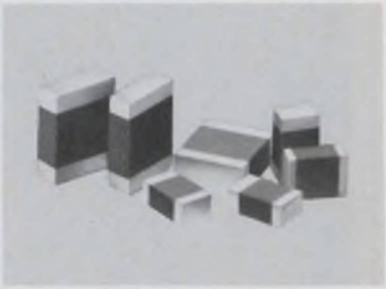
INFORMATION RETRIEVAL NUMBER 121 ▶

quick ads

New and current products
for the electronic designer
presented by their manufacturers.



HIGH Q MULTILAYER CAPACITORS feature very high quality factors at microwave frequencies. Offered in three standard sizes: .050 x .040, .080 x .050, .125 x .095. Capacitance values from 0.1 pf to 1000 pf with close tolerance and voltages to 1000 VDCW. Johanson/Monolithic Dielectrics Div., Box 6456, Burbank, Ca. 91510, (213) 848-4465.

INFORMATION RETRIEVAL NUMBER 601

Free catalog of 34,500 power supplies from the worlds largest manufacturer of quality Power Supplies. New '74 catalog covers over 34,500 D.C. Power Supplies for every application. All units are UL approved, and meet most military and commercial specs for industrial and computer uses. Power Mate Corp. (201) 343-6294.

INFORMATION RETRIEVAL NUMBER 604

Basic Engineering Sciences & Structural Engineering for E-I-T Exams. Sampling for test problems makes the best preparation yet for exams. #5712-1, 424 pp., $17.20. Circle the Info Retrieval No. to order 15-day exam copy. When billed, remit or return book with no obligation. Hayden Book Co., 50 Essex St., Rochelle Pk., N.J. 07662

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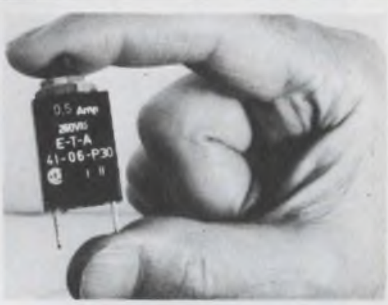
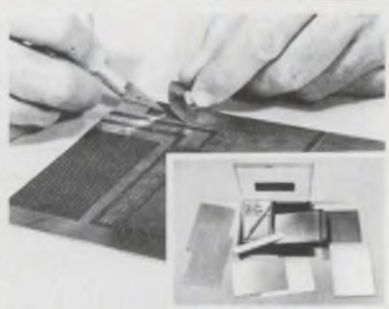


Overcurrent Protector, manual reset eliminates fuse replacement. Convenient panel mounting. 15 fractional ratings from 0.1 to 3 amp. Other models up to 400 amp. Trip-free and fool-proof, UL and CSA approved. High quality, low cost $1.29 ea. in 1000 lots. E-T-A Products Co. of America, 7400 N. Croname Rd., Chicago, Ill. 60648. Tel: (312) 647-8303. Telex: 253780.

INFORMATION RETRIEVAL NUMBER 602

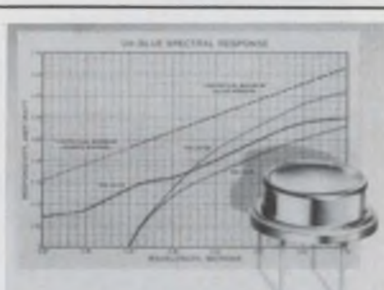


Cut & Peel Circuit Board Kit. Cut prototype boards or ground planes. Assortment of 7 includes one and two sided Cut & Peel Boards on .100" grid drilled and plain epoxy-glass, "X" and "X-Y" Board, a plug-in Cut & Peel GP Board with etched gold/nickel edge connector, and a special knife. Kit #8964 is $37.00. Circuit-Stik, Inc. Box 3396, Torr., CA 90510.

