VOL. 22 NO. 14

Electronic Design®

FOR ENGINEERS AND ENGINEERING MANAGERS

JULY 5, 1974

Keeping electronics cool pays off in longer equipment life. Trends to higher packaging density and power dissipation demand tight specification for lowest cooling cost. But unfamiliar and often unqualified or ambiguous specs hamper cooling-device selection. For tips on how to evaluate your design problem, see page 62.


Ultra reliability in ultra-miniature transformers...

Electronic Design 14

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JULY 5, 1974

NEWS

TECHNOLOGY

PRODUCTS

Departments

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From CPU
8080 Microcom

Intel's new 8080 n-channel microcomputer is here—incredibly easy to interface, simple to program and with up to 100 times the performance of p-channel MOS microcomputers.

Best of all, the 8080 is real—in production at Intel and available in volume quantities, today. It's also available through distributors along with a growing line of peripheral circuits and a new version of the Intellec 8, a program and hardware development system for the 8080, all supported with software packages, design documentation and manuals, and backed by more than 100 man years of microcomputer expertise.

The 8080 is the inevitable successor to complex custom MOS and many large discrete logic subsystems. It is the industry's first general purpose n-channel microcomputer and the first high performance single-chip CPU, with extremely simple interface requirements and straightforward programming. It runs a full instruction cycle in 2 microseconds.

As such, the 8080 extends the economic benefits of Intel's p-channel microcomputers to a new universe of systems that need fast, multi-port controllers and processors. These systems include intelligent terminals, point of sale systems, process and numeric controllers, advanced

to software, the
puter is here.

calculators, word processors, self-calibrating instruments, data loggers, communications controllers, and many more.

You can use 256 input and 256 output channels, handle almost unlimited interrupt levels, directly access 64 kilobytes of memory, and put many satellite 8080 processors around a single memory.

Interfacing is minimal and design is easy with the 8080 because all controls are fully decoded on the CPU chip itself and inputs and outputs are TTL compatible. There are separate data, address and control buses.

INTEL 8080

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8308	1024 x 8	AVL:	3RD Q
8316	2048 x 8	AVL:	NOW
PROM MEMORIES			
8702	256 x 8	AVL:	NOW
8704	512 x 8	AVL:	4TH Q
8604	512 x 8	AVL:	4TH Q
PERIPHERAL CIRCUITS			
8205	1 of 8 DECODER	AVL:	NOW
8210	4K RAM CLOCK DRIVER	AVL:	NOW
8212	8 - BIT I/O LATCH	AVL:	NOW
8216	BI-DIRECTIONAL BUS DRIVER	AVL:	3RD Q
8201	COMMUNICATIONS INTERFACE	AVL:	4TH Q

INTEL 8080 PRODUCT FAMILY

The 8080 microcomputer has 78 basic instructions, including the 8008 set plus new ones that make possible such features as vectored multi-level interrupt, unlimited subroutine nesting and very fast decimal and binary arithmetic.

Program development for the 8080 can be done either on a large computer using the Intel software cross products (PL/M systems language compiler, macro-assembler and simulator), or on an Intellec 8 development system with a resident monitor, text editor and macro-assembler.

The new 8080 product family includes performance matched peripheral and memory circuits configured to minimize design effort and maximize system performance. Large, low cost RAMs, ROMs, PROMs and I/O devices are available now and we will soon announce other 8080 LSI support circuits.

The 8080 is easier to use and more economical than any high performance microcomputer in sight. It's here now, in volume, from the inventors of the microcomputer and the people who lead the industry in production and design support.

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50 Essex St.
Rochelle Park, N.J. 07662
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TWX: 710-990 5071
Cable: Haydenpubs Rochellepark

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Editorial Field Offices

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P.O. Box 272
Easthampton, Mass. 01027
(413) 527-3632

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(213) 757-0183
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112 Coloma St.
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2506 Eye St., N.W.
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across the desk

JEDEC registration defended as effective

From "Focus on Power Semiconductors" (ED No. 23, Nov. 8, 1973, p. 80), one might infer that EIA/JEDEC registration generally fails to ensure interchangeability of devices.

While this failure may occur in isolated instances, JEDEC registration is well-accepted in the industry as a generally effective system. Many engineers will argue that the only way to ensure interchangeability is to apply a use test in the specific application. However, in lieu of this impracticable solution, standardization and registration offer the best approach, and succeed in the vast majority of cases.

Undoubtedly you are aware that JEDEC committees meet regularly to establish standards, to formulate precise definitions, to devise registration formats that are adequate without being unduly cumbersome, to clarify test methods, and to engage in other activities that will ensure device interchangeability.

When shortcomings are noted, revisions are made. Recent formats, for example, require specification of both a minimum and a maximum f_t.

You state that another problem arises when some manufacturers resist a change in registered specifications proposed by another manufacturer.

Whether the proposed change would tighten or relax the specifications, the company proposing the change can take out a new registration number—if all the manufacturers aren't willing to accept these changes on a device already registered and in production at several facilities. Unanimity is a prerequisite for reregistration and must continue to remain so.

F. S. Stein, Chairman
JEDEC Solid State Products Council

P.O. Box 1104
Kokomo, Ind. 46901

'TF 2370 is a fine instrument, but–'

In the New Products columns and front cover of the April 12 issue, the Marconi Instruments TF 2370 spectrum analyzer is described (ED No. 8, "Spectrum Analyzer Outperforms Rivals in 7 Areas—at a Price, p. 137).

From the account and after observing the equipment at the IEEE show, I have concluded that the TF 2370 is a fine instrument, but the claim that it "zooms ahead of all others in performance in at least seven key areas" is questionable in three of these areas:

1. The Ailtech 707 has 100 dB of display dynamic range, yet the TF 2370's 100-dB display dynamic range was claimed to be "highest by 30 dB."

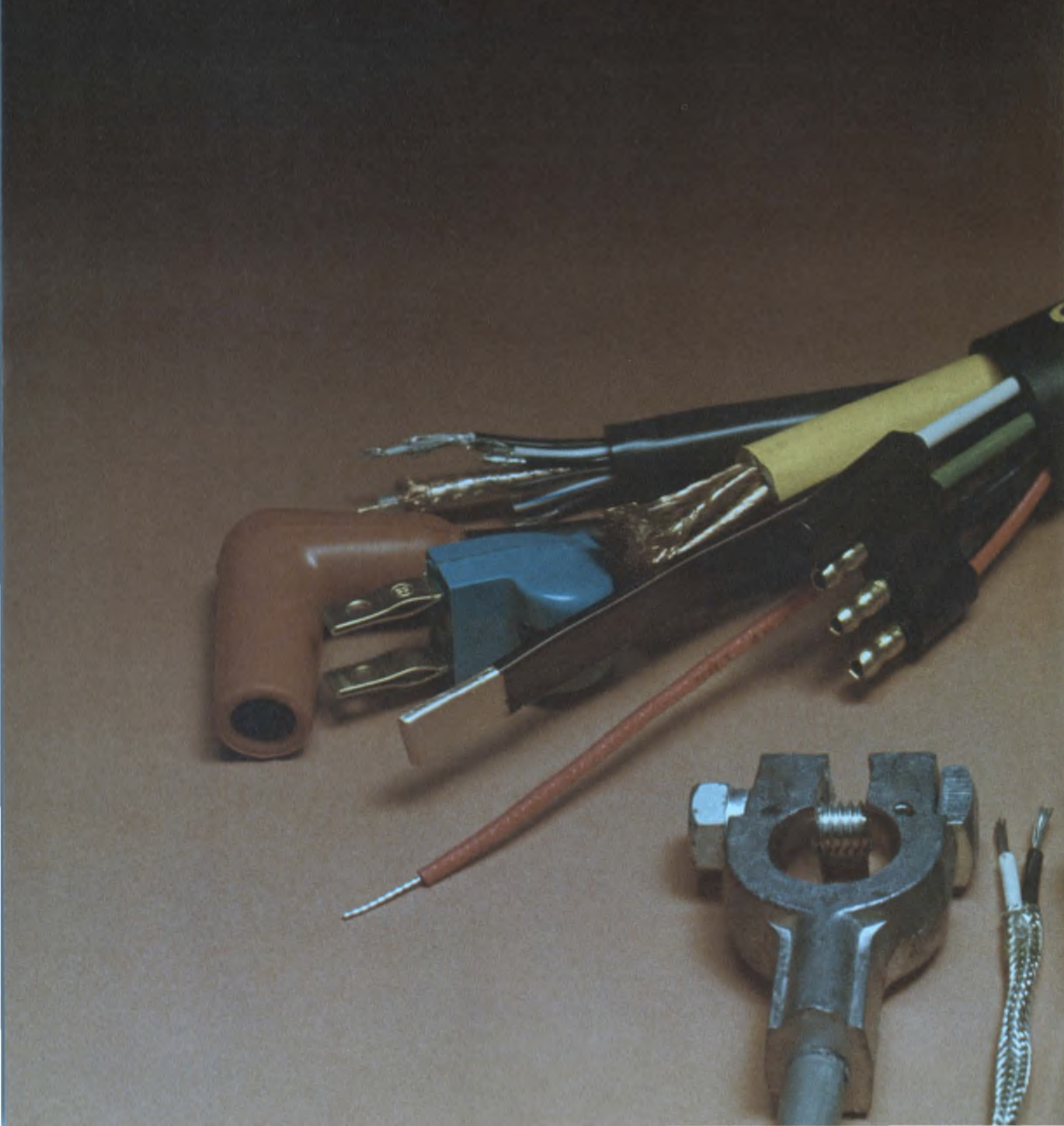
2. The 707 has a maximum cw input of ±20 dBm with 0 dB of rf attenuator setting, and +33 dBm cw input with 20 db or more of rf attenuator setting. The TF 2370 maximum input of +25 dBm was claimed to be "highest by 12 dBm."

3. The Ailtech 707 has a specified i-f filter factor of 5 to 1 and is typically 3.5 to 1 (ratio of 60 dB to 3 dB bandwidths) due to eight poles of crystal filtering. Yet the TF 2370 filter factor of 10 to 1

(continued on page 11)

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.

decoding the codes



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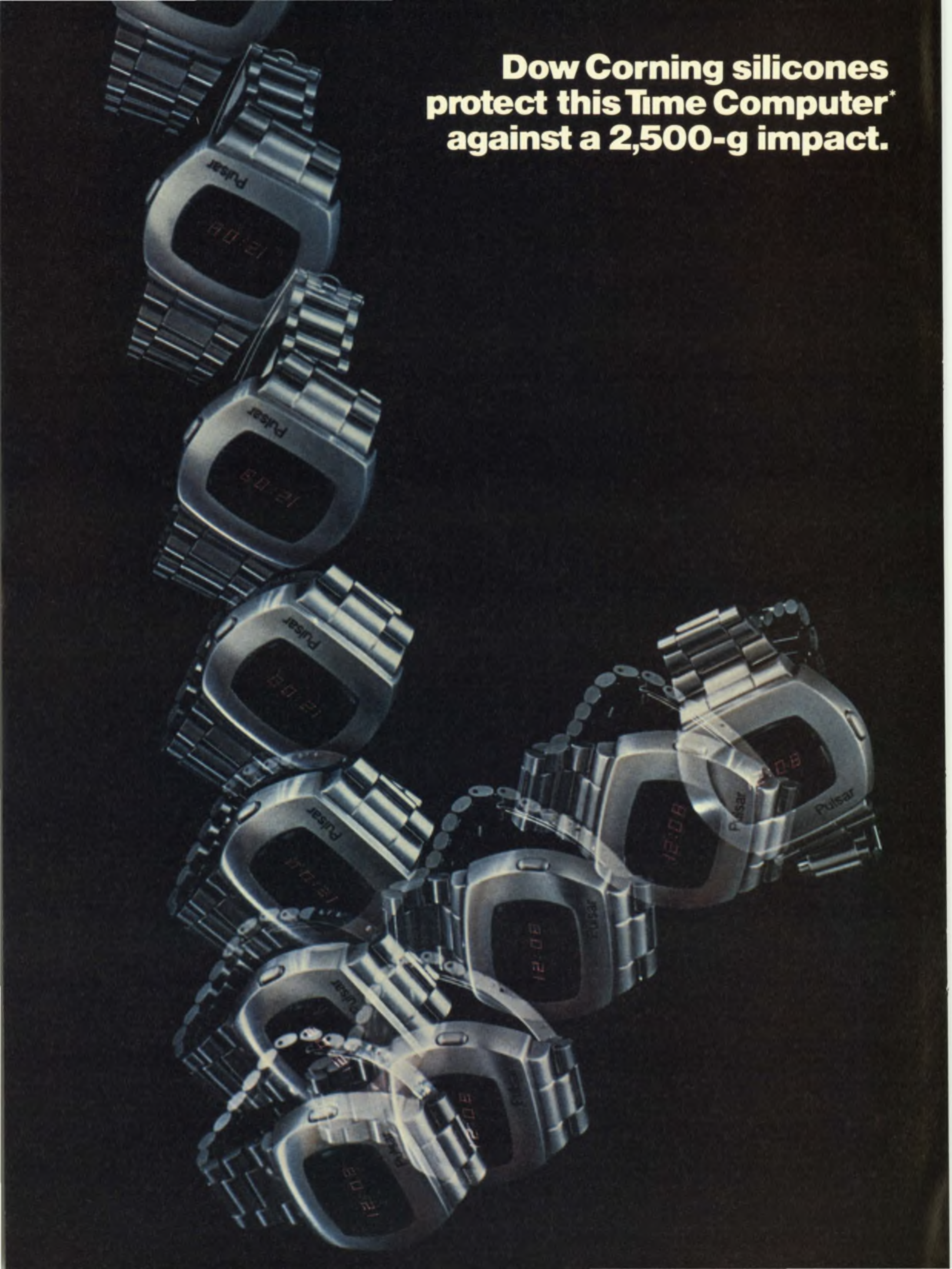
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Pulsar

ACROSS THE DESK

(continued from page 7)

was claimed to be "best of its class."

That the Ailtech spectrum-analyzer product line seems to have been overlooked is difficult to understand, since it has been on the market since 1970, described in *ED, EDN, Electronics, Electronic News, Microwave Journal, Microwaves, Telecommunications,* etc., and 1973 sales were a record high in the U.S., Canada and Europe.

Possibly the phrase "of its class" holds the explanation, since there are differences between the two. The 707 covers 1 MHz to 12.4 GHz with decreased sensitivity down to 10 kHz, and it costs $11,900. The TF 2370 is rated to 110 MHz and costs $14,750; however, it was only compared with the HP 8553B family, which also differs in quite a few ways.

Richard T. Knadle Jr.
Engineering Manager
Spectrum Analyzer Products

Ailtech
815 Broadhollow Rd.
Farmingdale, N.Y. 11735

Ed. Note: Obviously we can't compare a 100-MHz machine with a 12.4-GHz unit. The two aren't intended for the same application. By the same logic, we'd have to include 20-kHz analyzers, too, thus opening the flood gates to all analyzers.

When we review products, it's our policy to limit comparisons to what appears to be the closest competitive units.

Elliptic-filter idea needs debugging

The Idea for Design "Multiple-Feedback Bandpass Circuit Allows Use of Standard Capacitors in Elliptic Filter" (ED No. 7, April 1, 1974, p. 76) contains a number of errors that seriously affect its usefulness:

1. In Fig. 1, the ω^2 terms under $|V_{out}|$ both have the same subscript "n." This is incorrect.

2. In Fig. 1, the stop-band ripple is diagramed incorrectly. (For a correct example, see Fig. 1 of

(continued on page 16)

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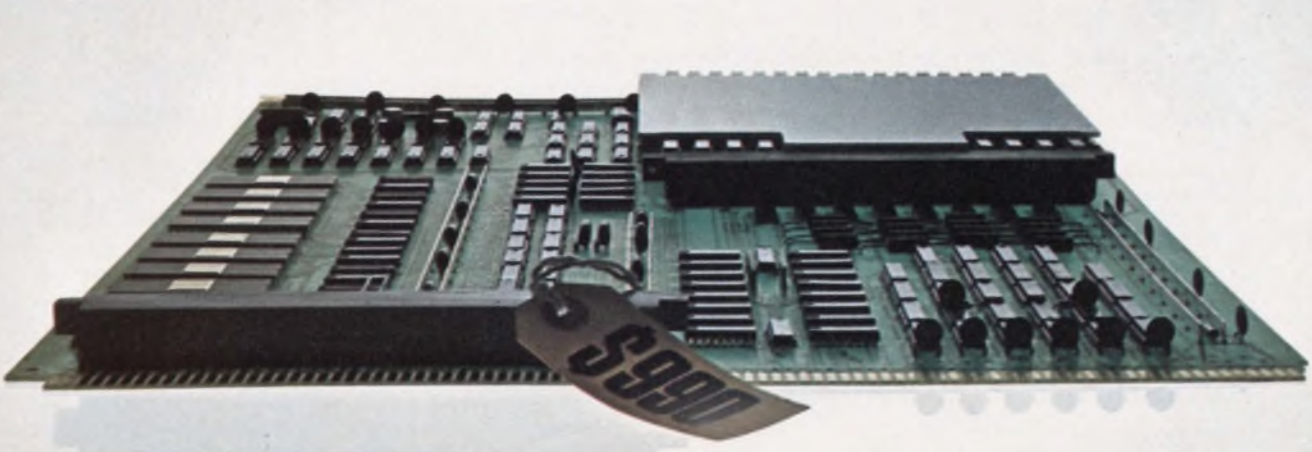

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(continued from page 11)

"Design Active Elliptic Filters Easily," ED No. 21, Oct. 14, 1971, pp. 76-79.)

3. In Fig. 2, the stop-band ripple is again diagramed incorrectly. The 0.3-dB passband ripple has no relationship to the ripple in the stop-band attenuation.

4. The caption to Fig. 2 says that the "prototype has a cutoff frequency of 640 Hz," but the diagram shows that ω_s, not f_{co}, occurs at 640 Hz. The filter cutoff frequency (where the attenuation first exceeds the value of 0.3 dB) is not specified.

5. The Y-axis of Fig. 2 is incorrectly labeled.

6. What does the 4.4-dB level signify in Fig. 2?

7. The title of the article incorrectly implies that the final elliptic filter circuit provides a band-pass response. The first sentence, however, corrects any misinterpretation. In my opinion, the following would be a better title: "Elliptic L-P Filter Is Obtained From Multiple-Feedback Circuit Using Standard Capacitors." The fact that a "synchronously tuned B-P function is used" is of secondary importance.

8. The author's discussion is vague, terms are not explained, and no calculation example is given.

9. In Fig. 1, the resistors between the positive terminals of A_1 and A_2 and ground have no reference designation.

10. In Fig. 2, the procedure for selection of the value of the 0.047-μF capacitor, shown across R_6 (12.7 k), is not explained.

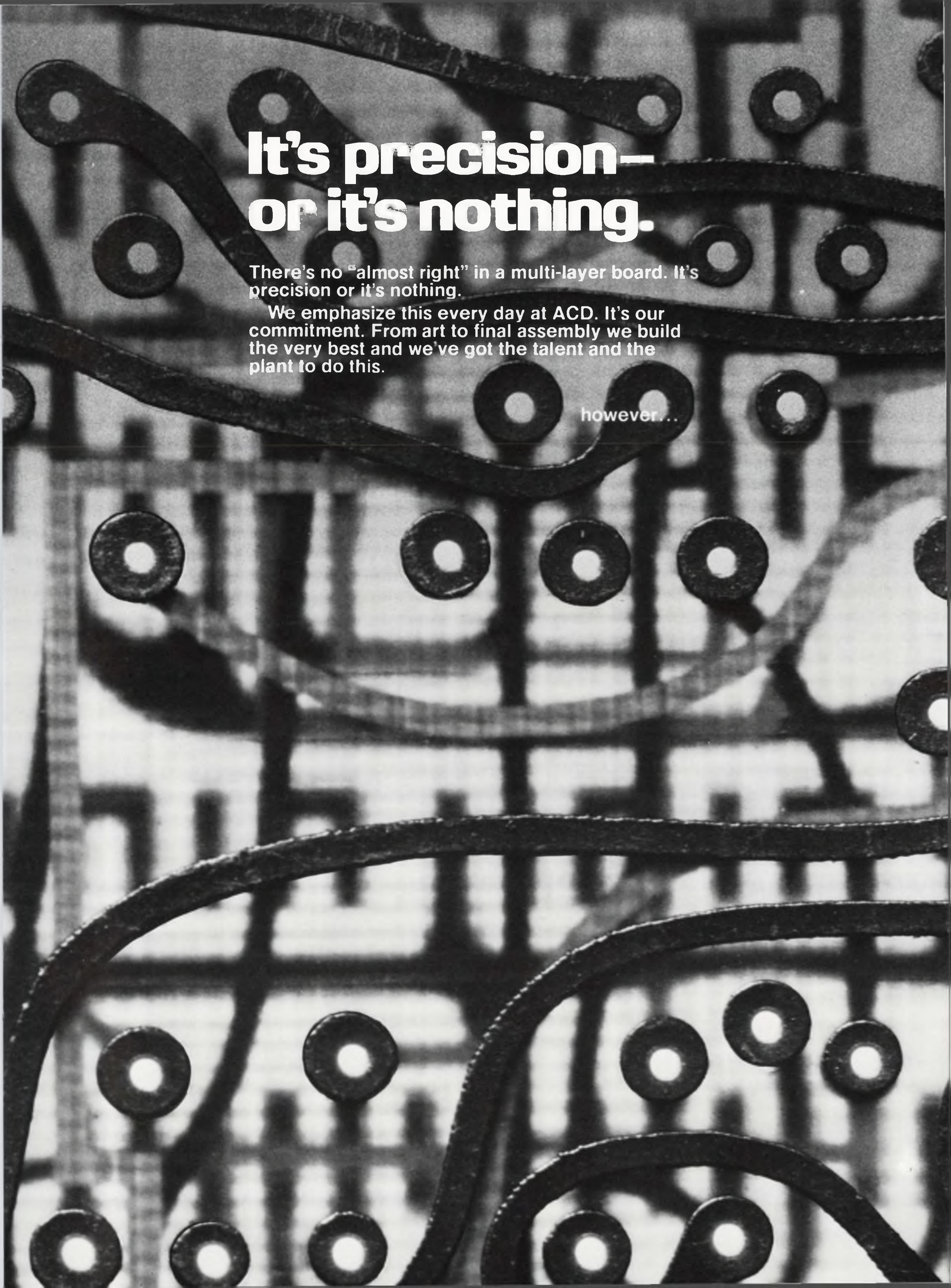
Edward E. Wetherhold
102 Archwood Ave.
Annapolis, Md. 21401

The author replies

The criticisms are accurate, on the whole.

In my original manuscript, Fig. 1 was labeled $H\omega^2_n/\omega^2_d$ on the voltage transfer function plot for the circuit shown. Point 1 that Mr. Wetherhold refers to was a typographical error. Points 2, 3 and 4 are just plain mistakes on my

(continued on page 27)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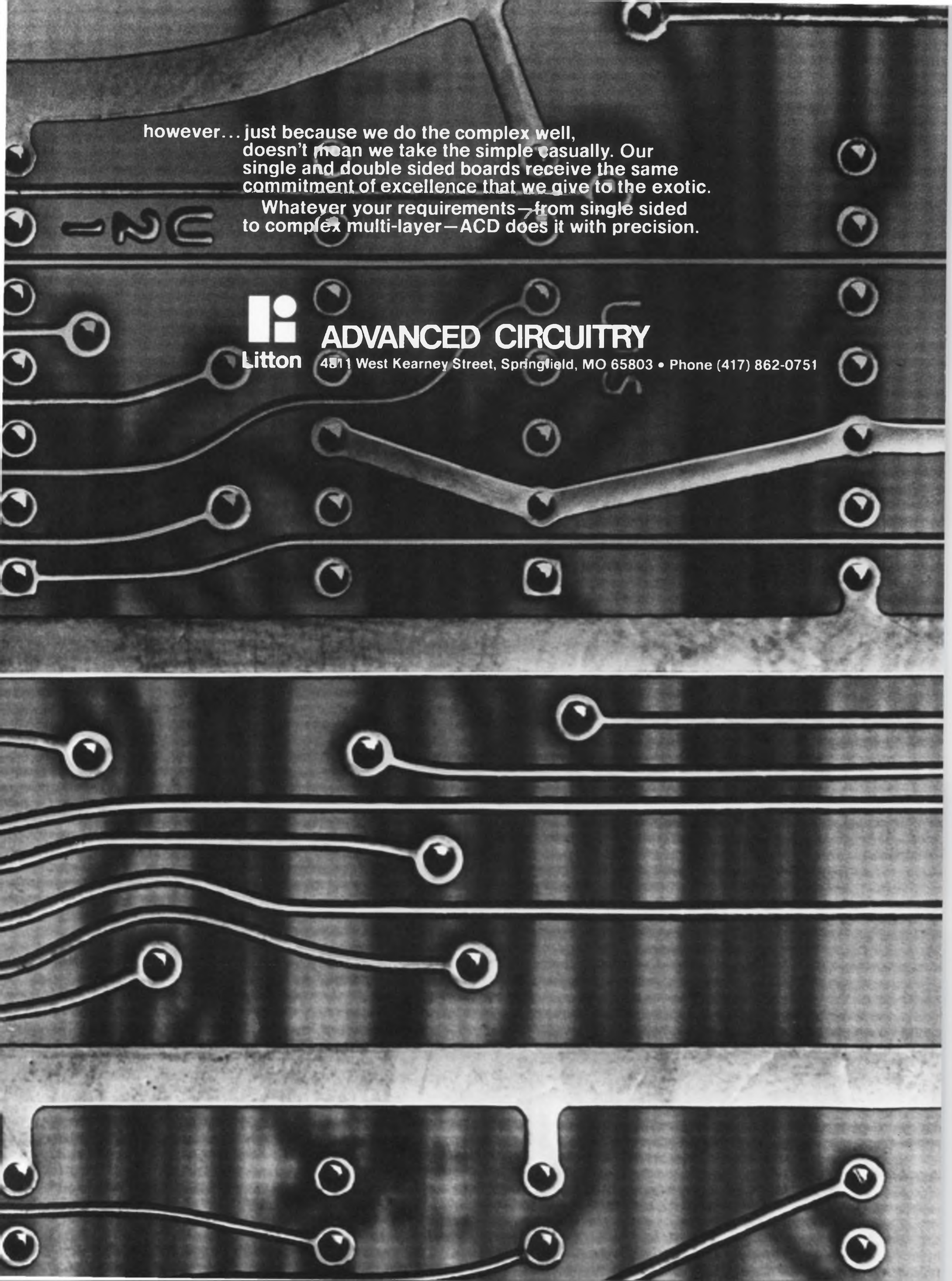
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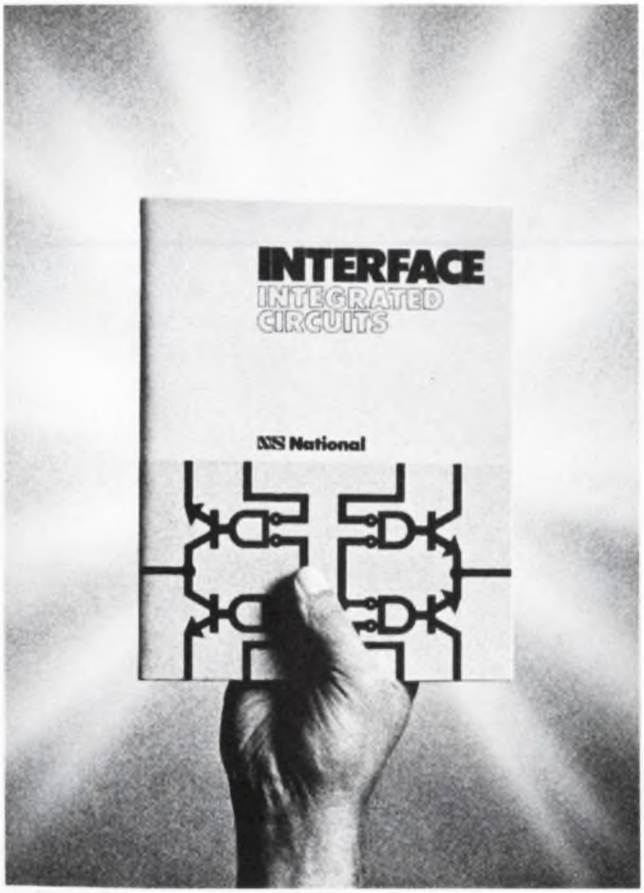

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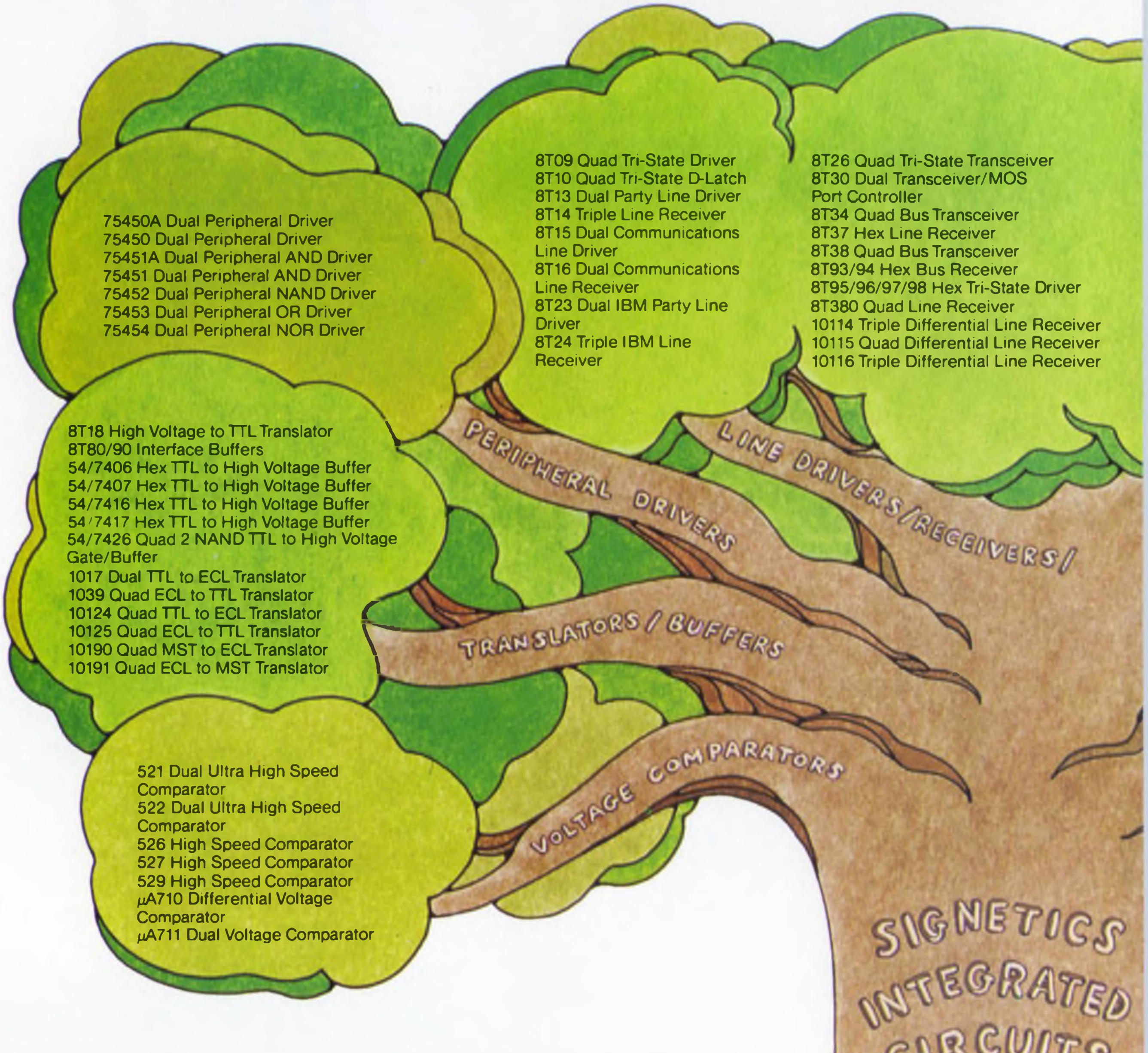

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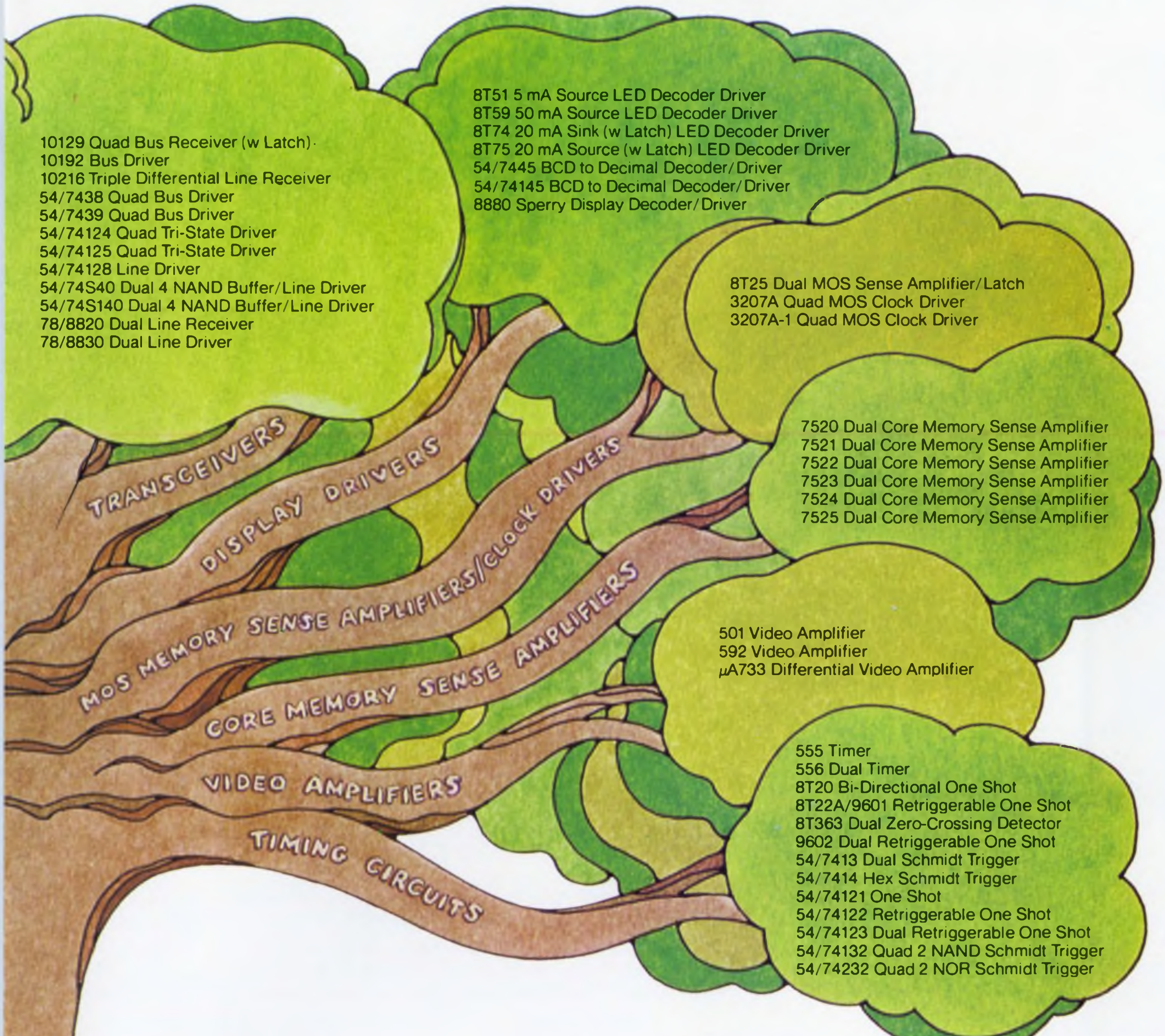

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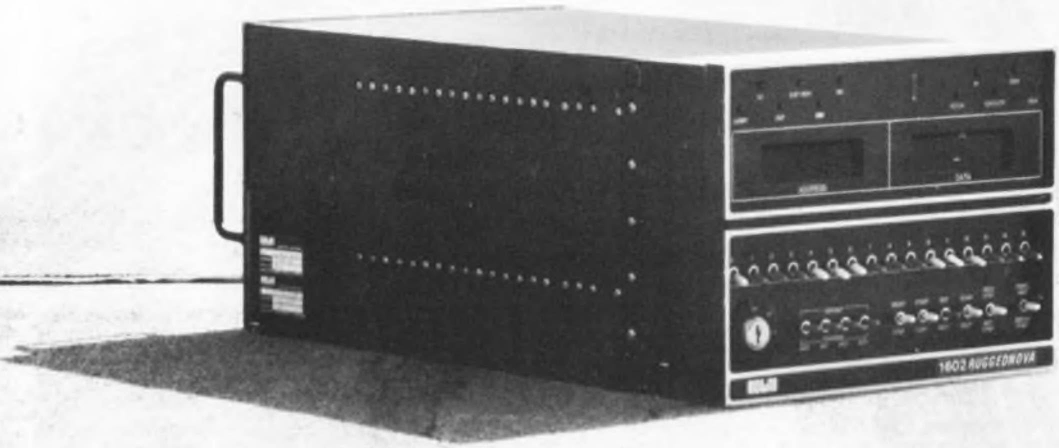

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acdc electronics inc

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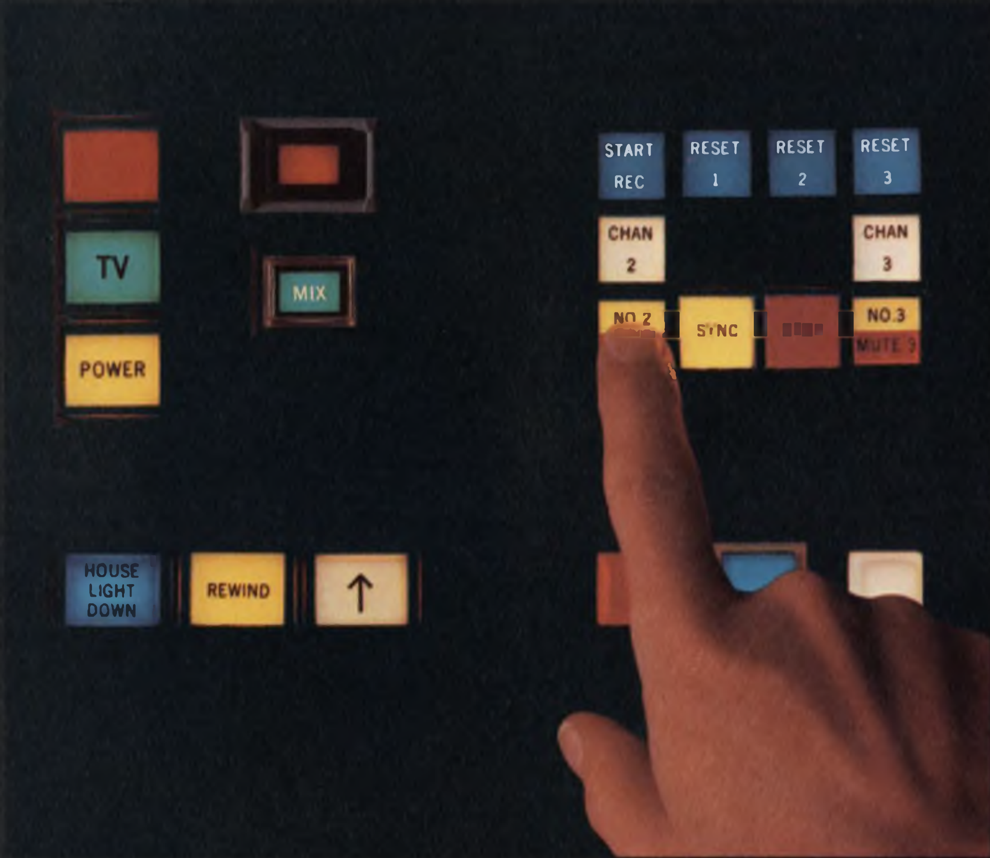
INFORMATION RETRIEVAL NUMBER 15

INFORMATION RETRIEVAL NUMBER 16 ▶

Industrial designers like the way they look. Engineers like the way they work.



MAIN PHOTO:
Series 3 (right) and Series 4 (left)

LOWER PHOTO:
Series 4, (left) lowest cost, all three energy levels, snap-in mount.

Series 2, (back) with modular design, up to 4 lamps and 4 poles, military versions.

Series 1, (right) with bushing mount, panel seal, military versions.

Series 3, (front) the smallest in our line, with snap-in or matrix mount.

If you've got a particular idea about what a lighted pushbutton should look like, we've got four important numbers for you: Series 1, 2, 3 and 4.

They represent one of the biggest selections of lighted pushbuttons in the world.

So you get to choose from a long list of options, depending upon the switch you select. Like buttons available in popular, highly consistent colors. Either transmitted or projected. Legending includes hot stamp, engraved or film insert, with an optional hidden legend available. Barriers and housings come in a choice of colors. Lighting is single or multiple lamp. Mounting either single unit, strip or matrix. You can also choose between round or square configurations, and most of them offer front-of-panel relamping without tools.

But your choice doesn't end at the front of the panel. In back of the button, there are three energy levels available—solid-state, low-energy and power. You can choose among solder, quick-connect, P.C. board mount or screw terminals. They're all U.L. and C.S.A. listed, with military-listed variations available. Circuitry can be single-pole, single-throw through four-pole, double-throw. With momentary or alternate action.

And, even though each of the four Series has its own particular advantages, they all have one thing in common: the kind of reliability you'd expect from the company that pioneered lighted pushbutton switches.

If you'd like more information on any or all of the MICRO SWITCH lighted pushbuttons, call toll-free 800/645-9200 (in N. Y. 516/294-0990, collect) for the name of your nearest Branch Office or Authorized Distributor.

MICRO SWITCH
FREEPORT, ILLINOIS 61032
A DIVISION OF HONEYWELL

MICRO SWITCH products are available worldwide through Honeywell International.

THE SWISS CONNECTION.*

The Quick-Lok Multicontact Connector.

To engage the connector, just push it straight in. To disengage it, pull straight out until the lock releases, then continue pulling to remove the plug from the receptacle. No twisting or turning is necessary.

The Quick-Lok feature;

Saves space because finger clearance is required on only two sides.

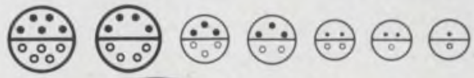
Reduces wear on the connector and cable because no twisting is necessary.

Grips firmly and remains locked until intentionally released.

The Lemo multicontact connector is versatile. Miniature sizes are available with 2, 3, 4, 5, 6, 8 or 10 contacts. In addition to standard cable terminating plugs and panel mounting receptacles, adapters, couplers and right angle plugs are available.

With a satin chrome finish, Lemo connectors complement the clean, modern design of instruments, components and systems. They are ruggedly constructed of machined brass components.

A complete catalog is available on request.



* Manufactured in Switzerland

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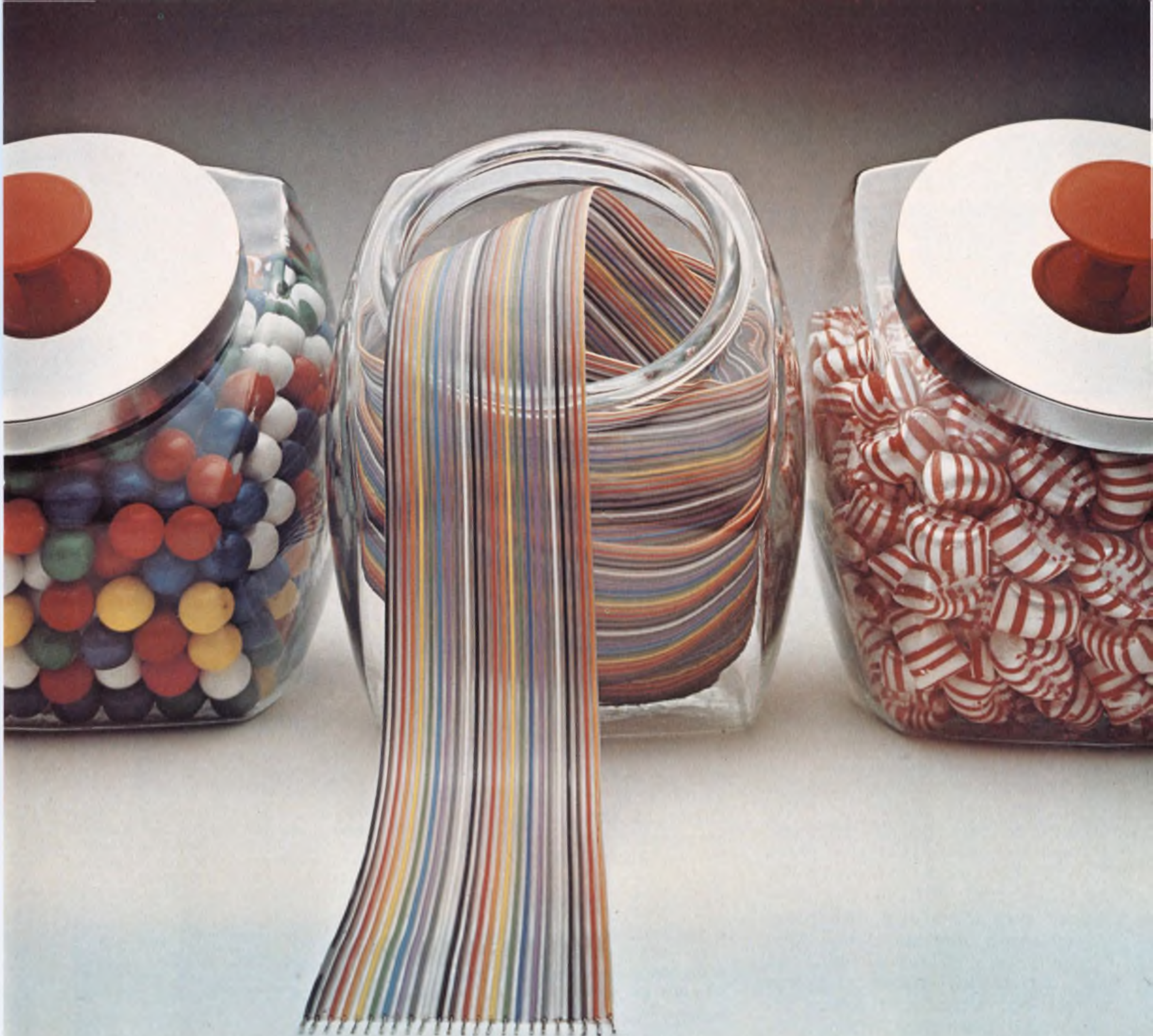


Fresh off the shelf. Ribbon cable from Hughes.

It could be as good an idea as penny candy: getting your ribbon cable from the same people who crack your tough flat conductor-cable problems.

We offer it by the foot, or as you like it. We not only make it, but we cheerfully cut it, strip it and terminate it for you.

Our new ribbon cable comes in widths from two to 100 conductors. The conductors are round (solid or stranded), and have color-coded PVC insulation. You can get 22 to 28 AWG.

Of course, all our cable comes with Hughes quality built-in. And we handle your order with the helpful attitude of one of the most competitive companies in the cable business.

So write us soon. Hughes Connecting Devices, 500 Superior Ave., Newport Beach, Ca. 92663. Or call (714) 548-0671.

HUGHES

HUGHES AIRCRAFT COMPANY
CONNECTING DEVICES

We crack the tough ones.

INFORMATION RETRIEVAL NUMBER 18

Centralab perspectives

FOR USERS OF ELECTRONIC COMPONENTS

CENTRALAB
Electronics Division
GLOBE-UNION INC.
5757 NORTH GREEN BAY AVENUE
MILWAUKEE, WISCONSIN 53201

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

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

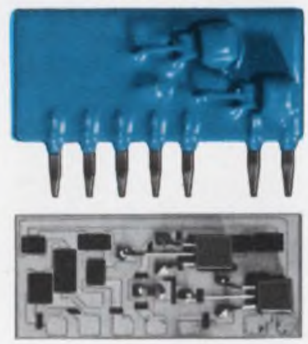
It's not surprising that the announcement of a breakthrough in thick film hybrid technology should come from Centralab. The product of a totally new concept in automated production, NEW PEC employs specially developed resistor paints that give these thick film circuits improved tolerance, better TCR,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

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

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

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

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



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

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

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

INFORMATION RETRIEVAL NUMBER 19

Centralab perspective:

Rotary Switches.

Design them in for multi-circuit switching needs.

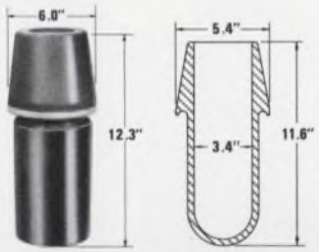
When your best circuit design requires switching an array of many circuits, the benefits of rotary switches makes them the logical choice. Centralab, with the most complete line, gives you benefits like this:

- **Simultaneous switching of many circuits by varying the number of switching decks.**
- **Choice of index types — for 2 to 24 positions — 15° to 90° throw.**
- **Shorting and non-shorting contacts can be intermixed on the same section.**
- **Phenolic, ceramic, glass or diallyl phthalate insulation — to match your dielectric specifications.**
- **Optional electrostatic shielding.**

Get the facts on total benefits. Write Centralab for Bulletin 1101SR.

Centralab perspective:

Transmitter Capacitors



Ceramic dielectric insert.

Meet Specs For Extra Reliability and Save 50%.

When selecting capacitors for transmitter equipment, Centralab can help. Example: one ceramic dielectric type can replace two vacuum types — increase reliability — yet reduce both weight and cost by 50% or more. The cup type shown, meets specs calling for 6000 pf, 10 kV and current ratings of 100 amps at 500 kHz.

Centralab's line of special capacitors includes header, feed-thru, tubular, slug and water-cooled types — plus custom designs to meet any spec.

All it takes is a call to Marty Hedrich at 414/228-2033.

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Electronics Division
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Centralab perspective:

CERAMOLITHIC® FILTERS HAVE EVOLVED WITH USE OF EVER HIGHER FREQUENCIES.

MSI and LSI technology have been shrinking the world of electronics, dictating higher, faster frequencies/speeds. With active circuit elements in intimate relationship, electromagnetic fields are straying into unwanted places; sharp filtering has to be an important design consideration.

U.S. Capacitor Corporation, the worlds' leading innovator of monolithic ceramic capacitors and filters, has tracked circuit speed developments with one idea in mind: improved attenuation at increasingly higher frequencies, in state of the art sizes and at *affordable prices*. Ceramic Filter evolution happens at USCC/Centralab by basic research in dielectric materials and new manufacturing techniques.

Today's products of this evolution are CERAMOLITHIC© subminiature EMI/RFI filters like our 9900 series feed-thru's giving better than 70 db at 10GHZ in only a .110" x .156" diameter case size — for use in medical electronics and CATV. Write for our new 1974 filter catalog or call Don Thommen direct, (213) 843-4222.

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Centralab perspectives

CENTRALAB
Electronics Division
GLOBE-UNION INC
5757 NORTH GREEN BAY AVENUE
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spice

VARIETY IN PUSHBUTTON SWITCH SELECTION. That's how Centralab can help put a little more spice in your work-a-day life. Because nobody else can give you all the up-to-date features and functions that let you design the way you want to. Start with the basic module . . . then select the options you want, and every functional and appearance specification suddenly becomes reality.

Maybe you'll select Centralab pushbutton switches* because they require so little space. That's important when you also consider that up to 29 modules can be ganged on a single bracket with horizontal or vertical mounting, rear or back-to-back coupling.