INFORMATION RETRIEVAL NUMBER 605

Manufacturing Management Systems. Technical and managerial expertise to handle today's progressive manufacturing systems. #5940-X, 160 pp., $10.50. Circle the Info Retrieval No. to order 15-day exam copy. When billed, remit or return book. No obligation. Hayden Book Company, 50 Essex St., Rochelle Pk, N.J. 07662.

INFORMATION RETRIEVAL NUMBER 608



UV Blue Response Photodiode: United Detector Technology now offers blue, super blue, and UV enhanced silicon photodiodes with near theoretical responsivity in the range from 200 to 550 nanometers. Available in both the Pin-5 .5 cm^2 and the Pin-10 1 cm^2 configuration. United Detector Technology, 2644 30th St., Santa Monica, Ca. 213 396-3175.

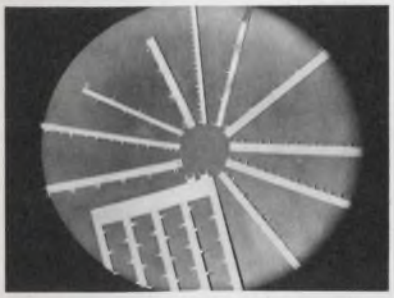
INFORMATION RETRIEVAL NUMBER 603

Touch Activators for solid-state switch circuits eliminate pushing, pulling, or flipping of switches. No moving parts; high reliability. A mere touch of finger activates switch circuit. Interface with CMOS, TTL, DTL, and HTL. Snap-in panel mounting. Lighted or unlighted. Master Specialties, 1640 Monrovia, Costa Mesa, Calif. 92627.

INFORMATION RETRIEVAL NUMBER 606

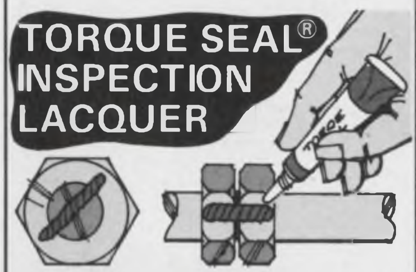
Atomic Frequency Standards. Models FRK-H/L for airborne/mobile systems, navi/comm TV-Broadcast Features: stability typi $1x10^{-11}$/month, rapid warm-up $<$ 10 Min., power 12W only, weight 2.2 lbs. Warranty 5 years lamp/cell. Price: $5100/$3480. OEM avail. EFRATOM CA., INC. 3303 Harbor Blvd., E1, Costa Mesa, CA. 92626 (714) 556-1620

INFORMATION RETRIEVAL NUMBER 609



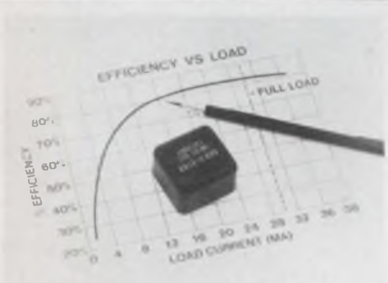
Mini/Bus® Evaluation Kit, $25, in stock. Lets you try Rogers' low-cost, noise attenuating, high packaging density power distribution system for PC boards. Millions in use. Standard parts on 2 weeks delivery, or less! Customer parts 4 to 6 weeks delivery. Rogers Corporation, Chandler, Ariz. 85224. Phone (602) 963-4584

INFORMATION RETRIEVAL NUMBER 610



Inspectors can visually detect any movement or tampering as TORQUE SEAL becomes brittle and will crack. Widely used as an Anti-Sabotage Lacquer. Fast Drying. Excellent Adhesion. In 1/2 oz. poly squeeze tubes. Available in fluorescent colors. Send for free sample and catalog. ORGANIC PRODUCTS CO., Box 428, Irving, TX 75060

INFORMATION RETRIEVAL NUMBER 613



Activate gas discharge readouts! DC-to-DC power supplies convert low DC line voltages of 5, 9, 12 or 15 volts to nominal 200 and 250 volt DC levels required to run gas discharge information displays. Ideal for battery powered applications! Free literature. Endicott Coil Co., Inc., 31 Charlotte Street, Binghamton, N.Y. 13905