Or, you may want the flexibility that 5 different center-to-center spacings offer you. You can have 10, 12.5, 15, 17.5 or 20 mm in non-lighted switches. Lighted pushbutton switches are available in 15 or 20 mm. For interlock and lockout functions, Centralab is your clear choice. We not only offer you momentary, push-push and interlocking action switches, but four types of lockout as well.

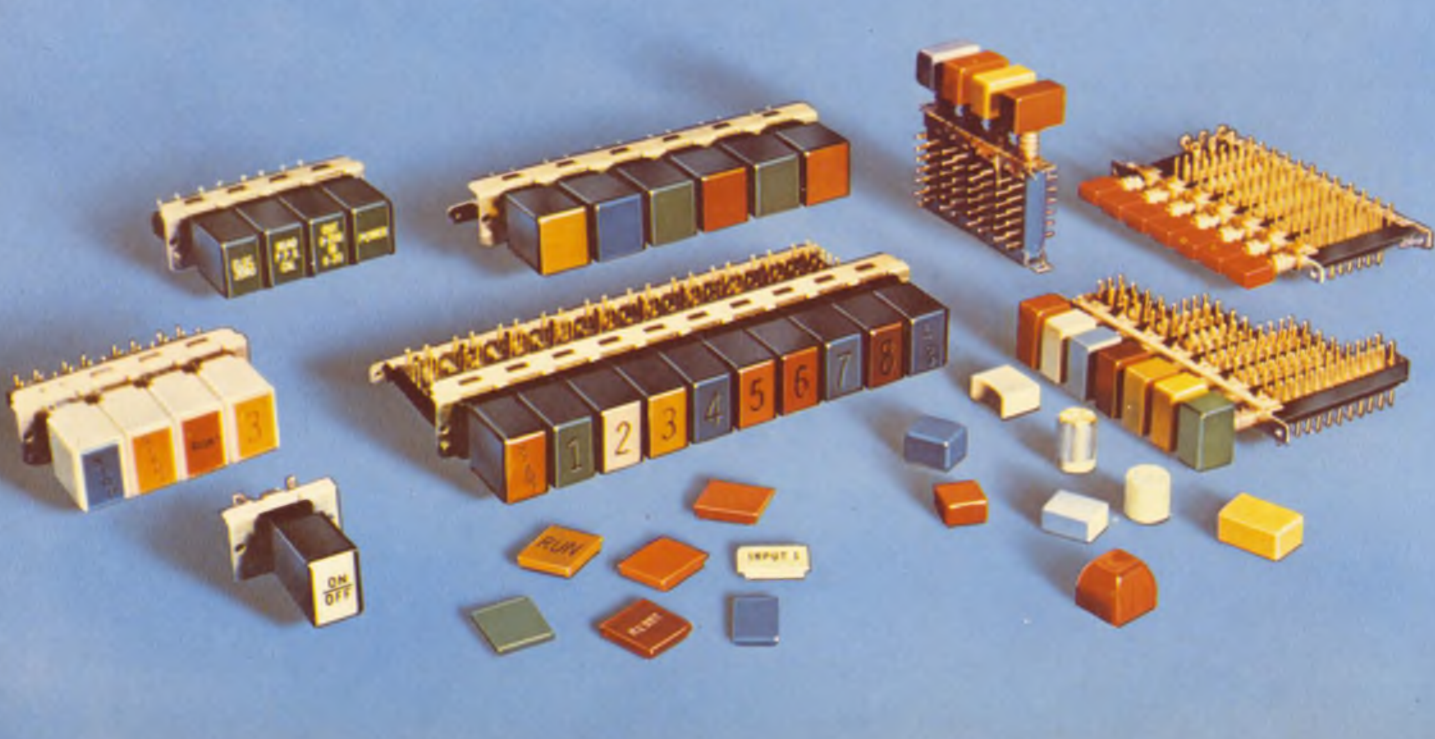
You'll find some of the brightest benefits in our lighted pushbutton switches. First, we supply both white and black lamp housings with a variety of filters and lenses for the precise control of light output over a wide range of ambient light conditions. And the snap-in lens permits relamping through a front panel. Our shock-mounted filament lamps are designed for low maintenance and long life.

The lamp circuit can be integral or separate from the pushbutton switch circuit. Where it's integral, lamp and switch circuits are in the same terminal plane and can be flow soldered simultaneously for easier installation and service.

If you're looking for the boundless variety that means true design flexibility, we've got your kind of pushbutton switch. We'd like you to know about our epoxy sealed terminals, selective pin cutting, wrap-around support bracket, dust-seal covers, line switch and 25 button styles in 18 colors. And how we can furnish legends for buttons, filters or lenses. We've put it all in a new 24 page catalog that includes complete specifications, dimensional drawings and ordering data. It's yours for the asking. Just circle the information service card or write Centralab for Catalog 1550P. Put some spice in your life.

*Isostat licensed

INFORMATION RETRIEVAL NUMBER 23



(continued from page 16)

part; I know better.

The assumption was made that the reader would have sufficient technical competence to derive the voltage transfer function for the circuit in Fig. 2. The reader would have realized that |A| represented voltage gain in the frequency response plot, and that 4.4 dB was the static gain. Thus the conclusion is that you fall below that competence level.

I agree that the title in Point 7 is much better. Point 8 is vague. The noninverting terminal resistors in Fig. 1 were not discussed in the text; hence they were given no reference number. Thus Point 9 would not add to the article. Once the basic principal had been grasped, it should have been obvious that the feedback transfer impedance of A_2 could be used to elevate the order of the filter from second to third—to the engineer who could derive common transfer functions. Your suspicions about the design procedure are well-founded. The correct calculations for R_4 and R_5 are:

$$R_4 = \frac{2}{\alpha_d \omega_d C}\left(\frac{\omega_n^2}{\omega_d^2} - 1\right)$$

$$R_5 = \frac{2d}{\omega_d C}\left(\frac{\omega_n^2}{\omega_d^2} - 1\right)$$

Robert J. Martin
Martin Marietta Aerospace
P.O. Box 5837
Orlando, Fla. 32805

Abbrevs. lv ths readr strnded & bewldrd

Here is an example of abbreviations used in ED No. 1, Jan. 4, 1974:

MOS, ROM, LED, ECL, TTL, CRT, NMOS, PMOS, FET, MECL, DAC, eMOS, RAM, pROM, FIFO, UART V-ATE, CMOS/SOS-RAM, MSI, LSI, MCM, GSE, AGE, TSE, EMI, RFI, ELF, GAO, CAD.

It's a jungle of words!

Vittorio Vallini
Via Rubio 79/A
10137 Torino, Italy

Now you have an alternate source for 2GHz & 3GHz microwave transistors

TRW's new 2GHz & 3GHz microwave amplifier parts are available right now, off-the-shelf, from any authorized TRW distributor. So, soon as you qualify these parts, you are no longer at the mercy of a single-source manufacturer!

And here's some more news: our transistors are **not** simply "just as good" as the originals; they're better! Gold metalized to last longer. Metal migration failure is virtually non-existent. The 2GHz parts can also withstand infinite VSWR and overdrive. Yet TRW's gold metalized parts cost the same as ordinary aluminum ones (maybe less!).

These are practically drop-in parts. You can use them right now, in your present amplifiers—and, of course, in future designs. That means instant improvement in the reliability of your amplifiers. Part for part:

	2GHz	PART NUMBERS	3GHz	
	Aluminum	**Gold**	**Aluminum**	**Gold**
1W	MSC2001	TRW2001	MSC3001	TRW3001
3W	MSC2003	TRW2003	MSC3003	TRW3003
5W	MSC2005	TRW2005	MSC3005	TRW3005
10W	MSC2010	TRW2010	—	—

For details, call Don Comm, (213) 679-4561.

Or write TRW RF Semiconductors, an Electronic Components Division of TRW Inc.,14520 Aviation Boulevard, Lawndale, California 90260.

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INFORMATION RETRIEVAL NUMBER 25

Explosive bonding is used to connect microcircuits

Explosive bonding—an unusual approach to the problem of making connections in microelectronic circuitry—has been demonstrated to be practical by researchers at Western Electric Engineering Research Center in Princeton, N.J.

Ben H. Cranston, member of the research staff, reports that microscale bonds have been made safely and reliably through the controlled deposition and detonation of explosives.

Although explosive bonding has been used for many years for large-scale bonding of different metals, the investigation at Western Electric has successfuly scaled down the process. The method offers the following advantages when microelectronic connections are made:

- Precious metals like gold are not needed in the process.
- Materials ordinarily difficult to join can be bonded together.
- The explosive bonds have greater strength than either of the parent materials.
- Changes in material properties, usually found because of the elevated temperatures common in other types of fusion bonding, are eliminated because the explosive bond can keep the materials below their melting points.
- Ultra-clean surfaces required for most solid-phase bonding systems are usually not necessary.
- The bonding cycle is very short, and the highly localized application of explosive force does not affect the surrounding areas.
- Only a relatively simple setup is required, as contrasted with expensive equipment or tooling needed for other methods of microelectronics conductor bonding.

As Cranston explains the explosive-bonding process, the metals to be bonded are laid one over the other, with a thin layer of explosive charge on top of the upper layer. The explosive is touched off by a hot tungsten filament at one edge of the upper layer.

The detonation propagates outward away from the initiation point, violently forcing the upper conductor down against the lower layer of material. At the point at which the upper and lower surfaces collide, a jet of material spurts out ahead and removes oxides, nitrides or adsorbed gases, thus providing a clean metal-to-metal bond.

Three types of bonds are possible with the explosive technique: A solid metal-to-metal bond, a bond formed by a layer of molten metal, or a bond that has an interlocking ripple due to small molten zones that were formed. The latter bond has the highest strength.

In fabricating bonds on microelectronic structures, the Western Electric researchers suspended the explosives in a special wet medium. The medium serves two purposes: It desensitizes the explosives for handling purposes, and it permits the explosives to be applied by use of screening techniques. An accurately controlled quantity of explosives is screened over the desired areas.

In some cases a buffer layer of material, like polyimide, was placed between the explosive and the metal to protect the surface and dampen the explosive force. Reliable bonds were formed by use of a buffer layer.

Materials bonded by Western Electric include copper to nickel, stainless steel to copper, and gold-plated copper to tantalum.

1-rpm video disc system shown to be feasible

The latest entry in the growing list of video disc players is an unorthodox 1-rpm system, demonstrated to be feasible by the Sydnor-Barent Scanner Corp. of Albuquerque, N.M. By contrast: most current video disc systems operate at 1500 to 1800 rpm.

The slow-speed system, invented by Dr. Iben Browning, President of Sydnor-Barent, substitutes optical technology for much of the electronics in other disc systems ED No. 13, June 21, 1974, pp. 31 and 46). Whereas all other disc players impress some form of the TV signal on the disc, the Sydnor-Barent system uses a 12-in. clear plastic disc that—for a 90-min. black-and-white program—has 65,000 microsized images impressed on the disc in a spiral. These images are converted to a TV signal through the use of a conventional flying-spot scanner.

For a 45-min. color recording, a twin spiral of 130,000 images will be used. One image will contain the black-and-white picture, and its twin counterpart will contain the color image or an analog from which the color signals can be reconstructed.

While the average disc speed is 1 rpm, the images pass under an optical pickup head at a constant rate of about 5 mm/s.

Because of the exceptionally slow disc speed, the sound is impressed on the disc not as a conventional sound track, but as an optical transform or "voice print," according to Nels Winkless III, marketing director.

"Our objective with the new system," says Winkless, is a $200 record player that has no precision instrumentation or servos. Also it must be a product that kids can work and which can't be damaged easily."

The disc is the one precision component in the system, he explains. The disc contains, in addition to the spiral of pictures on one face, an equal number of tiny lenses impressed on the opposite face of the disc. One lens is opposite each image. The images are enlarged and projected by the lenses into the flying-spot scanner. Resolution of these lenses, Winkless says, is better than that of a standard TV picture.

The disc will be somewhat thicker than a standard 12-in record. The thickness governs the required separation between the images and lenses to keep the images in exact focus. But the tolerances required are well within those of standard disc-pressing techniques. The optical-disc master is made by laser etching, says Winkless.

"We make a half-tone picture as a pattern of minute surface disturbances. In this case, light scatter—instead of light absorption—gives the image. From a metal master, clear plastic records can be pressed."

We have made experimental discs of polystyrene Winkless notes, "but we can use vinyl, which is what all the record makers use."

Because of the slow disc speed, the images pass the pickup head at only 12 frames per second—which raises motion and flicker problems.

But Winkless points out that motion becomes smooth at about 11 frames per second. And flicker is not objectionable with this system because there is no shutter. Instead as the disc rotates, the scene dissolves smoothly from frame to frame.

The reproduction of sounds at the disc rate of 5 mm/s was a problem, Winkless reports, because no conventional sound track would work. The solution was the use of sound spectrograms, otherwise known as voice prints.

TI MOSFET paces TV tuner race

An n-channel, dual-gate MOSFET from Texas Instrument has joined the race to develop a new generation of vhf/uhf TV tuners with MOSFET front ends.

Other entrants are DMOS transistors (MFE 591) from Motorola, Phoenix, Ariz., and the SD 301 series from Signetics, Sunnyvale, Calif.

The TI device, the 3N225, lists highest performance of the lot. The MOSFET was introduced at the IEEE Spring Consumer Electronics Conference in Chicago.

Paul Davis, manager of the Evaluation/Application Laboratory for small-signal products at Texas Instruments, Dallas, stresses: "These transistors have superior gain and noise-figure performance at uhf (900 MHz) with a tenfold improvement in cross-modulation, compared with conventional bipolar tuner transistors."

Designed for the 30-to-900 MHz frequency band, the transistors exhibit 25-dB gain in the low end of the band and taper off to 14 dB at 900 MHz. The typical noise figure is 5 dB, compared with 7 dB in conventional tuner transistors, and cross-modulation drops to 1% for 100 mV of undesired signal level, compared with 1% for 10 mV.

The TI transistors come in a plastic package and will sell for less than 50 cents in large quantities.

Pulse echoes to measure size of metal cracks

It's already possible to "hear" subminiature cracks deep inside a foot-thick wall of a nuclear-reactor container. Microphones on the side of the container pick up the sound, amplify it and feed it into a computer. The computer processes the data and produces a map that shows the crack's position.

But how big is the crack? Up to a certain size cracks are permissible, but once that size is exceeded, the plant is legally required to repair them. To determine size now, cracks must be examined visually, a procedure that isn't easy when you're dealing with nuclear fuel.

A solution, however, may be at hand. Engineers at the University of Michigan's Dept. of Mechanical engineering are devising a system that, after locating the crack by standard acoustic emission procedures, measures the size of the crack by an ultrasonic pulse-echo system. The procedure entails the sending of an ultrasonic sound into the metal, then the analysis of its echo to determine the size of the aperture.

The examination can be made in approximately one day, depending on the number of personnel working on the project, according to Professor Julian R. Frederick, of the University of Michigan. A crew with a truck that contains computers, tape recorders, amplifiers and microphones is needed. During the procedure, the principle vessel, which is shaped like a giant thermos bottle, is examined one section at a time.

"Twenty to 30 microphones spaced from 4 to 6 ft apart are firmly attached to its sides," Prof. Frederick explains. "They generally cover an area 40 ft by 20 ft with each test. The noise that the microphones pick up from the area is amplified and fed into a computer. As the computer processes the data, it produces a map that is read by a technician." With the present technique, the crack must be examined visually. With the new pulse-echo technique, the size of the crack will be shown on a computer readout. The Michigan engineers believe such a unit will be operational in the next two or three years.

Life-cycle appliance costs still rising

Hidden costs of major consumer appliances, such as color television sets, are at least equal to the purchase price and threaten to increase sharply in the future, according to a two-year study of consumer durable products by the Massachusetts Institute of Technology and the Charles Draper Laboratory, Inc., Cambridge, Mass.

The life-cycle costs studied include those for maintenance and repairs, servicing, electrical operating energy and disposal.

Least understood, according to the report, are servicing costs. Due to improvements in product reliability, the need for service for color television has declined by 50% over the past eight years. But this possible savings in the life cycle of the product has been wiped out by increased servicing costs.

For color television sets, servicing costs amount to 34% of the total dollars spent on a set during its useful life. Purchase price accounts for 53% and electrical power, 12%. This means that the owner of a $500 color TV can expect to spend about $500 more during its usable life.

The solution, the report states, is not to make servicing more productive but to improve the initial design. TV set manufacturers have an incentive to heed this advice because of warranty costs and the intensity of competition.

Reliability is a particularly important sales attraction for color TV sets, the report points out, because so many people—60% of those polled—expect to be overcharged for TV repair service, and 34% expect trouble of some kind in getting the work done.

SerenDIP-itous reminder

A versatile family of solid state DIP relays

Serendipity is a gift for finding valuable or pleasant things you hadn't looked for.

Teledyne, the world's largest maker of solid state relays makes serendipity for engineers — We make SERENDIP®s.

The SERENDIP® family includes four kinds of solid state DIP relays for different jobs. They up-grade, with all the advantages of solid-state — total input/output isolation, low-level logic input compatibility, fast response time, no "contact bounce" (drive IC's directly), and long life dependability. All this in low profile TO-116 DIP packs with equally low cost.

About those different jobs. The 640-1 features bi-polar output, AC or DC up to 50v/80Ma, with low ON resistance — 2 ohms typical. Use it for isolated line drivers and data couplers, A/D converters, modulators and demodulators.

The 641 is a small AC powerhouse — 1 AMP Triac output, 140 or 280 VAC with a 10 AMP surge rating. Try it for lamp or inductive load control — solenoids, motors, transformers, etc. And the 641 is now UL recognized.

The 643's are DC versions capable of switching up to 60v/400Ma or 250v/100Ma. They actually exceed current and voltage switching capabilities of opto-isolators. In communications, use them for keyer switching — or as telegraph relays.

Finally, the 644 is a low offset voltage unit that solves switching problems in instrumentation applications. Use it for low level transducer signal switching, series choppers, scanners, sample-and-hold, multiplexing, etc.

The SERENDIP® family — a pleasant reminder from Teledyne Relays. Ask your rep or distributor, or call us.

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INFORMATION RETRIEVAL NUMBER 26

A built-in heat pipe proposed to cool GHz power transistors

The use of a heat pipe directly on the chip may permit microwave power transistors to compete with klystrons and other gigahertz rf devices, according to Michael A. Merrigan, senior technical staff assistant at Hughes Aircraft, Fullerton, Calif.

Merrigan, a researcher who has demonstrated the feasibility of cooling rf power transistors with internal heat-pipe structures, points out that as the operating frequency of transistors increases into the microwave range, the transistor chip becomes small. This reduction severely limits the heat that can be dissipated and consequently the power output of the devices.

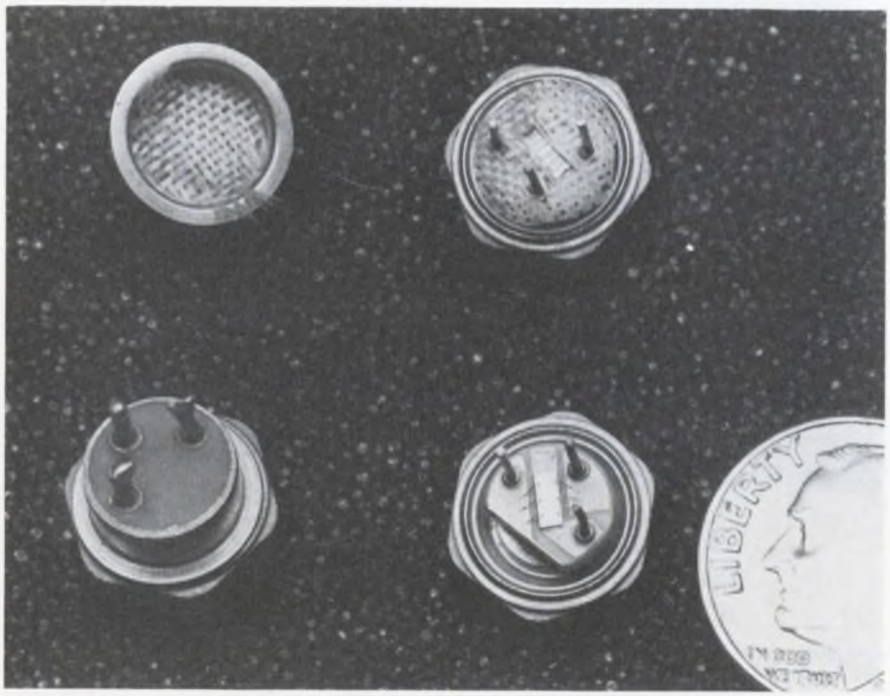
In Merrigan's investigation—performed for the Army Electronics Command, Ft. Monmouth, N.J.—the surface temperatures of the chip of a 2N5701 (35-W maximum rating) transistor operating at 76 MHz were reduced from 219 C at 29-W dissipation to 130 C at 42.5 W when the heat pipe was used.

Jim McDermott
Eastern Editor

With proper chip design, Merrigan is confident this technique can be extended to transistors operating in the 1-GHz region.

An advantage of the heat pipe, he says, is that it can be made of nonmetallic, dielectric materials and, as a result, can provide electrical isolation while maintaining high thermal conductance.

Another useful characteristic is the pipe's ability to carry off widely varying values of heat without variations in temperature. This insensitivity to local variations in input power is exploited in the transistor heat pipe to reduce hot spots on the chip.



Heat pipes for transistors are fabricated with Refrasil fiberglass wick structures. Here a 2N5701 transistor on a TO-60 header is in various stages of assembly. The sealed transistor is filled with 3M FC-77 fluid.

Application of heat-pipe cooling directly at the chip surfaces minimizes temperature irregularities over the chip surface and reduces the limiting thermal resistance—that of junction-to-case.

The heat-pipe approach was used in the Hughes investigation because of its high thermal conductance in dense high-power applications.

The basic pipe structure, Merrigan explains, consists of a sealed enclosure lined with a porous wick material that is wetted with a volatile liquid. No gas other than that of the pure vapor of the liquid is present. At normal vapor-flow velocity, the pressure is nearly uniform throughout the vapor space. The temperature along the wick surface then remains essentially constant at some equilibrium temperature.

The region of the heat pipe where heat is introduced is an evaporator; the cooling fluid is vaporized here. The section where the heat is removed is a condenser; the vapor is returned to fluid here. The flow of heat along the pipe is extremely rapid.

The working fluid chosen for the transistor heat pipe was 3M Co.'s fluorocarbon FC-77. It has a normal boiling point of 216 F, and because of its fluorinated structure, it is nonflammable and chemically inert. The fluid is essentially unaffected up to about 750 F.

Most important, the electrical insulating and dielectric characteristics of FC-77 are excellent, Merrigan reports. The liquid phase dielectric strength is about 500 V per mil, he says, and the dielectric constant less than 2.0 from 1 kc to 8.5 GHz.

Based upon the number of performance tests, Merrigan notes

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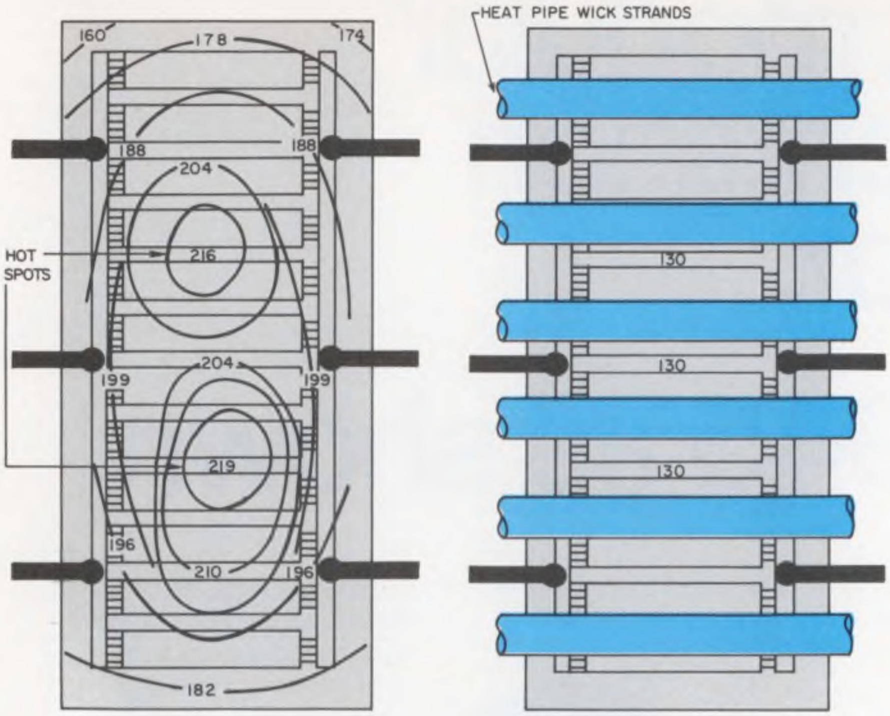

Thermal map of a 2N5701 transistor (left) with 29-W input shows hot spots on the chip. With a heat pipe, the same transistor (right) has no hot spots at 40 W. In addition the chip temperature is reduced by 89 C.

that the wick material chosen was Refrasil glass fiber. The wick consisted of fiberglass stranded bundles 0.004-in. in diameter spaced 0.02 in. apart over the chip.

The open configuration was chosen, Merrigan explains, because of the high heat-flux density at the chip surface and the low thermal conductivity of the wick material.

The remainder of the header was covered with a mat of glass fiber to provide fluid storage and fluid return.

The transistors used for the investigation were 2N5701's on TO-60 headers (see photograph). In fabricating the wick structure, Merrigan placed wick strands across the chip surface and glued the ends with epoxy. To ensure good contact between the primary strands and the chip, additional strands were placed at right angles across the top of the primary bundles.

The inner surface of the transistor case was lined with a layer of glass fiber matting that projected slightly below the cap surface.

The remainder of the chip substrate on the header was covered with a pad of woven glass fiber for the condenser wick. The inner surface of the case cap was lined with another layer of glass fiber that made contact with the wick structure surrounding the chip. The cap was then welded in place on the header.

On the TO-60 cases the projecting connector pins on the cap were cut off near the top, and the FC-77 heat-pipe fluid was injected through the pin openings. The transistor was then heated to slightly above the atmospheric boiling point of the fluid (97 C), and the fluid was allowed to vent through the pin openings. The pins were crimped and solder sealed.

As the power to the heat pipe transistor increased, the junction-to-case thermal resistance decreased. Merrigan points out that this characteristic is consistent with usual heat pipe performance. Test data showed that the thermal resistance was cut by 80%. ■■

Multiple-beam antenna could boost communication satellite capacity

Frequency reuse is the new marching cry in the communications industry. With this approach, the same portion of the crowded frequency spectrum can be used by several users simultaneously without interference.

A multiple-beam lens antenna that can produce up to six beams at the same frequency and can electronically aim those beams at any of 37 possible targets is under development at Philco-Ford, Palo Alto, Calif. The antenna was described by William G. Scott, multiple-beam antenna section supervisor, during the Fifth Communications Satellite Systems Conference sponsored by the American Institute of Aeronautics and Astronautics in Los Angeles.

David N. Kaye
Senior Western Editor

According to Scott, "It is a wideband microwave constrained lens and feed array using printed-circuit technology for each lens element."

The antenna, he says, will produce pencil beams at the same frequency with sidelobes below −34 dB for all positions within an 18° conical field of view.

The sidelobes must be down at least 27 dB to make the system practical, Scott notes.

Such a multiple-beam antenna could greatly increase the capacity of communication satellites. The pencil beams could be aimed from a synchronous satellite at several different regions or cities. If the beams were sufficiently isolated from each other, all of these regions could communicate through the satellite on the same frequency band without interfering with each

vactec phototransistors

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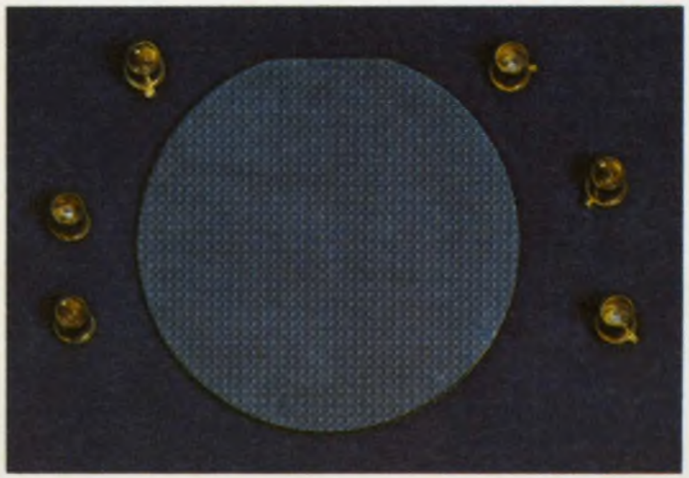
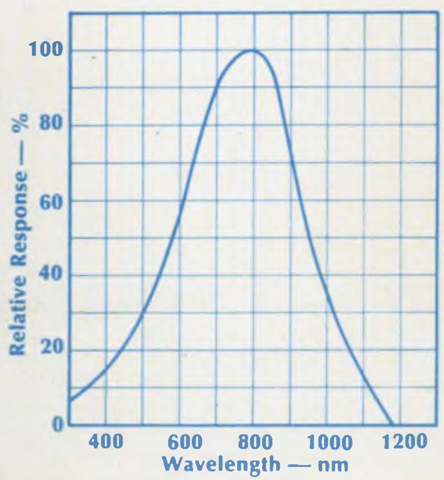
Vactec npn epitaxial large chip, high sensitivity phototransistor. An enlarged section of the wafer forms the colorful background.





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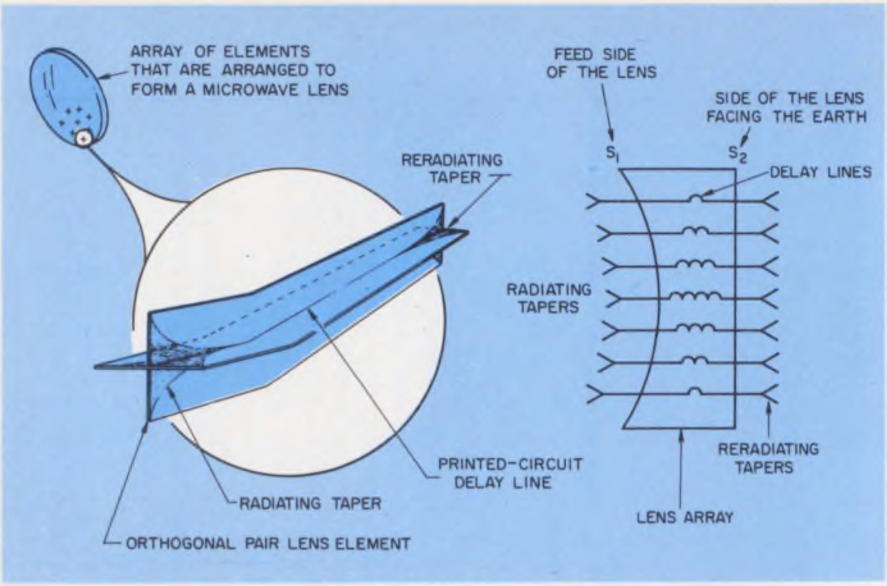
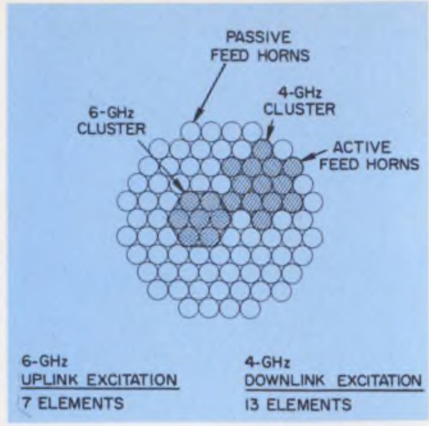


The Philco-Ford lens array will contain 400 elements. Each is a delay line constructed of a pair of orthogonal printed-circuit boards. Tapers are used on each end as the radiating elements, and a meander line connects the tapers. The delay lines are phased so that when one side of the lens is illuminated by the feed array, the energy is shaped into a pencil beam that can be as narrow as 1/2 degree.



A cluster of properly phased feed horns is necessary to keep the sidelobes at least 34 dB down from the main pencil beam. This allows several beams to be generated simultaneously but which are isolated from each other.

other's messages.

Each region would have its own ground station, with capability for two-way communications with the satellite. Thus one region could communicate with another region without the message being simultaneously transmitted to all other regions as well.

Current development of the Philco-Ford antenna is for a conventional 6-GHz uplink and 4-GHz downlink. With frequency reuse, all uplinks and all downlinks would be at the same frequency bands.

In the most common form of antenna, the antenna feed illuminates a reflector, which shapes the transmitted beam of energy. With any lens antenna, the feed illuminates one side of the lens array. The microwave energy is shaped by the lens—just as an optical lens shapes a beam of light—and retransmitted out the other side of the lens.

Scott describes the lens array as "a large number of radiating elements arranged in a circular grid to form a primary receiving array of small pickup antenna elements; a secondary reradiating array of elements, and a set of rf delay lines connecting, on a one-to-one basis, primary-to-secondary radiating elements."

The Philco-Ford lens array is illuminated by feed horns arranged in a circular cluster. Each of the beams requires several feed horns. The feed horns needed for all of the beams illuminate the lens array simultaneously. The position of the feed horns generating each beam determines the direction of the pencil beam that comes out the other side of the lens array.

Circular feedhorn cluster used

If single feed horns were used, the sidelobes of the antenna pattern would be too high for isolation of the multiple beams that are simultaneously generated, Scott notes. Philco-Ford solves the problem by using a circular cluster of feed horns to create each beam. The center horn is the primary feed, and the adjacent horns are phased so that phase cancellation of their signals brings the sidelobes at least 34 dB below the primary beam. At 6 GHz the feed cluster requires seven elements and at 4 GHz 13 elements to get sufficient isolation.

Printed circuits in lens array

In the experimental antenna that Philco-Ford is constructing, the lens will be a circular array of 400 elements on approximately one-wavelength centers. It will weigh between 120 and 150 lb. The estimated aperture efficiency of the lens is 25 to 30%.

Scott points out that "in order to get low sidelobes, not only is the feed cluster necessary; it is also necessary to have very low phase error in the lens." Since the lens phase error is a function of the phase error of each of the lens elements, an inexpensive precision element was required. Each element is a microwave delay line. The phase of each element is proportional to the length of the delay line.

The elements are constructed as orthogonal pairs. Each pair is two printed-circuit boards in the shape of an orthogonal cross. The radiating ends of the boards are curving tapers, and the delay line structures are meander lines. The delay lines are transverse electromagnetic transmission lines, and the lens is said to be of the TEM type. A typical element is about 2 to 12 in. long. The shorter elements are at the center of the lens and the longer elements are placed around the perimeter.

One surface of the lens is flat (outer surface), and the other is concave (feed side). The diameter of the lens will be about 5 ft and beamwidths as narrow as 1/2 degree will be feasible. The antenna is in the breadboard stage at present. ■■

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INFORMATION RETRIEVAL NUMBER 29

DIALIGHT

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A super-thin copper foil for PCs uses up to 75% less of the metal

Like the U.S. Cavalry galloping to the rescue, the developers of micro-thin copper foil plan to help save the circuit-board industry from assault by copper shortages.

A peel-off process for manufacturing a copper foil 5 μ thick—a process that could mean copper savings of up to 75% plus labor savings for suppliers of microminiature PC boards and could give users denser circuitry—has been developed by Yates Industries, Bordentown, N.J. The company produces and supplies copper foil to electronics and other industries.

The announcement was made by Bernard C. Alzua, technical director of Cu-Tronics, Inc., Timonium, Md., a company that makes printed-circuit boards from laminates supplied by U.S. Polymeric, Stamford, Conn. Alzua has worked closely with Yates and has provided feedback on how the foil might best be used in the printed-circuit-board industry. Yates sends the processed copper foil to U.S. Polymeric, and that company laminates the foil to PC boards for such users as Cu-Tronics, Inc.

Smaller width and lower spacing

In an interview, Alzua said that he had made several microminiature PC boards (Fig. 1) and that the most important result for designers was that minimum line width of 0.004 in. and spacings as low as 0.003 in. had been readily achieved. By contrast, conventional 1-oz. copper is 0.0014 in. thick, and the minimum line width is only 0.008 to 0.010 in. Alzua says he expects 0.002-in. line and 0.002-in. spacing in the future.

According to Alzua, electrodeposited copper foil 5 μ thick now can be smoothly laminated to the surface of a substrate, such as the epoxy glass series, polyester, phenolic and flexibles. This was impossible before the copper peel-off process was developed because the copper could not be applied flawlessly to the surface; what emerged was copper that was porous.

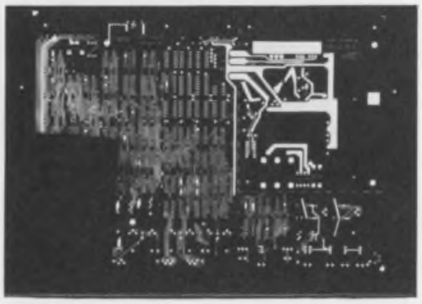
Use of micro-thin copper for circuit boards became practical when Yates electrolytically deposited a standard 2-oz. (.003 in.) copper foil, then laid in a barrier and built a second layer of copper 5 μ thick (Fig. 2). The combination of these two foils behave exactly like a single foil.

The bonding side of this micro-thin copper can be variously treated by the copper manufacturer to adhere to the type of substrate being used. Then the thick layer can be easily peeled off, leaving a 5-μ thick layer of fine, clean, virgin copper surface (Fig. 3). The copper peeling can be resold to a manufacturer who can recycle it.

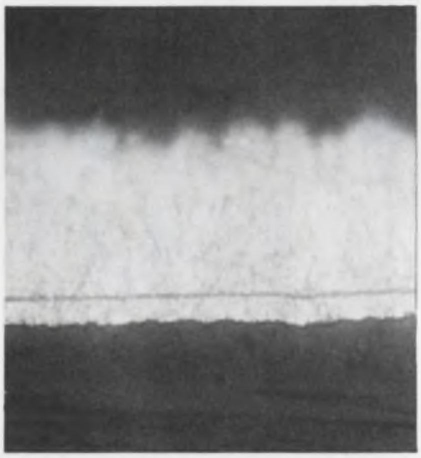
Apparently there are only a few disadvantages to using micro-thin copper. One is that micro-thin copper laminates may be from 25% to 40% higher in cost than the conventional 1 and 2-oz. laminates. Another is that someone has to peel off the top layer of copper manually or mechanically.

But, according to Alzua, the advantages far outweigh the disadvantages. Advantages that are of special interest to designers, and other users of circuit boards, are finer line control, smaller hole diameters, higher density of circuitry, no solder slivers and no pits and dents. Other advantages: no deburring of the hole after drilling, a reduction of 75% in etching time, etchant savings up to 80%, no undercut due to etching. ■■

Richard L. Turmail
Associate Editor



1. **This actual size microminiature** circuit design was made possible by the peel-off method of micro-thin copper.



2. **Cross-section of the copper foil** shows (top to bottom) carrier layer of copper, barrier line, and micro-thin layer of copper.

3. **The thick layer of copper is peeled** away leaving a five micron thick layer of copper.

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One-step process bonds copper to ceramic without adhesives

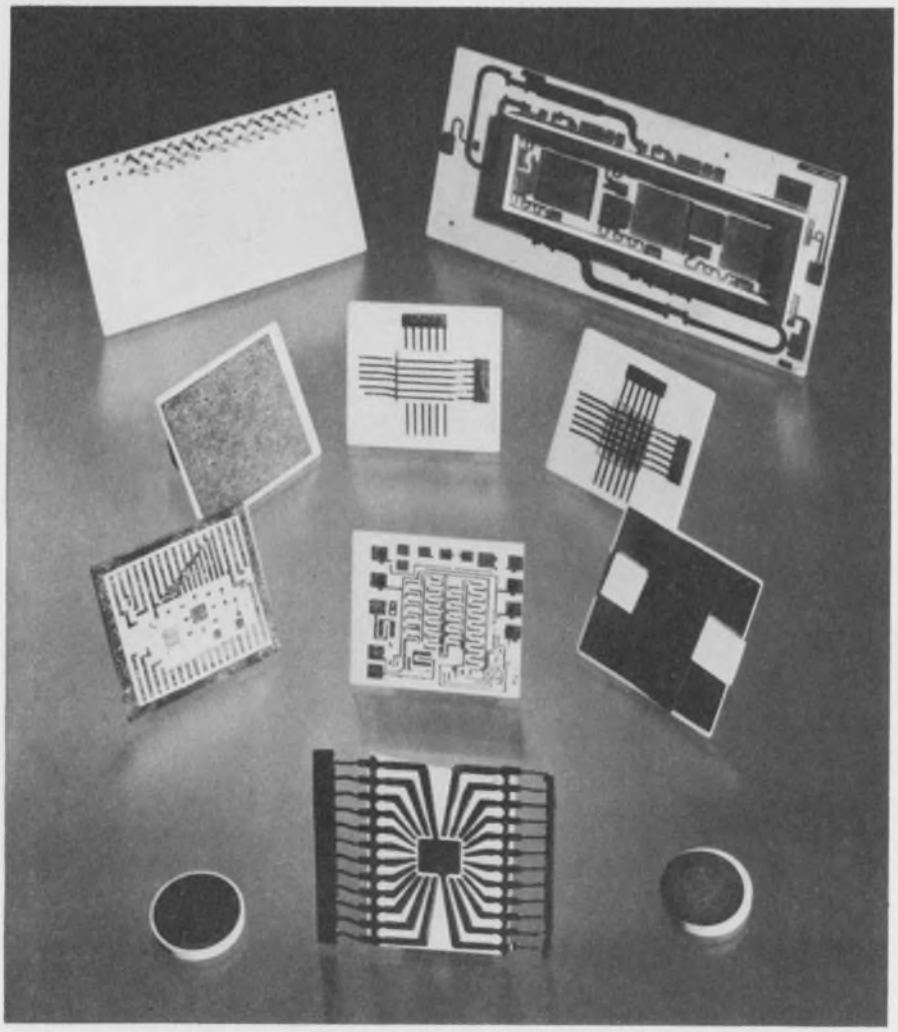
A one-step process for attaching copper foil to ceramic substrates like aluminum oxide and beryllia uses no adhesives. The new method —called Direct Copper Bonding by its developer, General Electric—is reported to be simpler, less expensive and more reliable than present methods of ceramic IC assembly.

The process can replace gold in IC packages, GE says.

According to James F. Burgess, staff member at GE's Research and Development Center, Schenectady, N.Y., other advantages include:

- The copper-ceramic bond routinely exceeds 20,000 psi.
- The electrical resistivity of the bonded pattern is essentially that of pure copper.
- Despite differences in the coefficients of expansion between copper and the ceramics, repeated thermal cycling from 77 K to 300 C does not cause mechanical failure.
- Holes in the ceramic can be sealed hermetically.
- Thick-film conductor screening and firing steps are eliminated.
- Brazing and hard soldering do not cause bond failure.

Burgess, who developed Direct Copper Bonding with Dr. C. A. Neugebauer and G. T. Flanagan, sees the process leading to improved heat-sinking of ceramic packages of all kinds. In addition, he says, it will be used in the fabrication of microwave IC packages and hybrid IC devices. Foils of 1 to 20 mils can readily be bonded, Burgess reports, but the process is also effective with copper sheets 1/4-in. or more thick.



A new direct-bonded copper process, by GE, was used to fabricate the conductor patterns on the ceramic packages. Copper heat sinks are also applied.

A eutectic is formed

The process creates a bond by heating copper in contact with a ceramic in a controlled, inert gas atmosphere that contains only a few hundredths of 1% of oxygen. The heat causes oxygen in the controlled atmosphere and the copper on the surfaces of the foil to form a eutectic—a mixture of copper and oxygen with a melting point that is lower than that of pure copper.

By careful regulation of the process temperature between the eutectic melting point of 1065 C and that of the copper (1083 C), the eutectic on the surface of the copper melts into intimate contact with the ceramic substrate. A strong bond is thus created without extensive diffusion of the two into each other.

Burgess points out that fabrication costs are considerably below those of conventional bonding methods because of the simplicity of the process and lower materials cost. ■■

INFORMATION RETRIEVAL NUMBER 31 ▶

Simplified waveform digitizer uses TV camera to capture the trace

After attempting for two years to obtain costly dual-gun scan converter tubes that would work satisfactorily in a waveform digitizer, researchers at Sandia Laboratories discarded that approach. Instead, they developed a digitizing system that costs less and simply takes a TV picture of a scope trace.

The TV camera output is then digitized and fed to a computer for analysis, as well as being displayed on a CRT in the digitized form. The system has several unusual features:

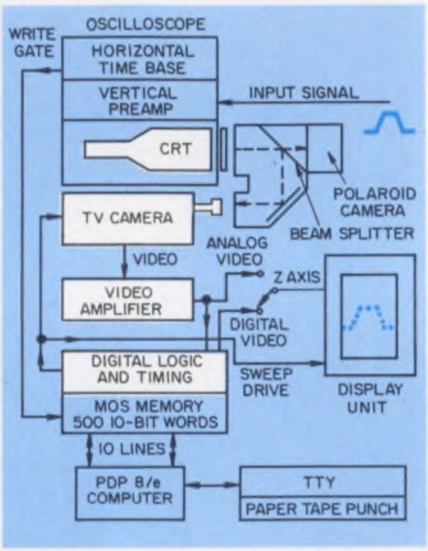
- It can be used with any commercial oscilloscope.
- Waveforms—whether fast transients or repetitive ones—can be digitized with an effective sampling rate of up to 25 GHz.
- A Polaroid camera can take photos of the trace being digitized.
- The system provides baseline—as well as waveform—digitizing, thereby freeing the operator of the need to adjust the oscilloscope trace position precisely.
- The system is available in two versions—for use in the laboratory and the field.

"In the original development, using dual-gun scan converter tubes, we obtained only two good ones out of 10," says Thomas L. Evans, a co-developer of the new system at Sandia in Albuquerque, N.M. "A major problem was dirt particles in the tube, which worked at 10 kV. The dirt caused voltage breakdown, and with 10 kV feeding into a chassis full of logic, we no longer had any logic."

The new system, Evans explains, consists of seven elements, a silicon-diode-array vidicon tube mounted in a commercial TV camera, an oscilloscope, mirror, beam splitter, logic chassis, display unit and Polaroid camera.

Light from the oscilloscope trace

The Sandia vidicon digitizer is checked by Thomas Evans, one of the developers. At top is the display, and below it the digitizer and computer.



System configuration of the Sandia digitizer includes an MOS memory, whose contents are recirculated for display or computer entry.

is coupled to the target of the vidicon through a beam splitter and mirror (see figure). The vidicon tube converts the light image to an electrical signal that is fed to a logic chassis. In the logic section the signal is sampled and converted to a series of 500 words of 9 bits each. These digital words are stored in an MOS memory, from which the data can be extracted and viewed on the display unit. The data can also be sent to a minicomputer—in Sandia's case, a PDP 8/e—or other types of peripheral equipment.

For maximum accuracy, Evans points out, the vidicon digitizer is calibrated, with highly accurate amplitude and time signals, before the waveforms are digitized. These calibration signals are analyzed by the PDP computer. The computer uses the calibration factors to scale the data directly in engineering units and to correct for horizontal and vertical nonlinearities.

The accuracy of the digitizer is limited only by its resolution, Evans points out. To verify this, Sandia measured pulse amplitudes independently with an oscilloscope differential-comparator amplifier. Pulse widths were measured with a time-interval counter. The digitizer always agreed within ±2 digital counts (0.4% of full scale) of the scope and counter measurements.

Test results have demonstrated that single-shot transients can be digitized at sweep rates of 2 ns per division. Since 500 digital samples are obtained, this represents a sampling interval of 40 ps.

The compact field version includes the digitizer and an accessory case containing the TV camera, camera mount, digital cassette recorder and cables.

The field model also has an added static MOS memory that is compatible with either fast or slow peripheral devices. ■■

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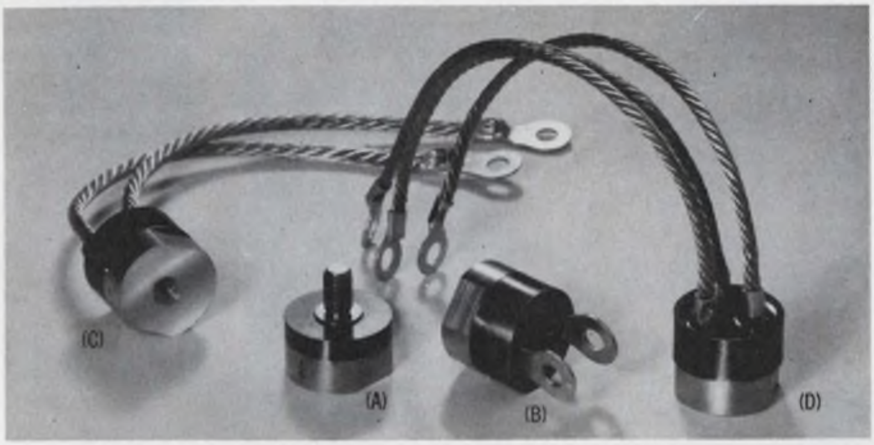

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Body Dimensions: 1.12" D x .70" H (+ stud)
FAST RECOVERY — (Trr) 200ns. (Fig. A)
Peak Inverse Voltage: 50, 100, 200 & 400V.
V_F (max.) (@ 100A): 1.40V, Tj @ 25°C; 1.35V, Tj @ 100°C.
Reverse Current (max.) @ PIV: 25μA @ 25°C; 1 MA @ 100°C.

MEDIUM RECOVERY (Trr) 2 μs.
PIV: 50, 100, 200, 400, & 600V.
V_F (max.) (@ 100A): 1.22V, Tj @ 25°C; 1.17V, Tj @ 100°C.
Reverse Current (max.) @ PIV: 25μA @ 25°C; 1mA @ 100°C.

•DOUBLERS & CENTER TAPS Figs. (B) & (C)
Body Dimensions: 1.12" D x .9" H (+ leads).
FAST RECOVERY (Trr) 200ns
PIV: 50, 100, 200 & 400V.
V_F (max.)(@ 50A): 1.40V@25°C; 1.35V@100°C.
Reverse Current, per leg (max.): 13 μA @ 25°C; 500 μA @ 100°C.

MEDIUM RECOVERY (Trr) 2 μs.
PIV: 50, 100, 200, 400 & 600V.
V_F (max.)(@ 50A): 1.22V@25°C; 1.17V@100°C.
Reverse Current, per leg (max.): 13 μA @ 100°C; 500 μA @ 100°C.

• 3 PHASE ½ WAVE BRIDGE Fig. (D)
Body Dimensions: 1.12" D x .9" H (+ leads).
FAST RECOVERY (Trr 200ns)
PIV, per leg: 50, 100, 200 & 400V.
V_F (max.) @ 33A: 1.40V, Tj @ 25°C; 1.35V, Tj @ 100°C.
Reverse Current, Per Leg @ PIV: 10 μA @ 25°C; 350 μA @ 100°C.

MEDIUM RECOVERY (Trr) 2 μs.
PIV, Per Leg: 50, 100, 200, 400 & 600V.
V_F (max.) @ 33A: 1.22V, Tj @ 25°C; 1.17V, Tj @ 100°C.
Reverse Current, Per Leg @ PIV: 10 μA @ 25°C; 350 μA @ 100°C.

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Peak Inverse Voltage: 30 & 50V.
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• ½ WAVE RECTIFIER

	@ 25°C	@ 100°C	@ 150°C
V_F (typ.) @ 20A	.86V	.77V	.72V
V_F (typ.) @ 60A	.95V	.88V	.85V
V_F (typ.) @ 100A	1.02V	.97V	.93V

• DOUBLERS & CENTER TAPS

	@ 25°C	@ 100°C	@ 150°C
V_F (typ.) @ 10A	.86V	.77V	.72V
V_F (typ.) @ 30A	.95V	.88V	.85V
V_F (typ.) @ 50A	1.02V	.97V	.93V

• 3 PHASE ½ WAVE BRIDGE

	@ 25°C	@ 100°C	@ 150°C
V_F (typ.) @ 5A	.86V	.77V	.72V
V_F (typ.) @ 15A	.95V	.88V	.85V
V_F (typ.) @ 25A	1.02V	.97V	.93V

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V_F (max.)@ 50A: 1.40V @ 25°C; 1.35V @ 100°C.