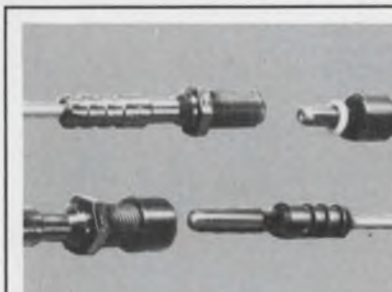
INFORMATION RETRIEVAL NUMBER 611

Ferrite Ring and Pot Cores, permeability ranges of 60 to 3000 mu, in a wide range of Ring Sizes; Pot Cores to IEC sizes 14 to 36, adjustable and no gap, mounting hardware, technical data available. Connolly & Company, Inc., 914 No. Rengstorff, Mountain View, Ca. 94043 (415) 967-6988

INFORMATION RETRIEVAL NUMBER 614

New combination spacer/bushing. Cut assembly time and costs substantially with these new, low Polyamide Spacer/Bushings from Johnson. Allows quick mount of PC boards to chassis. "Mechanically secure, yet P.C. boards easily removed." Made of non-conductive polyamide in various sizes. E. F. Johnson, Waseca, MN. 56093 (507) 835-2050.

INFORMATION RETRIEVAL NUMBER 612



Safe HV Connector Assemblies. Up to 20KVDC . . . with LGH single-position commercial high-voltage connectors. Deeply recessed pins prevent exposure to high voltage. Meet applicable min. clearance and creepage specs. Quick connect/disconnect. Leads any length. Contact AMP Capitron Division, Elizabethtown, PA 17022 (717-367-1105).

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IT'S **CLEARLY THE CHOICE** *OF*
ELECTRONICS ENGINEERS — WORLDWIDE

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Electronic Design's
GOLD BOOK
YOU DON'T NEED ANY OTHER INDUSTRY DIRECTORY

In just a few months, the first issue of *Electronic Design's* GOLD BOOK has become the leader among all directories used in this industry. Engineers have responded enthusiastically throughout the U.S. and from all over the world — especially in Europe where they've never seen anything like it before. The GOLD BOOK has become number one almost overnight.

HERE'S HOW YOUR FELLOW ENGINEERS RATE THE INDUSTRY ANNUALS

	Annuals Consulted Within Past Month	Annuals Preferred
Electronic Design's GOLD BOOK	85%	60%
Electronic Engineer Master (EEM)	63%	42%
Electronic Buyer's Guide (EBG)	32%	8%
Thomas Register	16%	7%
Conover-Mast Purchasing Directory	2%	1%

SOURCE: Study by Dr. Eugene D. Jaffe, Associate Professor of Marketing, St. John's University, Nov. 1974. Base: respondents using directories. Totals exceed 100% due to multiple mentions.

The GOLD BOOK has revolutionized directory use patterns in this industry. Here's why: The GOLD BOOK is by far the largest, most complete one-step electronics purchasing and reference tool ever produced. And it's far easier to use. Look at these comparisons:

COMPARISON OF ELECTRONICS INDUSTRY DIRECTORIES (1974-75 editions)

	EBG ELECTRONICS BUYERS' GUIDE	EEM ELECTRONIC ENGINEERS MASTER	ELECTRONIC DESIGN'S GOLD BOOK
Number of manufacturers listed	5,800	3,165	**7,528**
Total number of products listed	4,267	3,235	**4,799**
Number of direct products listed	2,479	2,250	**2,925**
Number of cross-reference products listed	1,788	985	**1,874**
Number of distributors listed in Distributors Directory — Alphabetic	0	1,720	**5,780**
Number of distributors listed in Distributors Directory — Geographic	0	1,720	**5,780**
Is complete mailing address given each time a company is listed in product directory?	No	No	**Yes**
Is telephone number given for each company listed in product directory?	No	No	**Yes**
Are distributors listed for each manufacturer?	No	Partial[1]	**Yes**
Does manufacturers listing include FSCM numbers?	No	No	**Yes**
Does manufacturers listing include facsimile equipment by make and call number?	No	No	**Yes**
Total Circulation	30,017[3]	89,169[3]	**Over 90,000**
Overseas Circulation[2]	1,339[3]	0[3]	**13,200**
Number of ad pages	590[4]	2,752	**2,820**