MEDIUM RECOVERY (Trr) 2 μs.
PIV: 100, 200, 300, 400, & 600V.
IR (@ PIV), Per Leg: 13 μA @ 25°C; 500 μA @ 100°C.
V_F (max.)@ 50A: 1.22V @ 25°C; 1.17V @ 100°C.

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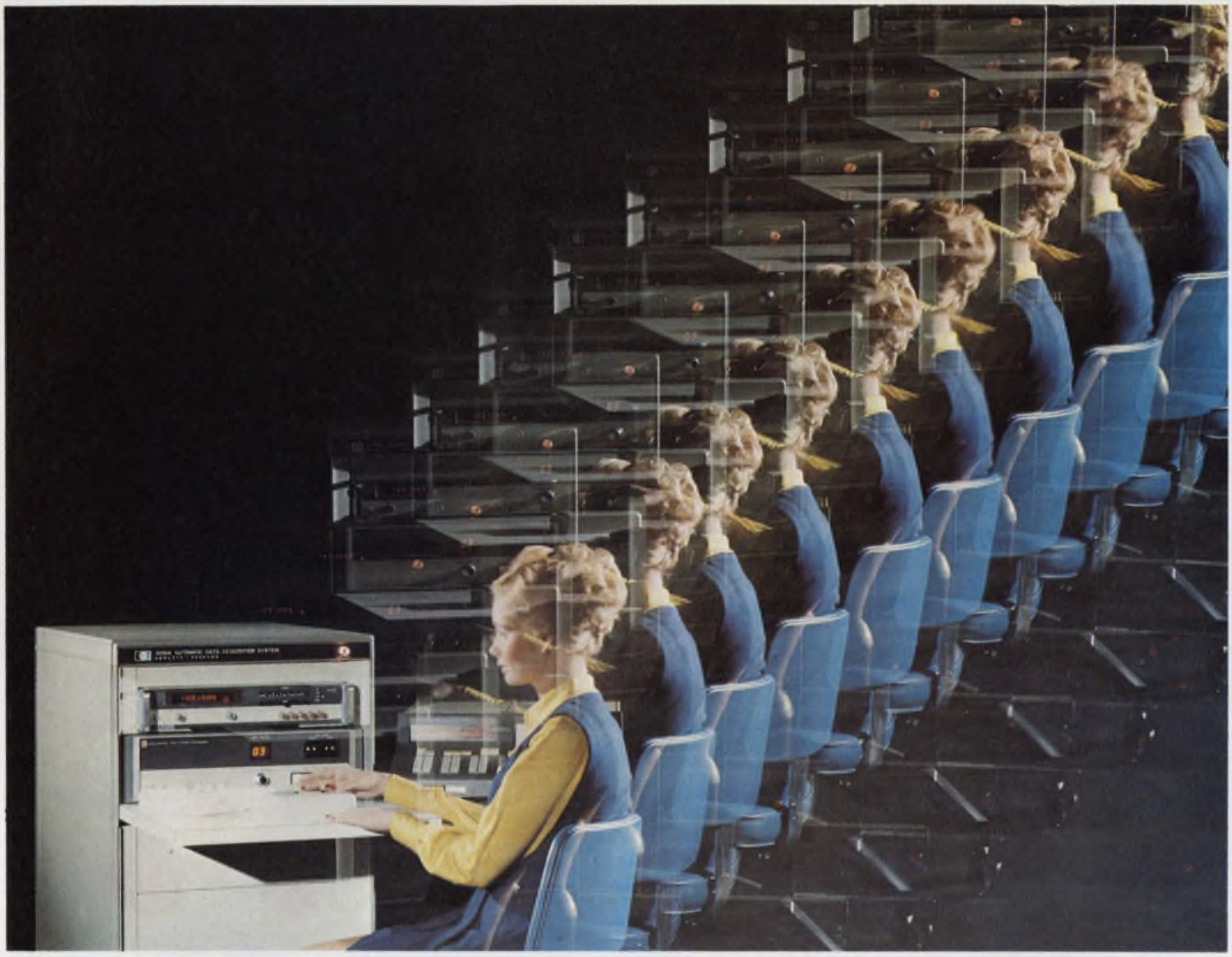

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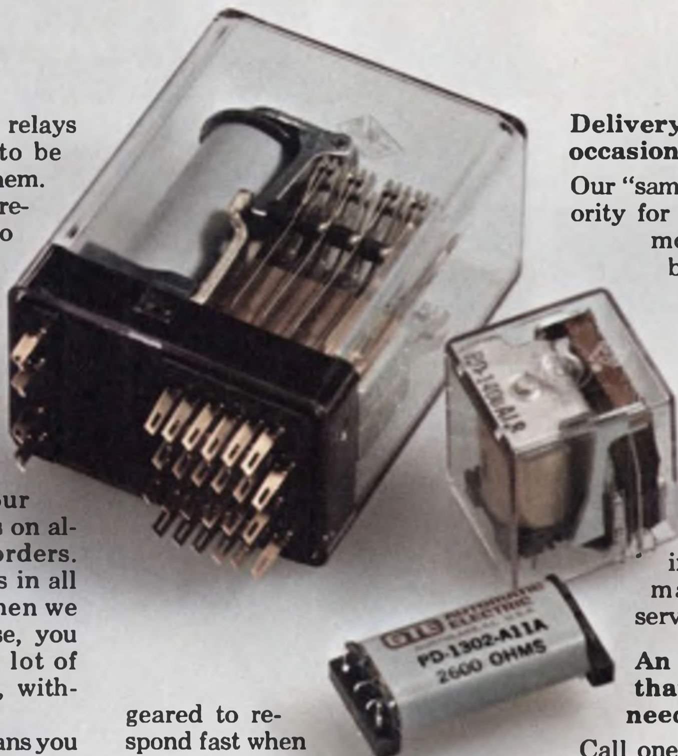

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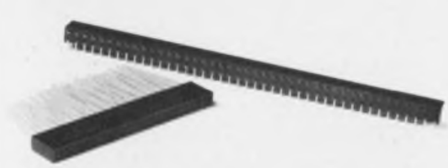
"CANNON'S ADAPTA-CON CONNECTORS MADE A BELIEVER OUT OF MANAGEMENT, and a hero out of me."

"But it started with Bronx cheers."

"I kept my cool when they blew their collective top at the mention of my specifying Cannon. I knew they still connected Cannon with aerospace cost, not aerospace expertise.

"So I laid out the facts and figures on Adapta-Con: Mates with 0.025" sq. posts; 0.100", 0.0125", 0.150" grid spacings: single or double row; low insertion force; low cost.



"But I told them that's just the beginning. With Adapta-Con we can use one connector type for all our equipment. For plugging to feed-through posts, backpanel tails, as I/O connectors, and jumpers. They'll outlast most edgecard connectors. Want to hear more? I said.

They did.

"It puts a crimp in your costs, too."

"So I brought up Cannon's automatic strip-and-crimp machine. It strips and crimps twisted pairs, jacketed cable and hard-coated wire, handles up to four gages at a single setting, and is faster and simpler to operate.

"They balked at capital expenditure, but brightened up when I explained we can lease it and more than make up the monthly charge by what we'll save in just a week's lower wire preparation costs.

"That cooled them off. And when Cannon delivered what it promised, on time, within cost, the cheers broke out. Real cheers this time.

"Want to know how I did it? It's in this book. Send for it today. Cheers."

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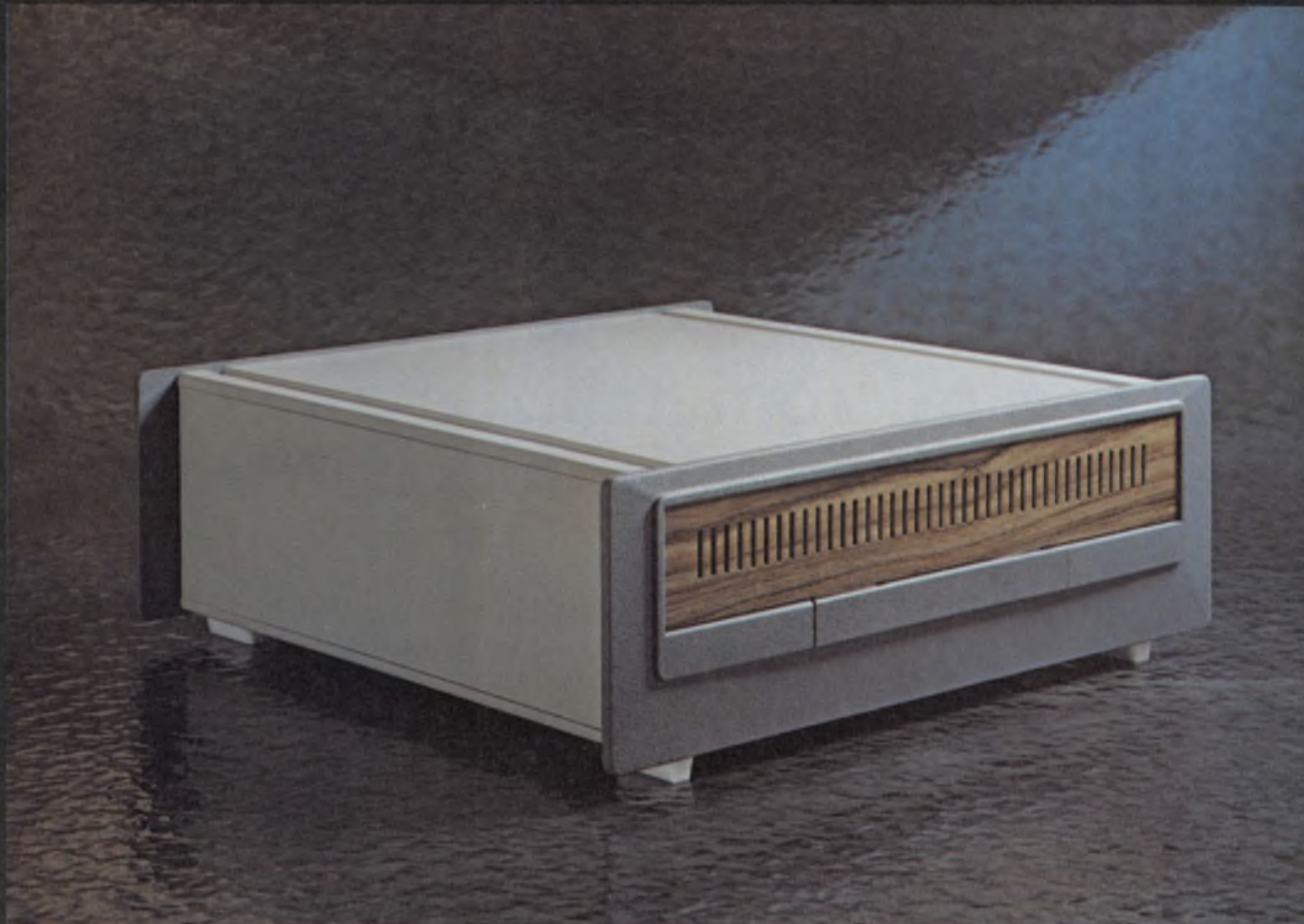

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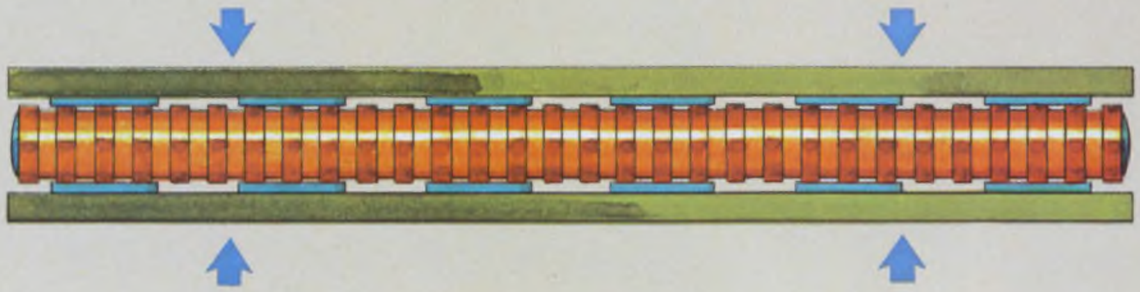

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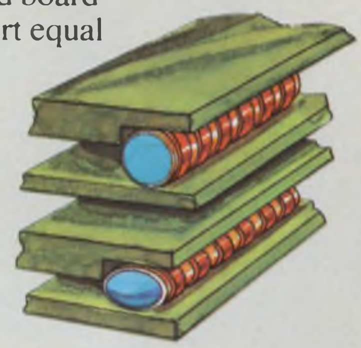

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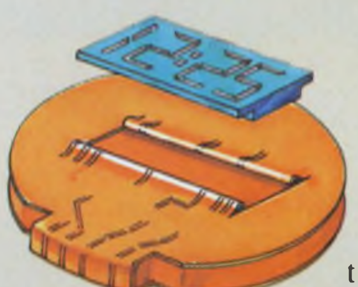

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INFORMATION RETRIEVAL NUMBER 40

washington report

Heather M. David
Washington Bureau

U.S. may liberalize R&D requirements

Federal contractors have for some time enjoyed a program that gives them funds based upon a percentage of their contract work, to pursue their own research interests. This money, particularly when given by the Defense Dept., must be used on research that is relevant to the interests of the Federal agency. However, this stipulation may be changed.

Industry, according to the General Accounting Office, would like to see the relevancy test dropped completely. If there must be a test, industry would prefer that the criteria be that the R&D be "in the national interest." The Defense Dept., the biggest supplier of such money, now appears to be considering switching to this position. In fiscal 1973, the Pentagon gave its contractors $738-million to pursue independent R&D programs.

Congress boosts NASA programs

Congress has told NASA to start work on an additional Earth Resources Technology Satellite (ERTS-C) and to accelerate a solar satellite power-station study. Both the House and Senate have approved the plan and have sent to the President an authorization bill that would add $12-million to the Administration's request for funds for space application. The next hurdle NASA faces is convincing the Office of Management and Budget that the projects should be pursued.

FAA to require quality-control plans on electronics

In a move that, if successful, could spread to other agencies, the Federal Aviation Administration has initiated a program that requires manufacturers of air-traffic-control equipment, navigation aids and related items to furnish detailed quality-control plans, along with their technical proposals, bidding on contracts. The FAA will check each contractor periodically to see that he is adhering to his plan. Failure to comply could mean termination of the contract, the agency says.

Senate rejects Pentagon trade veto power

Legislation that would have made the Secretary of Defense the final judge of what technology could be traded with the Soviet bloc has been modified by the Senate in a vote on the military-procurement bill. The proposal, offered by Senator Henry M. Jackson (D-Wash.), was opposed by the Administration but backed by organized labor, the Senator says.

Jackson explains that his intent was to prevent transfer of high-technology items, such as wide-bodied jets, computers and integrated circuits, that Communist nations could use to strengthen their military capability. The Defense Dept., he says, is the best place to make such decisions. But the Senate voted for a modified version of the proposal, making the Secretary of Defense co-equal with the Secretary of Commerce and other high officials in giving such advice to the President.

However, it's not all over yet, the Senate Banking and Finance Committee will consider export-control legislation in the near future.

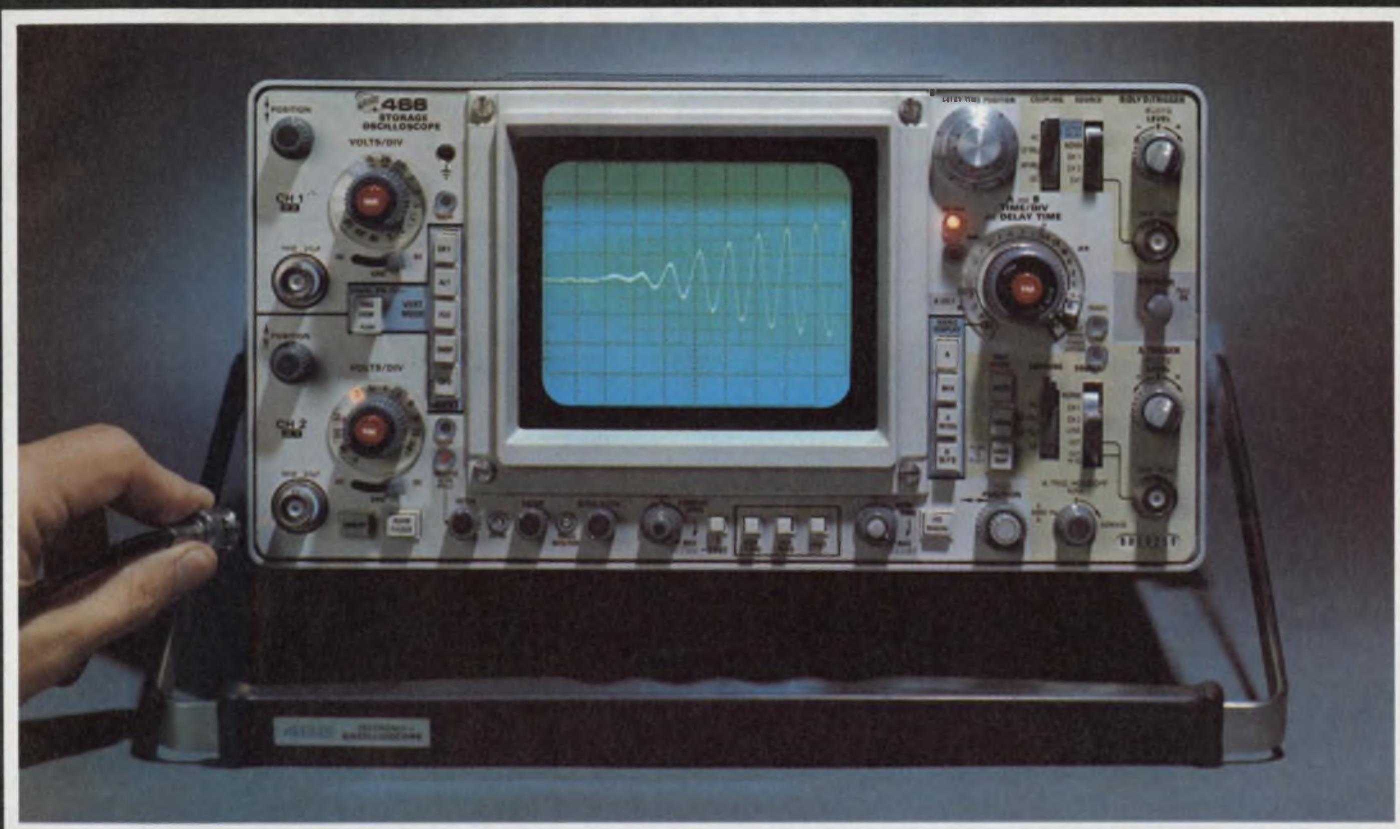
Design-to-cost: Real or public relations?

The effectiveness of the Pentagon's much-ballyhooed "design-to-cost" program, aimed at bringing cost consideration into the design phase, particularly in electronic equipment, has been attacked in the Senate. "After three years," said Sen. Thomas Eagleton (D-Mo.), "design-to-cost has influenced the management of relatively few weapon systems. Despite the setting of cost goals and the bureaucratic machinery to enforce those goals, tradeoffs of excessive sophistication have not been made." He added: "Sadly we continue to prepare for combat from the inside of research laboratories, where the imagination of defense scientists far surpasses the practicality of the weapons they produce." Recent cost estimates of weapon systems, the Senator said, led him to conclude that ingrained resistance among the services had "transformed a good concept into little more than good public relations."

Capital Capsules:

The Senate Antitrust and Monopoly Subcommittee has **resumed hearings on the communications industry, focusing on allegations of anticompetitive practices by American Telephone & Telegraph.** The hearings will deal with the interconnect area. . . . The Air Force's Avionics Laboratory, Wright-Patterson AFB, is **seeking sources to perform exploratory microwave research and development in the area of high power microwave switches.** The objective is to develop a high-power, high-speed, single-pole, double-throw microwave switch and its associated driver assembly. . . . Semiconductor industry reps have been told that a **planned reclassification of silicon material as a chemical, rather than as a metal, will not alter the present exemption of silicon products from tariff regulations.** WEMA got the news from the U.S. Tariff Commission. . . . The Air Force has **successfully tested a fiber-optic data link for carrying flight-control signals inside an aircraft from the pilot's cockpit to the controls.** Use of the fiber-optic data bus, developed by Hughes Aircraft, was the first for a fly-by-wire flight-control system. . . . Senator Birch Bayh (D-Ind.) **has called once more for the termination of the phased-array, Sam-D air-defense system.** He says the General Accounting Office has concluded that "even if the Sam-D technology works and even if the threat materializes," the missile will probably not be necessary if F-15 aircraft are available. . . . The Army Air Mobility R&D Laboratory, Fort Eustis, Va., is **embarking on a program to demonstrate remotely-piloted-vehicle technology.** It plans to award two contracts for a total of 50 aircraft with interchangeable sensors. . . . Comsat General Corp. has awarded a contract to Scientific Atlanta, Inc., for 100 shipboard antennas and associated terminal equipment as **part of a major program to provide improved communications via satellite to commercial ships at sea.** . . . The Defense Dept. **has explained the $7-billion cost growth reported by the General Accounting Office for 55 weapon systems.** It cited the following: inflation (36%), engineering changes (25%), schedule changes (20%) and an accumulation of minor factors. The $7-billion increase over only a six-month period ended Dec. 31, 1973, was in a large part due to such programs as the B-1 bomber, F-15 fighter, SSn688 submarine and Minuteman III missiles.

Single-Shot Storage to 100 MHz



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The 466 Portable offers the fastest stored writing rate of any Tektronix direct-view oscilloscope—1350 cm/μsec throughout its 100 MHz bandwidth. (5 divisions magnitude for single shot 100 MHz sine wave.) It provides up to a 5 nsec/division sweep rate through the X10 magnifier and vertical deflection sensitivity to 5 mV/division. You can view and retain fast rise, low repetition rate, single shot, or slow moving waveforms. Here are Tektronix's reliable trigger characteristics and CRT's that minimize residual image and burn problems. Now you can display phenomena that could never before be viewed with ease on an oscilloscope.

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The 466 is the answer to field troubleshooting and calibrations that require the same exacting standards as those originally specified in the lab, production, or engineering. Weighing under 30 lbs., it carries easily. And the 13-position handle provides a versatile support stand. Take an instrument with Option 7 to a missile site or into an aircraft and power it with 12-24 VDC or the 1106 or 1105 battery pack. Its 1350 cm/μsec stored writing rate can make the Tektronix 466 your most valuable test instrument.

If the high writing speed of the 466 is not required, the 464 (which is otherwise identical) features 110 div./μsec.
466 Oscilloscope, $3850.
464 Oscilloscope, $3300.

Discover what the 466 can mean to you. For a demonstration or more information, contact your local Tektronix Field Engineer, or write Tektronix, Inc., P. O. Box 500, Beaverton, Oregon 97005. In Europe write Tektronix Ltd., Guernsey, C.I., U.K.

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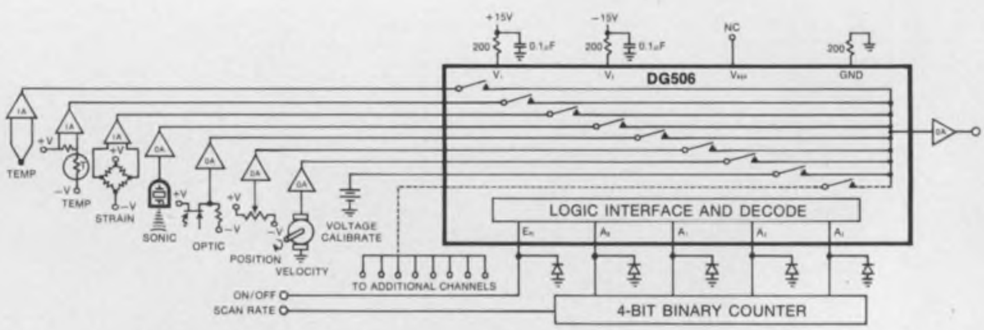

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INFORMATION RETRIEVAL NUMBER 44

editorial

Growing old youthfully

In *As You Like It*, Shakespeare, one of the better modern playwrights, takes us through the seven ages of man. Starting with the memorable lines, "All the world's a stage,/And all the men and women merely players," he draws a picture of man from mewling and puking infancy to old age, with its "Second childishness and mere oblivion,/Sans teeth, sans eyes, sans taste, sans every thing."

Were he alive today, Shakespeare would no doubt draw a similar picture of the ages of a modern corporation—or engineer. He would picture vigorous, imaginative, hard-working youth, then the mellowed middle age and, finally, pathetic senility. Skeptically, we would look for exceptions. We'd find them, but they'd be rare.

Many of us who have worked for those younger companies would recall the excitement and challenge of building something from almost nothing. We would recall the thrill of out-smarting powerful competitors. We would forget the occasional bitter defeats and the 25-hour work days.

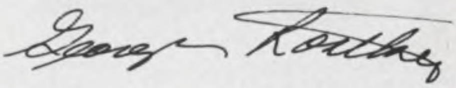
We might remember these companies as they arrive at middle age, when the arteries had not yet hardened—but were beginning to. We might recall the new luxuries. We didn't have to wire our own breadboards; we had technicians. We didn't have to make do with old second-hand test gear; we could buy brand-new modern equipment. And we enjoyed normal working hours. But something was missing—some spark. We had lost the fire, the excitement, the challenge, the feeling that we, as individuals, were very important.

As these companies grow older, they become engulfed in non-essential, non-productive routines. They are enmeshed in procedures, policies and tiers of managers. The attitude, "How do we get this job done quickly, effectively and profitably?" is replaced by "What's company policy?" and "What's the procedure?" We busy ourselves with filling out forms and operations manuals. And we become comfortable. Our hot young aggressive companies have become venerable institutions—"Sans teeth, sans eyes, sans taste, sans every thing."

Can we prevent this aging and decay? Or is that a hopeless search for a fountain of youth? I think there's hope. I recently visited a 35-year-old company with an enviable growth record and with sales exceeding half a billion dollars a year. The company kept its doors open all night so engineers could come in at any hour to try out an idea. And they did.

By our industry's standards, a 35-year-old company is very old, indeed. Yet the company, in some ways, was behaving like a youth. Perhaps that's the key.

It's probably impossible completely to escape the encumbrances of age and size. But maybe we can stall the onslaught of old age for a long time if we keep trying to emulate the vigor, enthusiasm and excitement of youthful companies—and engineers.



GEORGE ROSTKY
Editor-in-Chief

INFORMATION RETRIEVAL NUMBER 45

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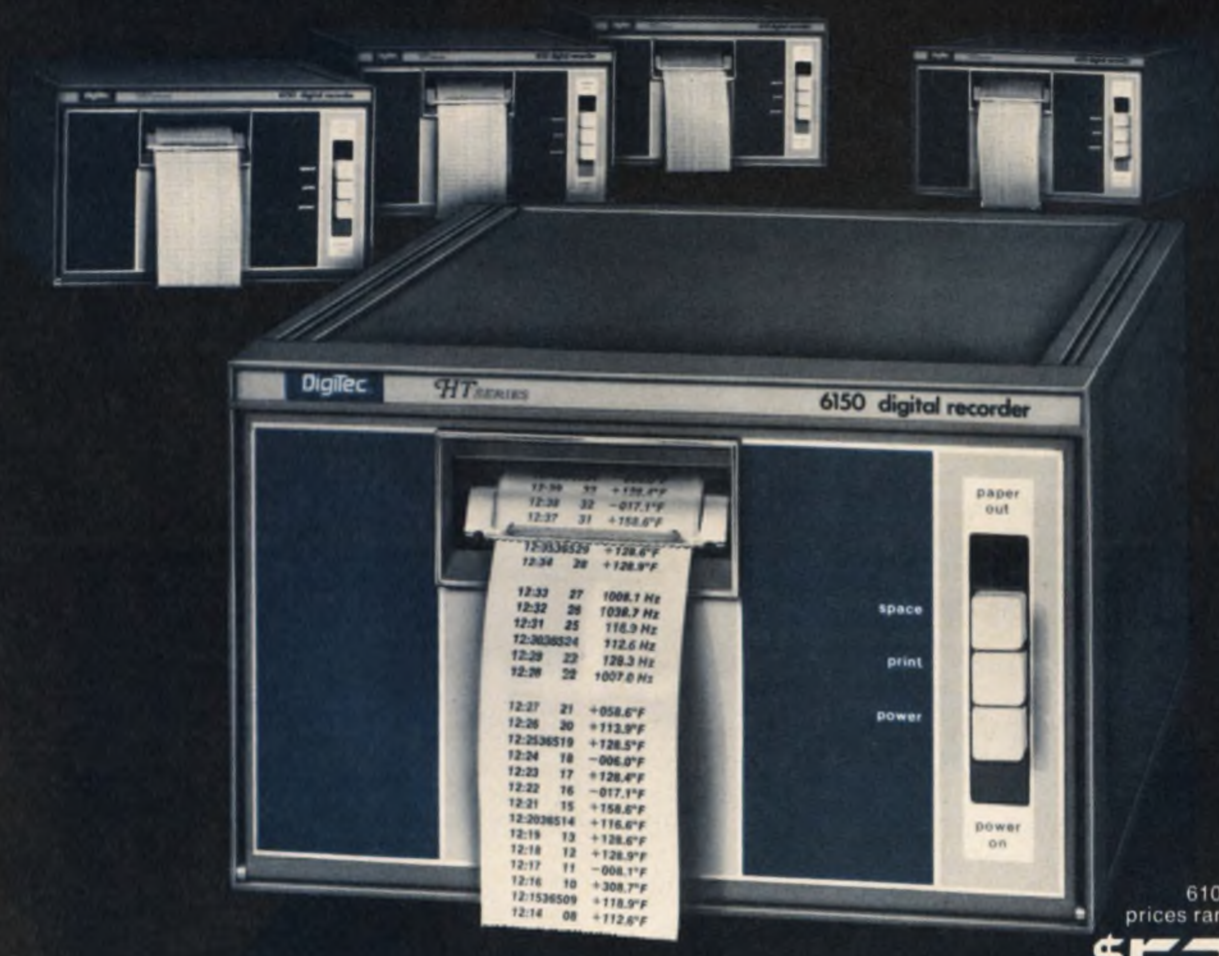

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INFORMATION RETRIEVAL NUMBER 241

FOR DEMONSTRATION, CIRCLE 242

FOCUS on Cooling electronic packages

Hot semiconductors can fail. And semiconductor failure can be catastrophic. Satellites may go out of whack. Computers may falter. And 1974 cars may not start.

A key way to ensure and improve reliability is to keep the junction temperatures of the equipment's semiconductors at a safe operating value. It's generally accepted that the semiconductor failure rate is halved for each 10-C reduction in the junction temperature below maximum.

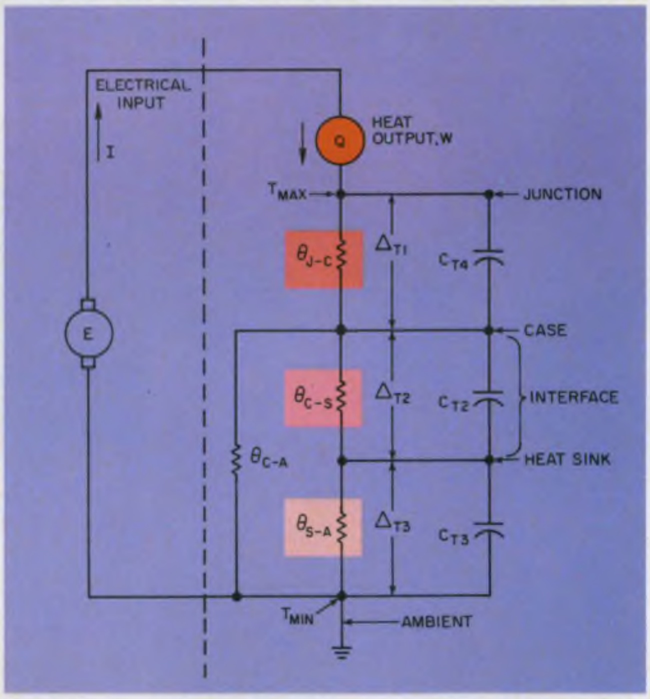
But how do you keep electronic components and packages cool? The problem is exacerbated by the trend to higher packaging densities.

Designers frequently neglect the selection of heat-transfer devices or systems because, first of all, the quantities, terms and concepts of heat-transfer technology are unfamiliar to some. And the specsmanship of heat-transfer device manufacturers—whether they package heat sinks, heat pipes, thermoelectric modules, fans and blowers, or heat exchangers—is compounded by the thermal jargon they use.

Thermal circuit design is becoming a crucial part of the electronic designer's bag of tricks, particularly when the penalty for neglecting thermal considerations early in the design can result in an add-on cooling kluge—and this can be costly in terms of both dollars and space. In some cases redesign from scratch may be necessary.

Fortunately the basic quantities in specifying heat-transfer devices and their related thermal circuits are analogous to electrical quantities. Thermal circuits can be evaluated on the basis of their electrical analogs.

For example, the flow of heat (Q) from one point to another along a thermally conducting path—usually stated as power in watts—is comparable to electrical current flow. The temperature difference (ΔT) between any two points in this path corresponds to a voltage drop. Thermal resistance (Θ)—the quality that impedes the flow of heat from one point to another—is equivalent to electrical resistance. Thermal conductivity (k) is analogous to electrical conductivity.



Understanding thermal circuits is easier with this electrical analog of a semiconductor and heat sink. Junction heat flows through the case and sink to the ambient.

Whenever heat is applied abruptly to a thermal mass, the temperature does not rise instantaneously but requires some finite time—or lag—to do so. This characteristic is similar to that of a thermal capacitance and is so indicated in the

Jim McDermott
Eastern Editor

The problem of keeping semiconductors cool has produced heat sinks and heat exchangers tailored for literally hundreds of applications. These devices by Thermalloy are representative of what's available for the designer, from thermal washers to liquid-cooled units. The latter units use water or other cooling fluids.

thermal circuit for a transistor.

The thermal problems of electronic equipment are almost entirely involved with the removal of heat from semiconductor devices—individually or in panels and racks. These devices range from milliwatt plastic transistors to ICs to high-power, kilowatt, liquid-cooled silicon-controlled rectifiers. David Hegarty, applications engineer of Wakefield Engineering, Wakefield, Mass., suggests that the problem be approached from the viewpoint of a system, in which each step in the chain of transfer of heat is identified.

The electrical analog in the figure is a fundamental approach that can be adapted to the solution of simple heat-transfer problems. An electrical input generates heat (W) at the device junction. This heat travels through the thermal resistance of the junction (Θ_{J-C}) to the case. From the case, the heat encounters the resistance of the interface between the case and the heat sink (Θ_{C-S}). This may be a dry, pressure interface, or the thermal resistance here may be lowered by use of a heat-sink compound. The heat entering the sink encounters the resistance of

Convection cooling is used for all of the heat sinks here, by Wakefield, except for the liquid-cooled and fan-cooled units at upper right.

Excellent thermal conductivity of beryllia rapidly dissipates heat in these National Beryllia headers and packages for rf and microwave semiconductors and ICs.

the sink (Θ_{S-A}). This value is determined by the following: The amount of heat dissipated to the ambient air—either by radiation, convection or forced-air flow—plus that carried off by conduction to the chassis.

Heat sinks in 3 major areas

The most widely used heat-transfer devices are heat sinks, which are produced in a seemingly endless number of designs. Thomas Coe, president of Wakefield Engineering, points to three major areas where these static cooling devices are found:

1. **In small, discrete components and integrated ceramic and DIP packages, usually mounted on circuit boards.** The devices are of small sizes and are usually produced in large quantities by sheet-metal-forming operations. The cooling device is frequently designed to fit a particular metal or plastic semiconductor case style. A problem encountered here is that the circuit designer doesn't leave enough airspace for adequate convection cooling. Or he doesn't orient the boards or devices for optimum airflow.

2. **In medium-power discrete components, usually in power supplies.** Here the cooling device is ordinarily designed to fit a class of semiconductors. Sometimes the heat-sinking device—most frequently made of aluminum extrusions—provides structural support. However, there is a tendency to expect too much structural support from these heat sinks, and that often results in extra machining and tolerances that make the price high.

3. **In high-power diodes and silicon-controlled rectifiers.** With these devices, the heat generated per component is much higher than in other applications. And the maximum operating temperatures of the junctions are lower, so that cooling requirements are tough. Ruggedness is required for these heat-dissipating assemblies, since they are frequently used in compression modes. A basic problem is to provide the required cooling at a reasonable price and with practical designs. Sometimes, when a system is being developed, there is no practical means of providing the required cooling, so the system has to be derated or changed; the use of larger components or more components in parallel may be necessary.

'Thermal resistance': What is it?

Probably the most ambiguous term used by heat-sink manufacturers is "thermal resistance," says John E. Markley Jr., executive vice president of International Electronic Research Corp., better known as IERC.

Many manufacturers spec the thermal resistance from the interface side of the sink to the ambient temperature. he points out. Others list the thermal resistance from the semiconductor case to the ambient. Since the latter spec includes the thermal resistance of the interface, the two figures do not agree.

Knowledge of the complete thermal circuit between the semiconductor, its interface with the heat sink and the final transfer of heat to the ambient is as important as the electrical circuit in today's high-density packaging, Markley notes.

Facts needed to determine if a heat sink will perform as predicted by the specs include (1) Interface losses; (2) Whether the manufacturer's thermal tests were conducted in an open bench or in a test cabinet; (3) Whether the test was conducted on a thermal model or on the actual device, and (4) Whether or not thermal paste was used for the tests.

Many discrepancies in specs stem from the fact that most manufacturers use their own test methods, even though an industry standard exists. These standard procedures—used by

IERC and some others—are defined in the Electronic Industries Association Bulletin No. 5, "Recommended Test Procedure for Semiconductor Thermal Dissipating Devices," and its Amendment 5-1. Bulletin 5 details tests for metal-case semiconductors, while the amendment describes testing for plastic devices.

While many manufacturers rate their heat sinks by thermal resistance, this approach is valid, Markley says, only if all the test parameters are given.

From curves of the case rise above ambient vs power dissipation, the engineer can easily obtain thermal-resistance figures at any power level by dividing the case-temperature rise by the power dissipation.

Richard G. Vossler, marketing manager of Astrodyne, Wilmington, Mass., points out that many suppliers of heat sinks give a thermal resistance for the sink but do not state the power at which this thermal resistance applies or the ambient temperature. This can be deceptive.

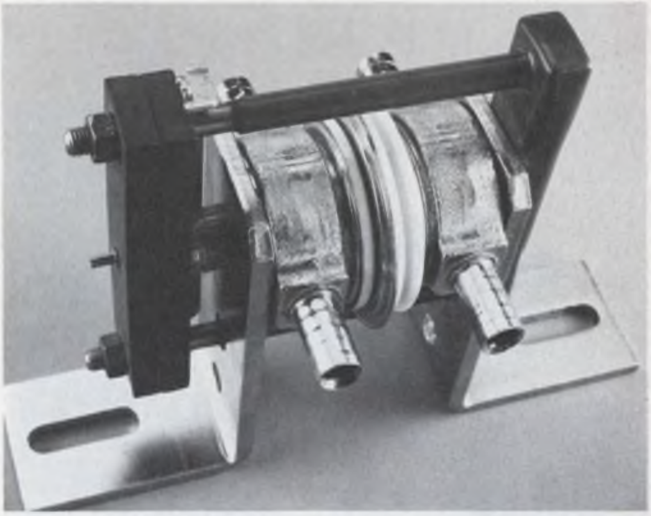
For example, a three-inch-long heat sink with a black, anodized finish—like the Astrodyne 2517-0300-A10B—will have a thermal resistance of 1.96 C/W to 1.24 C/W, depending on whether it is operating at 10 W or 100 and if the ambient is 20 or 25 C.

William C. Jordan, vice president of engineering for Thermalloy, Inc., Dallas, Tex., notes that the designer can also be misled if the heat-sink manufacturer does the following:

- Fails to locate the thermocouples at the hottest point on the device case when data are reported for TO-5 and TO-3 heat sinks.
- Fails to specify the thermocouple location on DIP packages. The gradients in the package can be very large. (Thermalloy has measured as much as 25-C variation on plastic encapsulated cases when measuring from the middle to the end on a 14-pin DIP.)
- Uses large thermocouple leads or poor installation techniques when measuring heat-sink performance. For example, a large thermocouple with 24-gauge leads can draw off 10 to 20% of the power of low-power DIP packages.
- Uses highly polished surfaces for measuring interface performance data—a move that lowers the thermal resistance—yet does not indicate in his test data that his sinks are supplied with a nonpolished surface. This practice is reported to be widespread.

Semiconductor failure can burn you

The figure most important to designers, Markley says, is the semiconductor-case temperature rise above ambient. Usually the user is forced to rely on the thermal resistance of the junction-to-case and the reliability stated by device manufacturers. But their information is frequently unreliable.



Thermal silicone grease, by Dow Corning, improves the heat transfer across the interface between these liquid-cooling elements and a high-power Westinghouse silicon rectifier clamped under pressure between them. Cooling with distilled water permits a 1110-A rectifier to carry 1700 A. For dielectric separation between multiple rectifier units, silicone cooling fluids can be used.

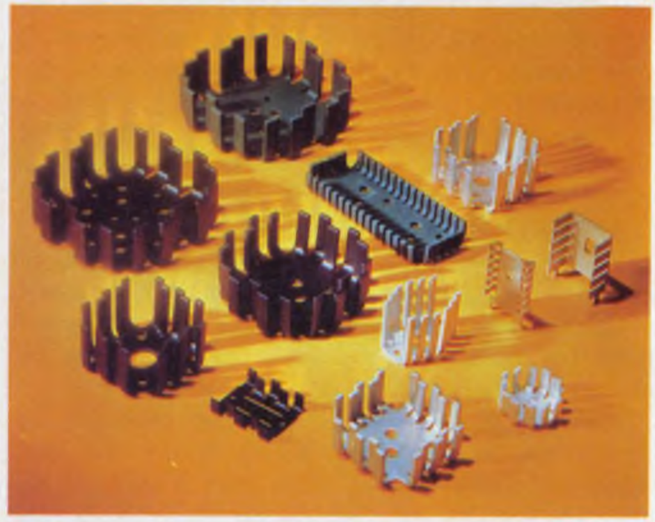
"Semiconductor suppliers tend to grossly overstate the reliability and the power-handling capabilities of their devices," says Len Dietch, vice president of TV engineering for Zenith Radio, Chicago. "And this includes the power-handling capabilities of an IC which may be a small-signal processor.

"We pay through the nose for semiconductor failures, because each service call under our year's warranty costs us $20. And for a shop call, it's almost doubled. The alternative to failure of a semiconductor is to use the same device with a bigger heat sink, or a bigger device with a smaller heat sink—or some other combination that is more costly initially."

When semiconductors are mated with heat sinks, a critical thermal barrier between the device and the cooling element is the interface between the two. It is here that the highest thermal resistance is ordinarily present (see table). This resistance is a function of the following:

- The cross-sectional area.
- The surface finishes of both the device and the sink.
- The flatness of the surfaces.
- The pressure between the surfaces.
- The thermal conductivity of fillers, if used.

Allen W. Scott, manager of advanced development for the Varian Microwave Tube Div., Palo Alto, Calif., and author of a recent Wiley-Inter-



These staggered-fin, fan-top heat sinks, by IERC, have a low profile for close quarters and are designed for press-on installation. The staggered-finger units have high efficiency and are smaller and lighter than some equivalent finned-extrusion designs that dissipate the same amount of heat.

science book, *Cooling of Electronic Equipment*, points out that unless care is taken to maximize the contact area, the temperature difference required to conduct heat across the interface can be as high as that needed to conduct it through several inches of aluminum heat sink.

To minimize this temperature difference, particularly for high-voltage applications, these procedures are advisable:

- Make the surface of the manufacturer's heat sink and semiconductor smoother where the two mate by abrasion, polishing or some other method.
- Apply large clamping forces, to bring the device into closer contact with the sink.
- If feasible, solder the device to the sink. Or bond it with an epoxy compound of high thermal conductivity.
- Use a thermal paste or heat-sink compound between the device and the heat sink. These compounds reduce the interface thermal resistance to a fraction of that of a dry surface.

The thermal pastes are usually grease-like silicones filled with heat-conductive metal oxides. These compounds resist drying out, melting or hardening even after long exposure to 200 C. Typical values of compound thermal conductivities range from 0.01 to 0.04 W/in. C—which is not very high. Consequently the compound must be applied in a thin layer.

Typical suppliers and their compounds are:

- Aavid Engineering—Ther-O-Link 1000.
- Emerson & Cuming—Ecotherm TC-4.
- Dow Corning—340 Compound.
- General Electric—G640 Compound.
- Jermyn—Thermoflow.
- Thermalloy—Thermacote.
- Trans-Tec—XL-500.
- Wakefield—Compound 120.

Robert Krasa, technical service and development engineer at Dow Corning, points out that some silicone sealants have the same heat-flow properties as the grease-like silicone compounds, with two added advantages. The sealants can bond a component in place, eliminating fasteners. Also, when cured, the sealants have no tendency to bleed or creep into areas where an insulating film is not wanted.

Krasa also notes that silicone fluids are used as dielectric coolants in large power devices, klystron tubes, communications transformers and capacitors. Unlike oil and other cooling fluids, they have little tendency to oxidize or gum up in long service at elevated temperatures. They flow freely at low temperatures.

Washers provide insulation

Frequently it's necessary to insulate semiconductors from their heat sink for electrical isolation. A variety of washers are available for this purpose, including epoxy-coated aluminum, hard-anodized aluminum, aluminum oxide ceramic, beryllium oxide (beryllia) ceramic, mica and high-temperature plastics like du Pont's Kapton and Mylar.

Beryllia washers—the most expensive—have the best thermal conductivity, the lowest thermal resistance and the highest dielectric strength—on the order of 5000 V. Hard-anodized aluminum washers are second best. But whereas the anodized aluminum washer costs about 10 cents in quantity, the price of the beryllia equivalent is 50 or 60 cents.

The thermal conductivity of beryllia at room temperature is as good as or better than that of aluminum, says James Wade, market manager of the Electronic Product Div. of 3M, Chattanooga, Tenn. It depends upon the percentage of beryllium oxide in the ceramic. However, with an increase in temperature, the conductivity decreases.

Worth noting is the fact that thermal compounds are used with washers of all types.

Mica washers on the order of 2 to 8 mils thick and about 1000 V dielectric strength have been used for years. But according to Thermalloy's Jordan, they are being replaced—for nonthermal reasons—by amber-colored Kapton and green Mylar washers of the same thickness and about half the dielectric strength.

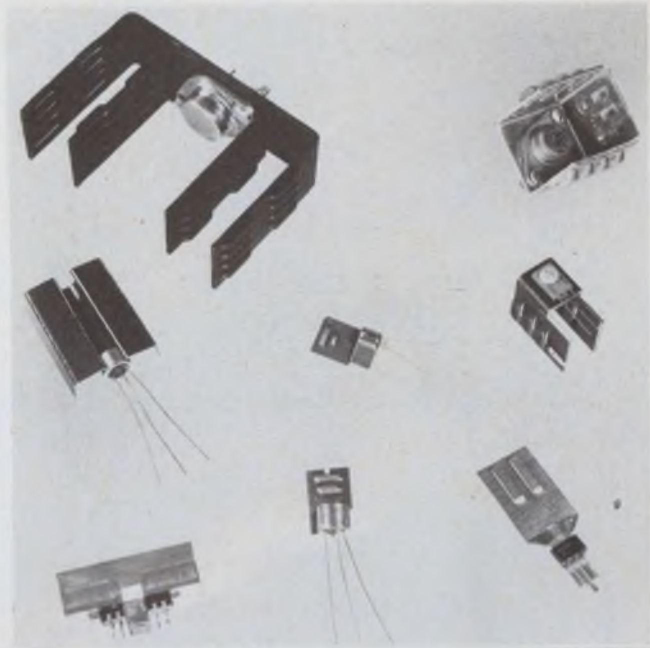
With the clear mica insulators, production workers may pick up two, stuck together, without realizing it. Experience has shown that when two washers are accidentally used, the thermal resistance is increased sufficiently to cause device failure. With the Kapton and the higher-temperature Mylar washers—which are becoming cost-competitive with mica—the shade of the color provides an instant clue to a double washer.

One approach to the problem of heat-sink insulation without use of mica or other washers is a proprietary coating system—Insulube 448—made by IERC. It is applied by spray during manufacture of the heat dissipator. The recommended thickness for application of the coating is 0.003 ±0.001 in. Its dielectric strength is 1000 V dc per mil with an insulation resistance of 50 GΩ at 500 V dc.

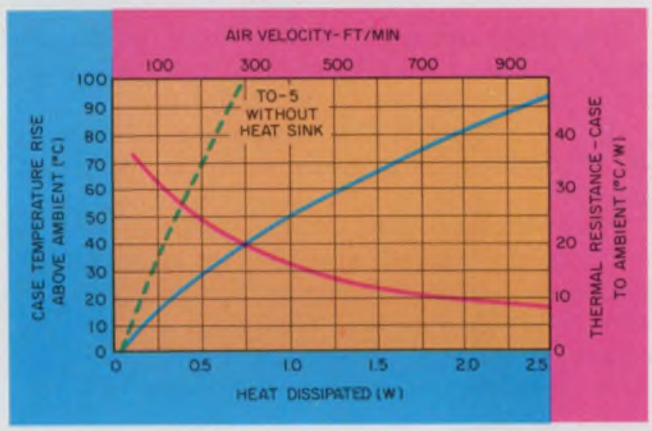
For thermal bonding of semiconductors and other components to heat sinks or chassis, thermally conductive epoxies are available from heat-sink suppliers. These have thermal resistivities on the order of 25 to 30 C/W.

Heat pipes for confined areas

Where the packing density of electronics is high, there may not be sufficient space within the rows of PC boards or other confines to use a heat sink. Or the air where the hot components are placed may be at an excessive ambient temperature. One solution is to use heat pipes—devices that absorb heat from a component in a restricted area and pipe it off, to be dissipated at a heat sink in a cooler ambient.