[1] Paid listings only
[2] Includes Canada
[3] Standard Rate & Data; Oct. 24, 1974
[4] Includes fractionals

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The effects of noise in terms of impaired performance have been widely recognized, and the **RELATIONSHIP BETWEEN NOISE AND COMPONENT RELIABILITY** generally accepted in the electronic industry. Thus the analysis of electrical noise generated by components is not only vital to the development and production of low-noise circuits, but also is becoming of major importance in achieving maximum reliability of instrumentation.

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CIRCLE NO. 171

Share in the nation's top managerial policies, strategies, techniques . . .

MANUFACTURING MANAGEMENT SYSTEMS

New Challenges and Opportunities Edited by Fred Gruenberger

By crystallizing the results of the 1973 Informatics/UCLA Symposium, this book offers a powerful blend of technical and managerial expertise for enhancing the overall success and profitability of today's manufacturing management systems. Some of the nation's top industrial and technical leaders speak freely and in depth of their organization's objectives and specific operations, as well as their personal strategies and methods. You'll find the newest computerized tools available to manufacturers . . . crucial managerial skills for directing progressive systems . . . the tact and care needed for the sensitive human problems of system implementation, and more. **#5940-x, 160 pages, $10.50.** Circle the Info Retrieval No. to order a 15-day exam copy. When billed, remit or return book. No obligation. **CIRCLE NO. 172**

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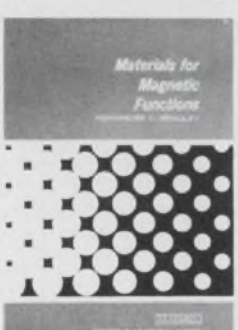

MATERIALS FOR MAGNETIC FUNCTIONS

by Fennimore N. Bradley

This valuable reference provides a thorough background as well as practical design techniques for the materials needed for magnetic functions. Included in its exhaustive coverage is detailed treatment of key parameters of about 30 classes of ferrite materials relating processing to costs and design trade-offs . . . and equally thorough coverage of about 40 classes of both conventional and exotic magnetic metals and processes. The book focuses on design problems encountered in a wide range of permanent-magnet applications . . . pinpoints design problems in nearly 30 categories of electromagnetic devices . . . and concludes with coverage of environmental influences such as corrosion, magnetic field, temperature, stress, etc. 360 pp., 6 x 9, illus., cloth, $17.20. **Circle the reader-service number to order a 15-day examination copy.** **CIRCLE NO. 173**

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Electronic Design

ELECTRONIC DESIGN's function is:

- To aid progress in the electronics manufacturing industry by promoting good design.
- To give the electronic design engineer concepts and ideas that make his job easier and more productive.
- To provide a central source of timely electronics information.
- To promote communication among members of the electronics engineering community.

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- To make diligent efforts to ensure the accuracy of editorial matter.
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- To encourage our readers as responsible members of our business community to report to us misleading or fraudulent advertising.
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INFORMATION RETRIEVAL NUMBER 125

WHO MAKES WHAT & WHERE TO FIND IT

Volume 1 of **Electronic Design's** GOLD BOOK tells all. And, when you look up an item in its PRODUCT DIRECTORY you'll find each manufacturer listed COMPLETE WITH STREET ADDRESS, CITY, STATE, ZIP AND PHONE. Save time. There's no need to refer elsewhere to find missing information.