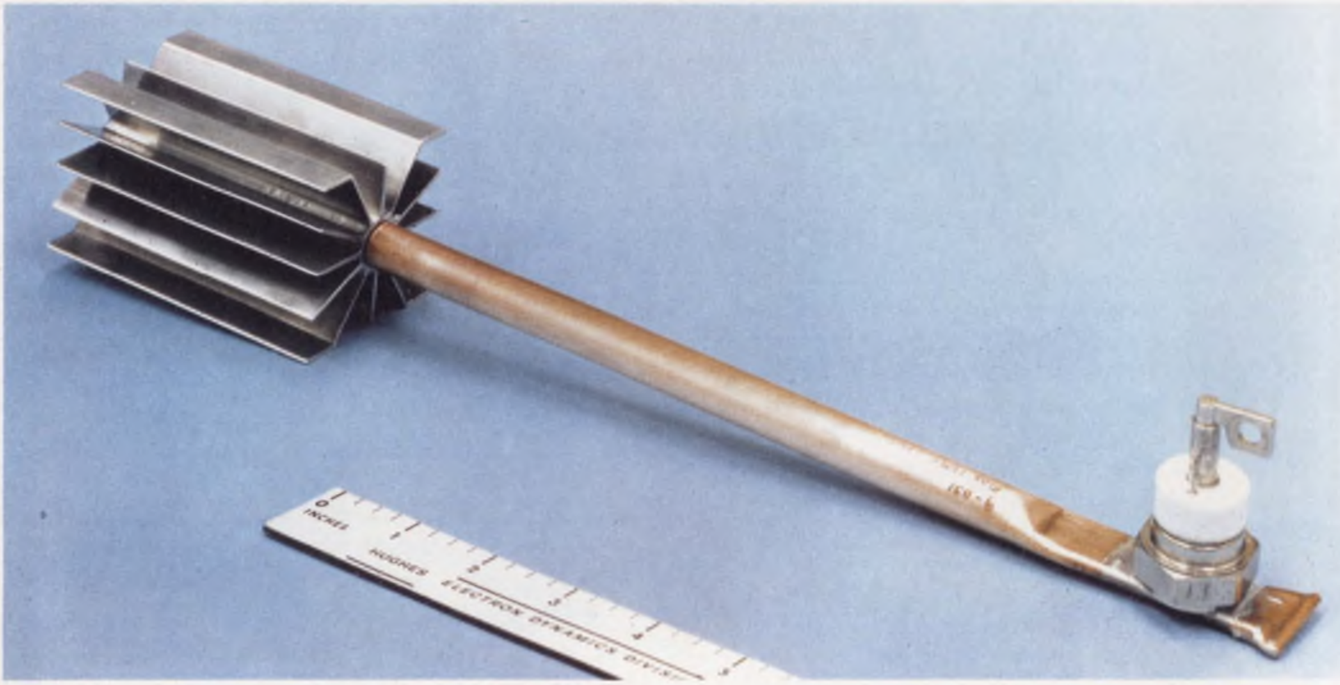
Low-cost heat sinks for consumer products, by Staver, range from devices for 500-mW plastic transistors (bottom center) to 12-W power transistors (top left).



Heat-sink thermal data are typically presented in terms of thermal resistance for air cooling and rise above ambient for convection cooling.

Interface thermal resistance (in °C/watt) for a TO-3 case

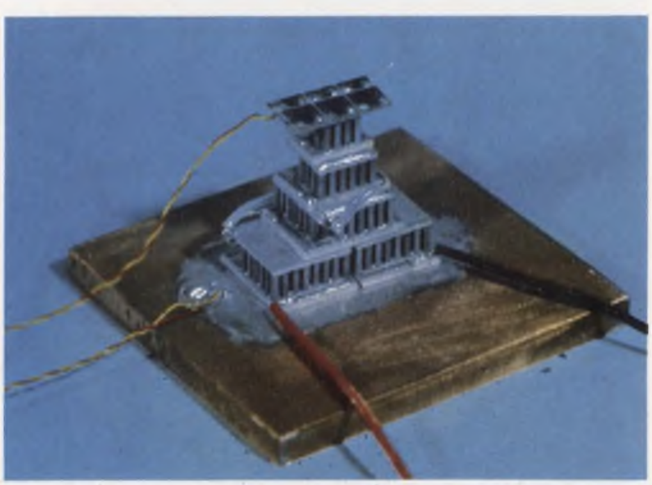
Semiconductor to mounting surface (no insulator, dry)	.05 – .20
Semiconductor to mounting surface (no insulator, with thermal compound)	.005 – .10
Beryllium oxide (BeO) wafer between semiconductor and mounting surface	.10 – .40
Hard anodized aluminum wafer between semiconductor and mounting surface	.35 – .70
2 mil. Thermalfilm plastic insulator between semiconductor and mounting surface	.55 – .80



The high-frequency SCR on this Hughes heat pipe dissipates 100 W, which is rapidly carried away by the thin-wall heat pipe to the aluminum fins for convective cooling. The major advantage here is that the cooling takes place away from the source of heat. The heat pipe distributes the heat evenly along the length of the fins.

Heat pipes, according to Ron Kemp, chief engineer of Jermyn, San Francisco, have high thermal conductivity—about 400 times that of solid copper. A pipe of 1/8-in. diameter can transport 20 W, while a 1/2-in.-dia unit can carry off 500 W.

While the heat pipe usually comes in tubular form, it can assume a variety of other hollow shapes—square or rectangular, for example—and even a flexible structure. The pipes are made of copper, aluminum or stainless steel, and they have an inner lining—a wick—of some capillary material. The wicks come in a variety of configurations.



Thermoelectric cooler by Borg-Warner has unusually high efficiency, pumping 33.5 mW of thermal load at a temperature of 193 K, with use of but 2.06-W input.

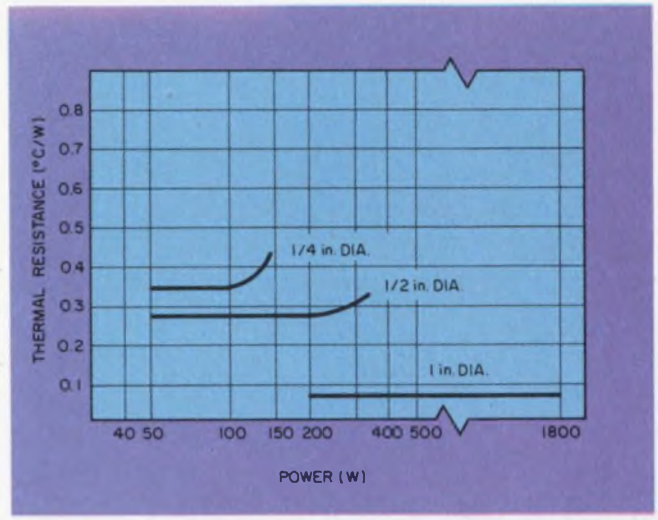
A small amount of fluid—such as of water, ammonia or other dielectric—is sealed in the pipe in a partial vacuum. The heat pipe's operating temperature is dictated by its working fluid. It can operate as low as −170 C or as high as 400 C for electronic applications.

T. A. Hummel, thermal products marketing manager for Hughes Aircraft Co., Electron Dynamics Div., Torrance, Calif., describes the operating cycle this way:

The heat from the component or source being cooled vaporizes the working fluid in one end—the vaporizer region—of the heat pipe. The hot vapor moves to the cooler end—the condenser region—where the vapor gives up the thermal energy as the heat of condensation and returns to a fluid state. The condensed working fluid then is fed back to the evaporator section by the capillary action of the wick.

The performance of heat pipes varies with their orientation relative to gravity, notes Richard Vossler, marketing manager of Astrodyne, Inc., Wilmington, Mass. Heat pipes are rated at 100% of their effective transfer capacity when operated in the horizontal plane, he says. But as the condenser and heat-sink end are raised above the evaporator end, the heat-transfer capacity increases. With the pipe in a vertical position, the heat transfer can be two or three times that of its rated performance.

Finned heat pipes by Jermyn are used to conduct heat away from TO-66 and TO-3 power transistors. In still air the pipes dissipate (left to right) 20, 30 and 40 W.



Heat pipes developed for electronics applications, by Hughes, can be used in any position. But their thermal resistance is higher than standard units.

Hummel of Hughes points out that small heat pipes for electronic applications have been designed to operate against gravity—in any position—by use of thick, homogeneous wicks. But they have relatively high thermal resistance—on the order of 0.33 C/W for a 1/4-in. unit, 0.28 C/W for a 1/2-in. pipe and about 0.7 C/W for a 1-in. dissipator.

This thermal resistance, Hummel notes, must be considered in all applications.

Thermoelectric modules can cool or heat

There are three basic areas where thermoelectric modules can be used to advantage:

1. **In cooling a small heat load to a low temperature.** A good example is the cooling of infrared detectors from −70 C (203 K) to −128 C (145 K). The mass to be cooled is small, and the power dissipated by the mass is small. The detector-module combination is mounted in a vacuum enclosure to reduce ambient heat loads and to prevent water or other gases from condensing on the detector. Operating temperatures can be achieved within a few seconds to minutes. To lower the module temperature, power input must be increased. Typically, 3 to 6 W are required for operation at −80 C and 50 to 80 W for −128 C.

2. **In cooling a component or a small package to 5 to 10 C.** A typical example is cooling a parametric amplifier or oscillator, to decrease noise.

3. **In temperature-stabilizing a component, a package or an entire system at 25 C.** An illustration here is stabilizing an IR system. If the ambient rises above 25 C, the thermoelectric module operates in the cooling mode. If the temperature decreases, the thermoelectric module heats. Thus the optics and other temperature-sensitive components are stabilized. The heat load may vary from a few watts to 100 W.

The major tradeoffs when a thermoelectric module is chosen for an application are in voltage, current and cost. A module will pump a specified quantity of heat over a defined temperature differential for a given amount of power.

Several combinations of modules have vary-

Thermoelectric cooling modules, like these from Ohio Semitronics, can be built up from single thermoelectric couples into multicouple and multistage devices for greater cooling.

Most fans used in cooling computers range from 3-1/8 to 6-in. dia., like these Amphenol units. They deliver from 17 to 260 cfm of air.

ing voltages and currents for the same amount of total power.

For lowest cost, the designer should select as large a current as practical and build the voltage to the required power level. However, if the required voltage is 3, 6 or 12 V, the number of thermoelements are well established, as shown in this table:

Power (W)	Current (A)	Voltage (V)	No. of Elements	Cost ($)
10	1	10	100	100
10	2	5	50	50
10	10	1	10	10

A designer can be misled if he fails to consider the thermal resistance of the hot junction and the consequent problems involved in getting that heat dissipated, says Dr. Warren E. Bulman, Ohio Semitronics, Columbus. He points out that module performance depends on the hot-side temperature.

As an example, Bulman cites a module intended to give a 70-C difference, with the hot side, or base, held at 25 C. With the base temperature elevated to 75 C, a temperature difference of 100 C can be obtained.

Two common problems in customer-assembled systems, according to Dean R. Hoppens, marketing manager of Nuclear Systems, Inc., Garland, Tex., are (1) Inadequate thermal contact between the cool side of the thermoelectric module and its component, and (2) Poor design of the heat-removal system for the hot side.

Forced air dissipates heat fast

Forced-air cooling of electronic components provides an order of magnitude or more of heat dissipation over natural convection cooling. According to Rotron, Inc., Woodstock, N.Y., this result is due to two factors: First, there is an improvement in the heat-transfer coefficient of the individual components when heat is transferred to the air flowing directly around them. And, second, there is a general reduction of the air temperature in the vicinity of the components being cooled.

The best way to determine cooling requirements accurately, says Rotron, is to make an actual test of the equipment. Because of the complex nature of flow paths in electronic equipment, standard pressure-drop calculations do not generally provide useful answers. For designers who do not have equipment to perform the tests, manufacturers like Rotron do the testing at their laboratories at no charge.

For each type of air mover, there is a range of "specific speed" for which its efficiency is highest. Specific speed is defined by the following formula:

$$N_s = N\sqrt{(\text{cfm})}/\Delta P^{3/4},$$

where N is shaft rpm, cfm is the cubic feet of air delivered per minute and ΔP is the pressure drop in inches of water.

Evaluation of this formula shows that air-moving devices with high specific speeds are most efficient when delivering high flows against low static pressures. Conversely air movers best suited for transporting air at high pressure and low volume have low specific speeds. The figure gives the specific speeds for a variety of common air-moving devices.

For example, the specific speed for a 60-Hz, 3300-rpm motor to move 125 cfm of air at a pressure drop of 1 in. of water would be:

$$N_s = \frac{3300\sqrt{125}}{(1.0)^{3/4}} = 37{,}000.$$

With a specific speed of 37,000, reference to the figure indicates that the application can be satisfied with a squirrel cage or centraxial blower.

If the same flow and pressure requirements were specified for a military application, where 400-Hz power is available and if shaft speed of 11,000 rpm were selected, the specific speed would be 122,000. Tubeaxial or vaneaxial fans are well-suited for this application.

Fans and blowers cool computers

Major application areas for cooling fans are in the computer industry, says Lawrence F. Edwards, product manager for Amphenol, Broadview, Ill. They are used in mainframes, for both large-scale machines and minicomputers, and also peripheral gear, like CRT terminals, printers, point-of-sale terminals and modems. Other applications are in test and control equipment.

Fan specifications are, for the most part, comparable among manufacturers. However, the airflow measurements of one or two manufacturers overstate the air delivery at low static pressure, because they use the pipe method of measurement. The fan blows air through a pipe that is about the same size as the fan's diameter. As a result, a significant velocity pressure component is present, which gives a boost to airflow.

Most manufacturers use the chamber method, in which a fan blows air into a chamber that is many times larger than the fan's diameter. Consequently the velocity pressure component is near zero.

The noise spectrum of different fans can be compared by examination of manufacturer data and curves. But this may be misleading, because the same absolute sound pressure is not used by all manufacturers.

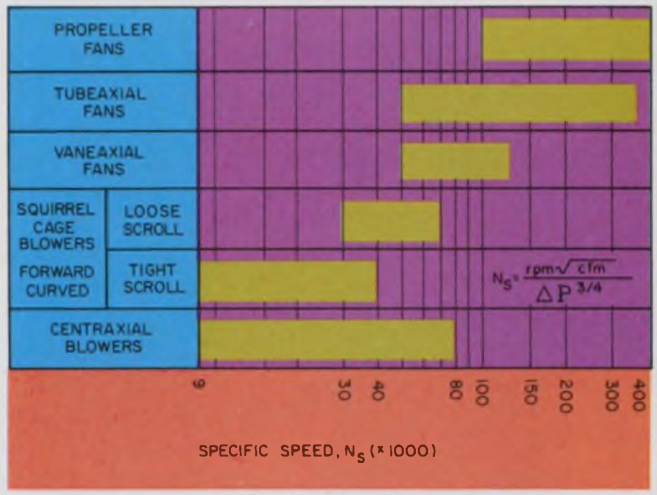
Be wary of published life data, Amphenol's Edwards cautions. Often the life data for a fan do not specify whether it is for a long-life ball-bearing fan or low-cost sleeve bearing model; it can make a drastic difference.

It probably takes up to 10 years of testing accurately at 20 C to determine the life of a fan, Edwards says. But in 10 years the fan's design may change radically. Motor-life guarantees are usually more sales talk than practical, Edwards notes. The designer must pay the cost of a defective fan's removal, its reinstallation and its shipping; under these conditions the user usually finds it is more expensive to exercise the warranty than it is to replace the fan from his own stock.

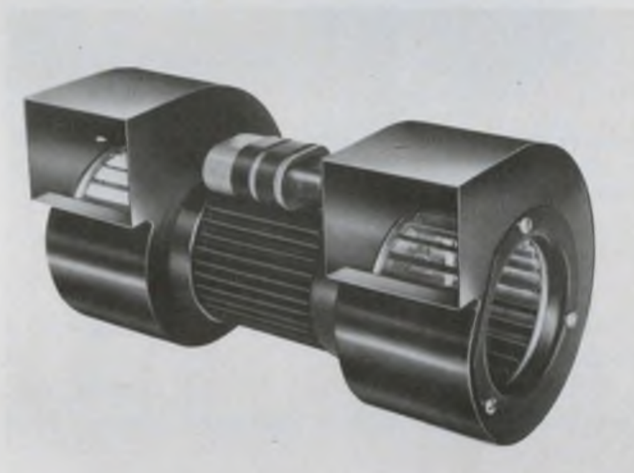
There are three major tradeoffs in fan selection:

1. **The initial purchase price vs long-term cost.** Longer fan life results in lower maintenance costs and less downtime, which can more than offset the difference in the purchase price of a longer-lived fan. This is especially important when the manufacturer leases the equipment and bears the cost of upkeep.

2. **Cooling performance vs noise.** A lower noise



A figure of merit for applying a fan or blower—specific speed, N_S—is based on the shaft speed, the air volume moved and the pressure drop required.

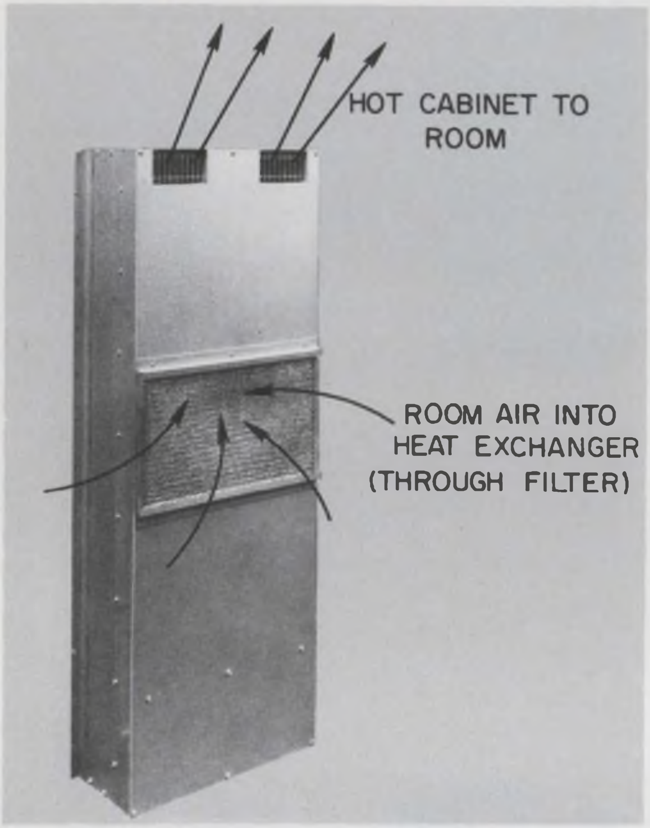


Designed for cooling ducted or tightly packed electronics packages, this Rotron duplex centrifugal blower is produced in six models, with capacities from 100 to 600 cfm.

level is achieved when the rpm of the fan is reduced. However, the amount of airflow is directly proportional to speed. And, more important, the static pressure generated is a function of the square of the speed. As a result, noise reduction is paid for with a drastic reduction in cooling capacity.

3. **Structure vs noise.** Obstructions to airflow on the intake side, including the supporting struts of the fan itself, increase noise. Minimum obstructions should therefore be sought.

When high packaging density produces relatively high dissipation per board, or where the electronics must be protected from adverse environments—like those in an aircraft or in industrial plants—the use of closed cabinets and



Adverse environments require sealed cabinets with built-in cooling systems. This heat exchanger, by Kooltronic, cools the air inside the cabinet.

either integral or separate heat exchangers is necessary.

When about 0.1 W per in.^{2} of cabinet surface is exceeded, Thomas Sheppard, head of heat transfer at Bendix, Teterboro, N.J., suggests the use of a cold-wall cooling technique that Bendix has used for airborne computers. With this, the walls of the cabinet are doubled, and the space between them is filled with radiator-type cooling fins.

Filtered air is forced under pressure through inside walls, Sheppard explains, as well as through the walls of the enclosure sealing the electronics. While the seal is not hermetic, it prevents dust, dirt, moisture and water from contaminating the PC board components, Sheppard notes.

In essence, a heat exchanger is built into the wall of the box, he says, and large computer manufacturers like IBM are adopting this technique.

For on-line process-control equipment in harsh industrial environments, sealed electronic cabinets and closed-cycle cooling are required. Here a heat exchanger is incorporated into one side of the cabinet, explains William G. Stewart, vice president of engineering for Kooltronic, Inc., Princeton, N.J. It may be an air-to-air or air-to-water exchanger, with the air inside the cabinet continually cooled and recycled internally. Or it may be a specially packaged air-conditioning system.

Integration of this type of cooling system into an electronic cabinet requires close collaboration between the electronic designer and the system supplier, Stewart points out. Such collaboration should generally begin in the conceptual stage, he says, to integrate the cooling unit into the electronic system at minimum cost, space and noise. ■■

Need more information?

The companies and products cited in this report have, of necessity received only brief mention. They've been selected for their illustrative qualities. The product lines marketed by these and other companies are identified below. The code to these products is: FB—fans and blowers; HE—heat exchangers; HP—heat pipes; HS—heat sinks; HW—heat washers; TG—thermal grease; TE—thermoelectric coolers; TS—thermal sealants; LC—liquid coolants.

Aerotronic Assocs., Inc., Riverside Dr., Contoocook, N.J. 03229. (603) 746-3141. (M.R. Longley). (HE) **Circle No. 400**

Agnew-Higgins, Inc., Box 857, Garden Grove, Calif. 92642. (714) 893-1301. (M. L. Burleson). (FB) **Circle No. 401**

AHAM, P.O. Box 909, Azusa, Calif. 91702. (213) 334-5135. (Harold Sullivan). (HS) **Circle No. 402**

Alpha Components Corp., 115 Eucalyptus Dr., El Segundo, Calif. 90245. (213) 322-7780. (J. T. Cataldo). (HS),FB) **Circle No. 403**

Amco Engineering Co., 7333 W. Ainslie St., Chicago, Ill. 60656. (312) 867-8500. (F. A. Johnson) (FB) **Circle No. 404**

Ametek/Lamb Elec., 627 Lake St., Kent, Ohio 44240. (216) 673-3451. (R. O. Swift). (FB) **Circle No. 405**

Amphenol Component Marketing Services, 2875 S. 25th Ave., Broadview, Ill. 60153. (312) 345-4260. (L. F. Edwards). (FB) **Circle No. 406**

Ashland Electronic Products, 32-02 Queens Blvd., L.I.C., N.Y. 11101. (212) 392-4010. (J. R. Lukasik). (FB) **Circle No. 407**

Astrodyne, Inc., 353 Middlesex Ave., Wilmington, Mass. 01887. (617) 658-9191. (Dick Vossler). (HE,HS,HP) **Circle No. 408**

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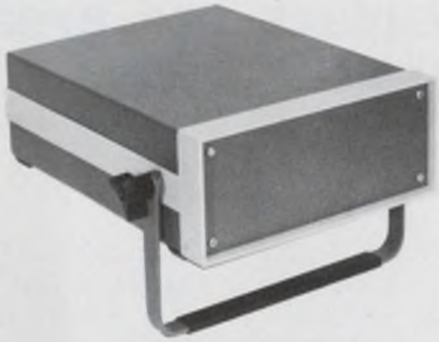

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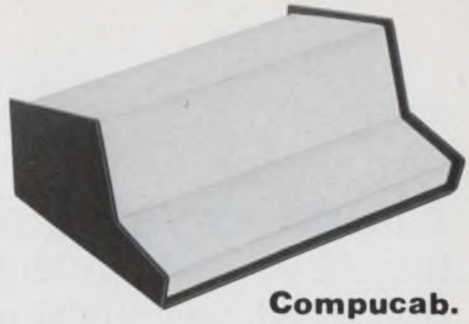

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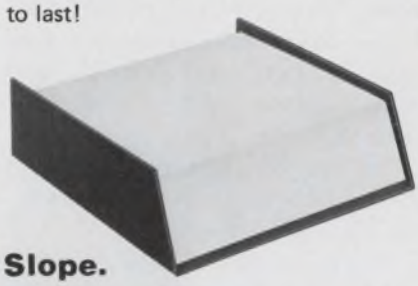

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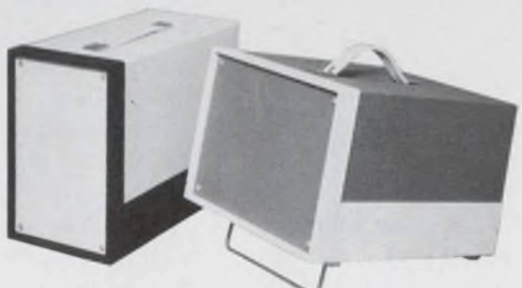

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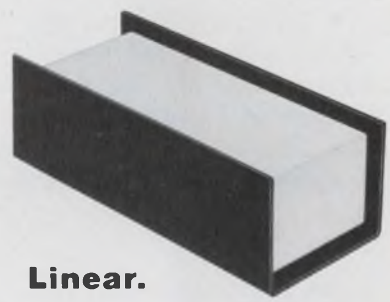

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INFORMATION RETRIEVAL NUMBER 47

Liquid crystal displays are great–but...

they have lighting, temperature, voltage and drive limitations that must be considered before you design with LCDs.

For digital readouts, liquid-crystal displays (LCDs) have a lot to offer: They're inexpensive, have low-power electrical drive characteristics that are compatible with those of MOS-logic drivers and provide good contrast, even with outdoor lighting. But LCDs also have limitations.

Before you can incorporate them successfully into your designs, you must consider characteristics like these:

- The so-called display may require additional artificial light. Unlike other displays, LCDs don't generate their own self-lighted characters.
- The sensitivity of LCDs results in a narrow operating temperature range, generally from 0 to 105 C. LCDs draw varying amounts of current, depending on the temperature. And their characteristics can be altered by storage temperatures.
- The very low-current demands of LCDs—which account for their low power needs—are accompanied by the need for a relatively high voltage of 15 to 20 V.
- The operation of LCDs requires a low ac-frequency drive that contains no superimposed dc.

Break the ambient-only rule

Both modes of the liquid-crystal display—dynamic-scattering and twisted-nematic—are intended to work primarily with ambient illumination. The display reflects light that has bounced off its energized structure back to the viewer. But if the user's application demands night or low-ambient performance, back-lighting is required.

The transmissive-mode LCD is chosen, for instance, when a calculator is designed for use in areas lighted to less than 10 foot candles. A lamp, rated at a half watt per half-inch of height, can illuminate a dynamic-scattering LCD from behind. The resulting light level can be as bright as that for a gas-discharge or light-emitting display that operates in normal ambient conditions.

No additional power is drawn by the LCD, even if the ambient light level increases. Both reflective and transmissive modes are immune to high ambient washout.

Power for artificial illumination can be independent of the display, and does not have to be switched with it. The selected source usually is based on available power. The user can add color easily to a back-lighted LCD with a colored light source.

Back-light displays

Several back-lighting schemes are outlined in the accompanying figure. Schemes A, B and E make use of light spillage, a desirable feature when a keyboard or writing surface is lighted. Back-lighting adds about a dollar or two to the cost of an 8 or 12-digit display.

It's simpler to back-light a twisted-nematic than a dynamic-scattering LCD, since the twisted nematic has less directional sensitivity. Flood lighting is all right for back-lighting. when used with a diffuser that helps to even out the illumination.