IT'S ALL THERE in Electronic Design GOLD BOOK

We're #1 in MINIATURES

Alco was FIRST to realize Industry's need for miniature switches. FIRST with realistic pricing, FIRST with highest quality and FIRST with originality.

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INQUIRE DIRECT

product index

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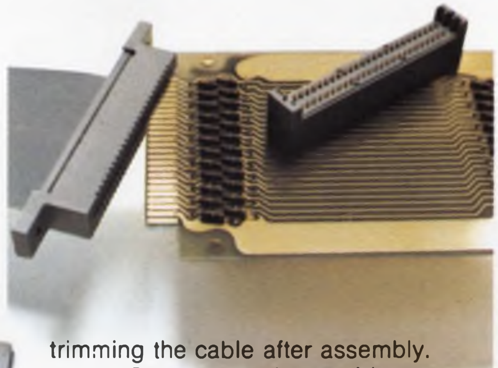
Design with the complete flat cable/connector system.



Assembly-cost savings are built in when you design a package with "Scotchflex" flat cable and connectors. But more important, 3M Company offers you the full reliability of a one-source system: cable *plus* connectors *plus* the inexpensive assembly aids that crimp the connections quickly and securely (with no special operator training required).

The fast, simple "Scotchflex" assembly sequence makes as many as 50 simultaneous multiple connections in seconds, without stripping, soldering or trimming the cable after assembly.

Connector units provide positive alignment with precisely spaced conductors in 3M's flat, flexible PVC cable. The connector contacts strip through the insulation, capture the conductor, and provide a gas-tight pressure connection.

With cable, connectors and assembly tools from one design and manufacturing source, you have added assurance the connection will be made surely, with no shorts or "opens."

And "Scotchflex" now offers you more design freedom than ever. From stock you can choose shielded and non-shielded 24-30 AWG cable with 10 to 50 conductors, and an ever-increasing variety of more than 100 connectors to interface with standard DIP sockets, wrap posts on standard grid patterns, printed circuit boards, or headers for de-pluggable applications. 3M's DELTA "D" type pin and socket connectors are now also available. For full information, write Dept. EAH-1, 3M Center, St. Paul, MN 55101.

The 3M DELTA pin and socket connector.

3M COMPANY

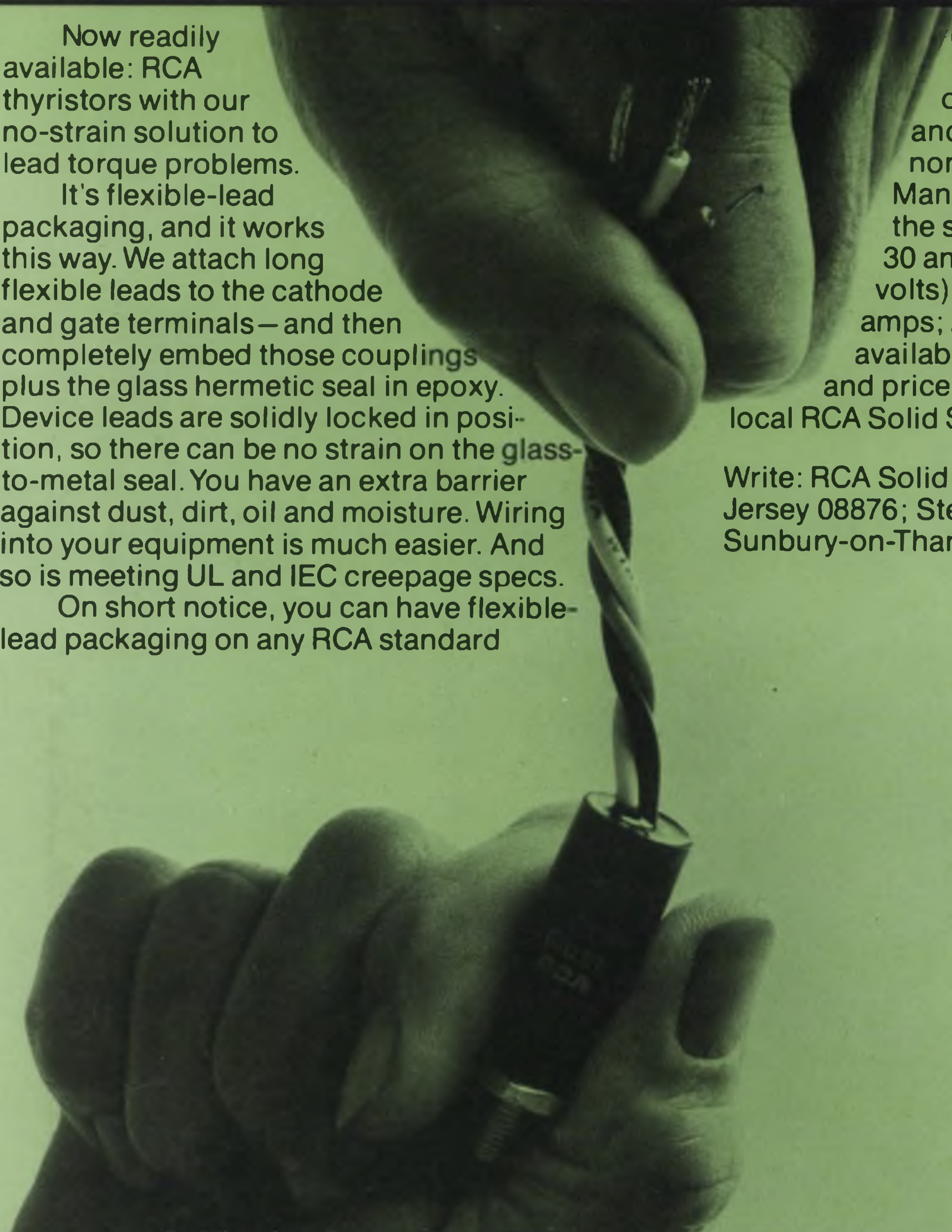
3M's "Scotchflex" line.

"Scotchflex" is a registered trademark of 3M Co.

INFORMATION RETRIEVAL NUMBER 253

What's new in solid state...

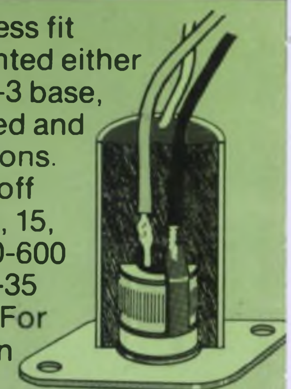
Leak-proof, torque-proof thyristors from RCA.



Now readily available: RCA thyristors with our no-strain solution to lead torque problems.

It's flexible-lead packaging, and it works this way. We attach long flexible leads to the cathode and gate terminals—and then completely embed those couplings plus the glass hermetic seal in epoxy. Device leads are solidly locked in position, so there can be no strain on the glass-to-metal seal. You have an extra barrier against dust, dirt, oil and moisture. Wiring into your equipment is much easier. And so is meeting UL and IEC creepage specs.

On short notice, you can have flexible-lead packaging on any RCA standard commercial press fit thyristor, mounted either on a stud or TO-3 base, and in both isolated and non-isolated versions. Many are available off the shelf: Triacs (10, 15, 30 and 40 amps; 200-600 volts), and SCRs (20-35 amps; 200-600 volts). For availability information and prices, contact your local RCA Solid State distributor. Or RCA.



Write: RCA Solid State, Box 3200, Somerville, New Jersey 08876; Ste. Anne de Bellevue 810, Canada; Sunbury-on-Thames, U.K.; Fuji Bldg., Tokyo, Japan.

RCA

INFORMATION RETRIEVAL NUMBER 254

RCA. A powerhouse in thyristors.