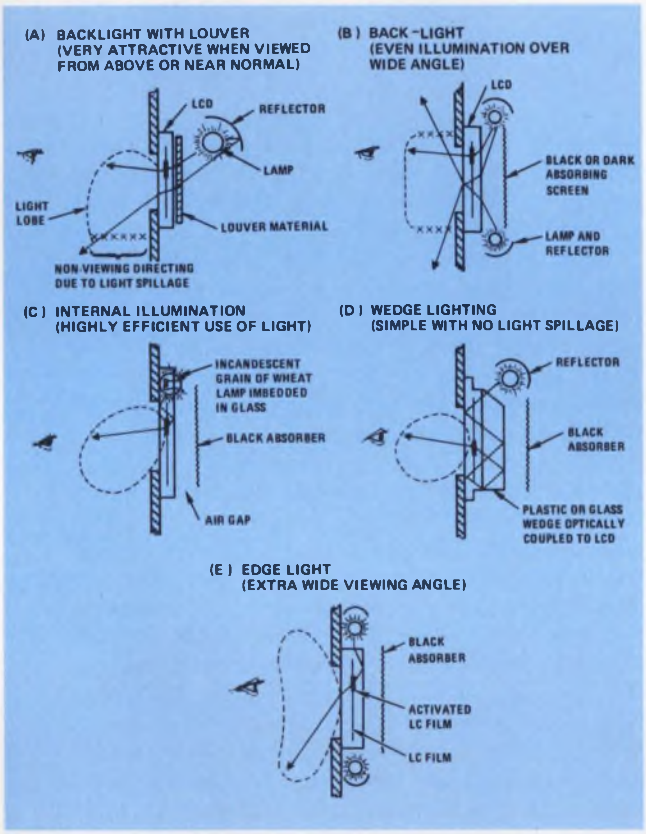
When you design the product package, there's no need to place fillers, grids or the like in front of the LCD. Integrate the display so it becomes part of the external package.

If nomenclature is desired on the face of the display, print it directly on the LCD rather than on an intermediate glass surface. This eliminates two potentially troublesome reflecting surfaces.

The best way to combat LCD reflecting problems is to put a shallow etch, or frosting, on the front glass surface. This breaks up the image of any reflection and renders it less distracting. If etched glass is not available, laminate a piece of commercially etched picture-frame glass to the front of the display. Use a transparent epoxy resin to simplify optical coupling between both pieces of glass.

All liquid-crystal displays can be made im-

Larry E. Tannas, Jr., Group Leader of Display Techniques, Electronic Research Div., Rockwell International, 3370 Miraloma Ave., Anaheim, Calif. 92803.



Five basic lighting techniques are used to back-light a dynamic-scattering, transmissive-mode LCD. One scheme (A) gives limited light spill when viewed from above or nearly head-on. Another (B) uses two lamp/reflectors to spread light over a wide angle. A third (C) uses light very efficiently. The fourth (D), called wedge-lighting, eliminates light spillage. And the fifth (E) offers the user an extra-wide viewing angle.

mune to washout—transmissive as well as reflective. For example, scattering centers in a dynamic transmissive-mode LCD help trap light. The centers, through internal reflections, reduce washout within the glass confines.

Light-traps keep half

If the efficiency of the LCD is high, a small percentage of the ambient light is internally trapped. But, of the portion trapped, only half the light can return out of the front side.

The liquid-crystal material does not back-scatter, and the display has immunity to high point light sources, like a spotlight, the sun or a window. But it is not so immune to continuous light sources, such as an open bright sky or a very large illuminated area. The loss of immunity is largely due to glare.

When glare, caused by first surface reflection, is directed toward the viewer, the display may wash out. This can be eliminated if the first surface is made to reflect a dark image. In one outdoor application, a user tilted an LCD-equipped traffic sign slightly forward, so that the first surface reflection was from the ground, not from the sky.

Electrical interface and characteristics

Liquid-crystal displays are high-impedance devices. High impedance, which lowers power requirements, also offers the user a choice of connector-assembly methods and styles—a feature not always offered with other displays.

Connector contact resistance of several hundred ohms does not affect the brightness of the LCD. One reason is that the transparent conductor on the LCD connector edge is usually either indium or tin oxide, both very hard and abrasive-resistant materials.

A pointed connector pin, which penetrates a connector edge that contains these materials, completes the physical interface. When 10 or more insertions are desired, or a high-vibration environment is expected, use gold-pressure contacts.

The connector edge should then be silk-screen-printed with gold to mate with the gold pin. Where screenable silver has been printed, wire can be bonded directly to the glass edge via indium-gold alloy solder. The user can also weld beam leads ultrasonically onto gold or silver pads printed on the glass.

At room temperature dc resistivity is typically 10^9 to 10^{10} Ω/cm, depending on whether a dynamic-scattering or twisted-nematic LCD is used. Cell requirements range from 50 to 5 μW, respectively, for a half-inch-high display.

The ABCs of liquid-crystal displays

A liquid-crystal display (LCD) is passive; it does not emit light regardless of the mode of operation. The two basic types of LCDs are dynamic-scattering and twisted-nematic (or field-effect). In turn, each can be obtained in either a reflective or transmissive mode. The major features of these four LCDs are shown in the accompanying table.

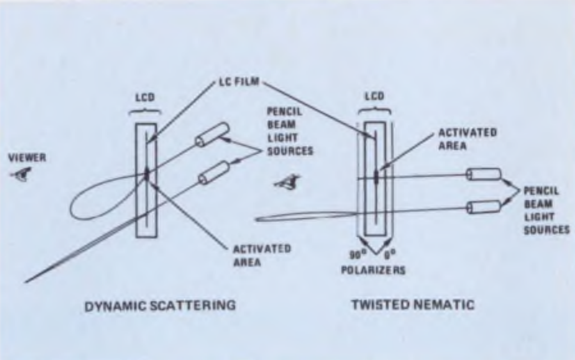
For all types, light falling upon the display is refracted or rotated by the thin film of the LC material. The display area is electrically controlled to produce a contrast over the unexcited area.

In dynamic-scattering (left-hand figure), many small domains of liquid crystal are formed with the application of the electric field. Multiple refractions at the boundaries of the domains cause the ballooning of a pencil beam of light, so an off-axis viewer sees a definite contrast. The unactivated area remains transparent, while the activated area appears frosty and opaque, and takes on the color of the light source.

The pencil beam that goes through the unactivated area can be seen only if the viewer looks down the beam itself. The lobe on the left side represents a polar diagram of light intensity, with a $\pm 10°$ half-power angle typically. Note that light is only forward-scattered. To obtain the reflective mode, simply place a mirror on the left side. The mirror permits the light source and viewer to be on the same side of the display. This can be detrimental if the viewer sees the image of the light source or cluttering images.

Light rotates in the twisted-nematic mode (right-hand figure) as opposed to being refracted in the dynamic-scattering mode. The LC material in the twisted-nematic cell aligns parallel to the inner surface. With the two surfaces rotated 90° during cell construction, polarized light rotates the same amount.

When unactivated, the pencil beam is first



polarized, then rotated 90° by the liquid-crystal film; the light passes through the second polarizer. A viewer on the left who looks directly at the display sees the beam.

When the liquid-crystal film is activated, the rotating ability is destroyed by a breakup of the crystal order. The second polarizer now absorbs nearly all the light incident on it, and gives this area a black appearance. Inverse images can be achieved when both planes of polarization are made parallel.

The reflective mode is achieved by use of a reflector in place of the left polarizer. Again the viewer and the light source are on the same side. No image can be seen here (as with dynamic scattering) because of the polarizers.

A limited viewing angle, caused by excessive rotation, is an inherent property of the twisted nematic. The degree of rotation depends on the thickness of the liquid-crystal film. Therefore light passing obliquely through the film passes through more LC material. For a large enough angle, the light can be rotated beyond the optimum angle for complete transmittance. Reliable display interpretation should be expected at $\pm 30°$ to the normal, although half of the light is absorbed at the first polarizer.

Dynamic scatter		Twisted nematic	
Reflective	Transmissive	Reflective	Transmissive
Efficient use of ambient light good down to moonlight Viewing angle sensitive to location of ambient light Background cluttered by image of viewer and surroundings (desirable on a woman's watch) Aesthetically interesting characteristics can be incorporated in colored dichroic mirror	Widest viewing angle Lowest cost Readable in total darkness with back light Changeable color by changing back-light color Back light (or front light) desirable in some form at all times	Most efficient use of ambient light No background image clutter as diffusive reflector can be used Narrower viewing angle Lowest power	Narrower viewing angle Readable in total darkness with back light No light spillage Changeable color by changing back-light color Back light in some form desirable at all times

The material resistivity of the LCD changes by almost three orders of magnitude over the operating temperature range. The dielectric constant, approximately 5, also varies by 50%.

Dynamic scattering displays usually specify 20 V ac. The display responds best to a square-wave drive, with a frequency in the range of from 20 to 200 Hz. The lower frequencies are used to excite the LCD when temperatures are low. However, the display won't respond to excitation frequencies above a so-called critical frequency—in this case, 400 Hz.

The LCD cell is black-boxed to simulate a leaky capacitor. This capacitor time constant is 1 ms at room temperature. Since an LCD presents a capacitive load to the drive electronics, power loss varies with drive frequency. Typical values of power loss are 1 μW for dynamic-scatter and twisted-nematic, referenced to a half-inch-high character.

Response time is also a function of temperature—about 200 ms at room temperature. This parameter changes by two orders of magnitude over the operating range. But display speed cannot be increased significantly by use of faster drive electronics.

Material viscosity represents a limiting factor of LCD response speed. The lower the ambient temperature that surrounds the display, the slower the display's speed.

LCD temperature range—a 'nematic' band

Most dynamic-scattering displays use a mixture of materials called butylanilines, doped for conductivity with a proprietary ionic material. This combination gives the display an operating range of approximately −15 to 55 C.

Depending on ambient temperature, a complete reversal of LCD characteristics can occur. The effects are similar to the melting and freezing of water. The useful operating temperature range is limited to a band called the nematic range. Above this, the material becomes an isotropic liquid and ceases to exhibit anisotropic (liquid-crystal) properties.

Below the nematic range the material becomes a solid, and, once again, it shows isotropic properties. Ordinarily you don't have to worry about temperature-induced expansion. The material closely matches that of the surrounding glass envelope.

At present, users as well as manufacturers face nematic-band problems. One possible solution widens the nematic band so the lower limit of the operating range falls below room temperature. Eastman Kodak, for example, uses this technique for a dynamic-scattering material that achieves a range of 0 to 105 C.

The user must know how to evaluate a good LCD and how to spot potentially defective ones. A malfunctioning display can be detected by one of the following characteristics:

- *A slippery feeling or peculiar odor.* This means that the liquid-crystal material is leaking out of the glass sandwich. Bubbles develop in a few hours of operation, and sooner or later they void a segment.
- *Irregular dark and light areas when a display on standby is viewed through cross-polarizers.* This indicates poor alignment of the liquid-crystal molecules relative to the glass walls. Hair-like lines, frosty surface or other irregularities show poor alignment and can lead to a visually disturbing appearance.
- *Excessively slow ON or OFF response.* This indicates an excessively thick liquid-crystal space, which normally remains stable unless caused by contamination.
- *Low resistance.* This shows excessive doping or contamination of liquid-crystal material. The display should be rejected immediately, since this defect causes shortening of display life.

Characteristics of good LCDs

Properly functioning displays meet the following criteria:

- *Wide operating temperature.* A net operating band of at least 65 C should be expected from any LCD. The low end of the nematic band must approach 0 C. Check to make sure the response time is not too slow at the lower temperature and that current consumption is not excessive at the higher temperature.
- *A low critical frequency.* This increases proportionately with temperature, and it is the upper frequency at which the display stops dynamic scattering. Excessive conductivity is one cause of a high critical frequency. For the dynamic-scattering mode, the critical frequency must be above the drive frequency at the lowest operating temperature. At room temperature, the critical frequency should be about 500 Hz and consistent (±50 Hz) from one display to another. Character-to-character consistency also should be ±50 Hz within each display.
- *Wide storage temperature.* The liquid-crystal envelope must survive the storage temperature. Alignment of the display material can change, depending on storage history, at the lower temperature extremes. This is a particularly important parameter with twisted-nematic LCDs, since reliable hermetic seals have been developed only recently. The seal may leak at storage temperature extremes because of a mismatch in the thermal expansion of sealing materials. Storage temperatures of −50 to 100 C should be used.
- *Consistent upper and lower transition tem-*

Who makes LCDs?

The following manufacturers offer liquid-crystal displays. Readers may consult these vendors for full product-line information by circling the appropriate information retrieval number:

AEG Telefunken, Fachbereich Rohren, D-79 Ulm, Soflinger Strasse 100, West Germany. **CIRCLE NO. 500**

American Microsystems Inc., 3800 Homestead Rd., Santa Clara, Calif. 95051. **CIRCLE NO. 501**

ElectroVac, A-1194 Rampengasse 5, Vienna, Austria. **CIRCLE NO. 502**

Hamlin Inc., Lake and Grove Sts., Lake Mills, Wis. 53551. **CIRCLE NO. 503**

IEE (Industrial Electronic Engineers), 7740 Lemona Ave., Van Nuys, Calif. 91405. **CIRCLE NO. 504**

Integrated Display Systems, Inc., Montgomeryville, Pa. 18936. **CIRCLE NO. 505**

ISE International Corp., Shinbashi Kokusai Bldg., No. 2-7-7, Higashishinbashi, Minato-Ku, Tokyo, Japan. **CIRCLE NO. 506**

ILIXCO (International Liquid Crystal Co.), 26101 Miles Rd., Cleveland, Ohio. **CIRCLE NO. 507**

Liquid Crystal Inc., 208 Route 206, South Somerville, N.J. 08876. **CIRCLE NO. 508**

Optel, Box 2215, Princeton, N.J. 08540. **CIRCLE NO. 509**

Orega-Cifte, 50., Rue J. P. Timband, 92-Courbevoir, France. **CIRCLE NO. 510**

RCA Solid State Div., Somerville, N.J. 08876. **CIRCLE NO. 511**

Rockwell International Corp., Microelectronics Div., P.O. Box 3669, Anaheim, Calif. 92803. **CIRCLE NO. 512**

Toshiba Ltd., Tokyo, Japan. **CIRCLE NO. 513**

Transparent Conductors Inc., 26 Coromar Dr., P. O. Box 549, Goleta, Calif. 93017. **CIRCLE NO. 514**

perature. A variation of 1 C in upper transition temperature indicates a change in material purity, type or doping level. The transition temperature should be constant from batch to batch, and constant with time on any one batch. Failure is evident when the display temperature band narrows by 10% after an initial operation period of 100 hours.

▪ *Wide scattering lobe.* An LCD's scattering lobe depends on the type of material, dopant and operating voltage used. If off-axis view is important, specify a wide-lobe LCD. Scattering lobe can be increased if the ac drive voltage is raised.

▪ *Speed of response.* If the response speed rises above 200 ms, it becomes noticeable and may be objectionable. The response is proportional to the square of the display-film thickness. A high drive voltage causes the display to turn on quickly, but also to extinguish slowly. The opposite is true for a low-drive voltage.

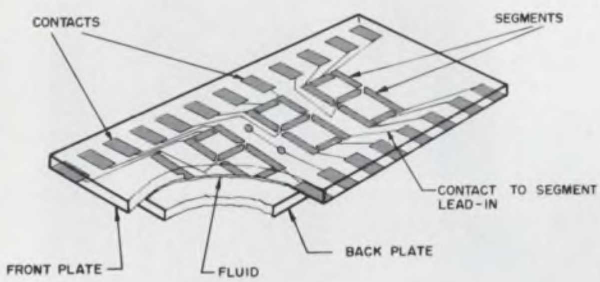
▪ *Material color.* The display should be transparent or have only a slight but bright yellow tinge. Reject displays with a dull yellow or brownish tinge, since this invariably indicates contamination.

▪ *Voltage.* Display performance should be relatively insensitive to normal supply-voltage fluctuations. However, a 200% overvoltage may cause damage and shorten display life, if applied for more than a few minutes. ▪▪

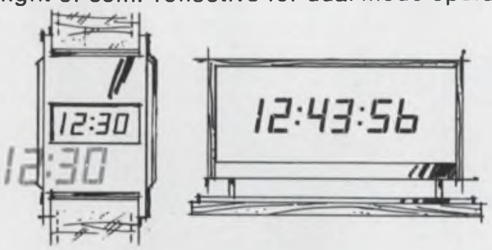
The case for Liquid Crystal Displays

Liquid crystal displays; light emitting diodes; incandescent and flourescent displays and "Nixie" tubes are popping up frequently in circuit designs as the trend to digital readout continues. Each has a purpose and the design engineer should become familiar with all types. We make liquid crystal displays.

The display of the future?
Our display is a sandwich of two plates, joined and hermetically sealed at the perimeters. A space of about .0005" separates the plates, and this is filled with a nematic liquid crystal solution.



When the liquid is not electrically excited, its long, cigar-shaped molecules are parallel to one another in a position perpendicular to the plates. Thus, the liquid appears transparent. Applying an electric current creates ion activity which leads to turbulence and causes the liquid to scatter incident light. The visual effect is that of a frosted glass. LCD's can be made completely transmissive for back-lighting, reflective for ambient light or semi-reflective for dual mode operation.



Producing an image — digital or other — simply requires a conductive surface the shape of the desired image on the glass plate toward the viewer. Current flowing from the conductive image on the front plate through the crystal liquid to the common-ground back plate causes the liquid to change from clear to a frosted appearance in the current-carrying area.

These images are almost always in the form of seven segments that make up the numerals 1 through 0. Energizing the proper segments produces the desired numerals. Lead-ins connect the segments to external contacts on the sandwich (display).

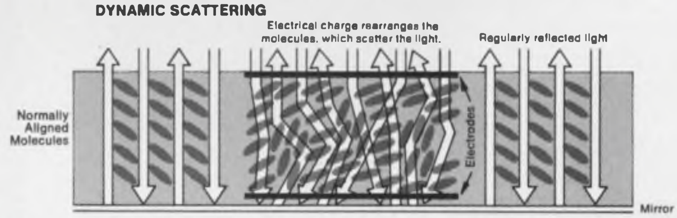
Consider the advantages.
Liquid crystal displays have a number of distinct advantages. Simplicity is the reason for several of these. The elements are few and passive — very little can go wrong with an LCD and this means reliability and long life.

Simplicity means low cost, too — lower than that of most comparable displays. Packaging costs are low because LCD's can be driven directly by MOS and C/MOS circuits. In our dynamic scattering displays very narrow character widths are possible and still provide a good viewing angle — 60 degrees in many cases.

Low power consumption makes the LCD a logical choice where power limitations rule out other display types. Watch type LCD's use only 30 μW, for example, with all segments energized at 15 volts.

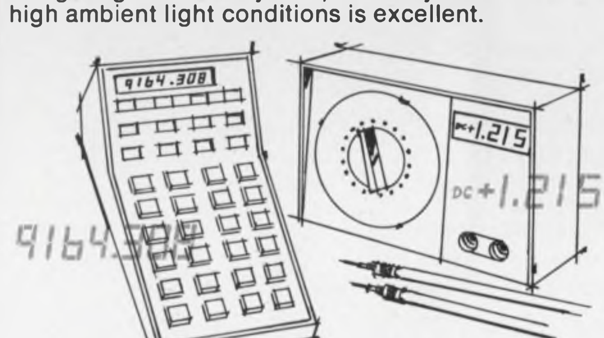
LCD's offer the greatest flexibility of any display type. Several standard displays are immediately available from Hamlin's stock. Special displays with virtually any type of image can be produced with surprisingly low preparation or "tooling" cost. Because of the LCD's simplicity, lead time on specials is only a matter of weeks.

A few limitations.
LCD's have limitations, too. Operating temperature range is one. Liquid crystals slow down and may even cease to function at temperatures below 0°C. Above 50-60°C, crystals go into solution and will not function normally.



Extremes do not damage LCD's. Once the temperature returns to normal, operation is automatically resumed.

LCD's do not generate light, and they are somewhat difficult to read under low ambient light conditions. (Side or back lighting can remedy this.) Visibility under medium to high ambient light conditions is excellent.



In the majority of display applications, MOS and C/MOS compatibility, reliability, flexibility and low power requirement are important considerations. No other display type can match the liquid crystal display on these jobs. They could become the display of the future. And that's the case for the LCD. For specification and application data, write Hamlin, Inc., Lake Mills, Wisconsin 53551. Or call, 414/648-2361. (Evaluation samples are available at moderate cost.)

HAMLIN
INCORPORATED

9701

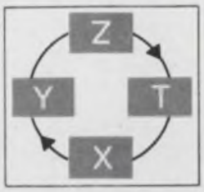
INFORMATION RETRIEVAL NUMBER 50

The HP-45 uses RPN.

That's one reason it's the most powerful pre-programmed pocket-sized scientific calculator. Here are 8 others:

1. It's pre-programmed to handle 44 arithmetic, trigonometric and logarithmic functions and data manipulation operations beyond the basic four (+, −, ×, ÷).

2.



It offers a 4-Register Operational Stack that saves intermediate answers and automatically retrieves them when they are required in the calculation.

3.

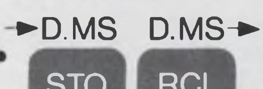
It lets you store up to nine separate constants in its nine Addressable Memory Registers.

4. It gives you a "Last X" Register for error correction or multiple operations on the same number. If you get stuck midway through a problem, you can use the "Last X" Register to unravel what you've done.

5.

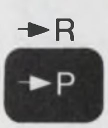
It displays up to 10 significant digits in either fixed-decimal or scientific notation and automatically positions the decimal point throughout its 200-decade range.

6.



It converts angles from decimal degrees, radians or grads to degrees/minutes/seconds and back again.

7.



It converts polar coordinates to rectangular coordinates . . . or vice-versa. In seconds.

8.

Its Gold "Shift" Key doubles the functions of 24 keys which increases the HP-45's capability without increasing its size.

The HP-35 uses RPN too.

If the HP-45 is the world's most powerful pre-programmed pocket-sized scientific calculator, the HP-35 is runner-up. It handles 22 functions, has a 4-Register Stack, one Addressable Memory Register and also displays up to 10 digits in either fixed-decimal or scientific notation.

*Domestic U.S.A. prices, not including applicable state and local taxes.

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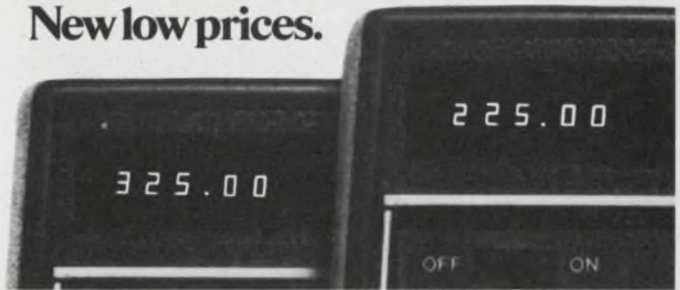
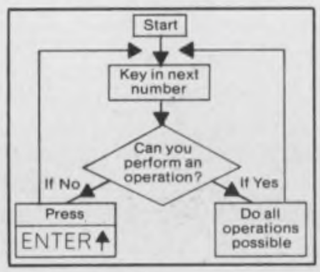


HP-45: $325* HP-35: $225*

Now the exceptional value of these exceptional instruments is even more apparent, because we've cut their prices by $70.* You can now own the world's most powerful pocket-sized pre-programmed scientific calculator, the HP-45, for only $325.* The HP-35 now costs just $225.*

Send for our booklet "ENTER vs. EQUALS."



It demonstrates the superiority of Dr. Lukasiewicz' language by comparing it to other calculators' systems on a problem-by-problem basis, and it explains the algorithm shown above which lets you evaluate any expression on a calculator that uses RPN and an Operational Stack. This booklet is must reading for anyone seriously interested in owning a powerful pocket-sized calculator.

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INFORMATION RETRIEVAL NUMBER 51

Why not use hybrids? For small size, long-term reliability, true hermetic sealing and adaptability to the latest technologies, they're a good choice.

Most PC-board circuits that use discrete components can be replaced by a microcircuit hybrid package. Hybrid packages need three to 10 times less circuit area.

The largest hybrid substrate available is about 6 in.[2], but the usual one is between 0.25 and 2 in.[2] Therefore, with a reduction factor of 8 to 10, the circuitry on a densely packed 3 × 5-in. PC is about the maximum that is usually hybridized into a single package.

But small size and corresponding light weight are not the only reasons for going hybrid. Other advantages include these:

- Reliability and long-term stability.
- Excellent matching of components, especially resistors, for temperature tracking.
- Hermetic sealing in metal and ceramic packages.
- Production by volume processes.
- Moderate costs for medium-volume quantities (1000-10,000).

Hybrids are versatile

A hybrid is an integrated circuit that uses a versatile mix of technologies—a composite of thick and thin-film passive components, a wide range of interconnecting and packaging technologies and both discrete semiconductors and monolithic ICs. By this combination of almost all the major technologies, wide flexibility and high density in circuit configurations are possible. A hybrid circuit can use the most advanced monolithic ICs and the best active and passive discrete components. Thus hybrids can provide a wide performance spectrum for both analog and digital applications.

The long-time stabilities of film resistors are excellent—far exceeding those of carbon-composition resistors. The temperature coefficients of film resistors, especially thin films, are also superior to carbon types. When resistance ratios are used, 5 ppm/°C tracking is routinely attained, even for thick films. Low-cost, automatic, resistor trimming can also produce initial tolerances of better than 0.1%.

Functional, or dynamic, trimming eliminates trim potentiometers and trim capacitors in circuits that require accurate adjustments to better than 0.05%.

And for many capacitors of less than 100 pF, screen-printed devices are economical and stable. Capacitors to 0.01 μF can also be produced in film form, but for the higher values, chips are more economical. Chip capacitors come in a wide range of types and sizes for use in a hybrid. For example, types like K1200, NPO and tantalum have capacitances from 10-pF to 10-μF.

Both thick and thin films are used

Most resistors are applied by thick-film methods. However, for extra high stability, wide resistivity range and superior ratio matching, the thin-film resistor might be the better choice.

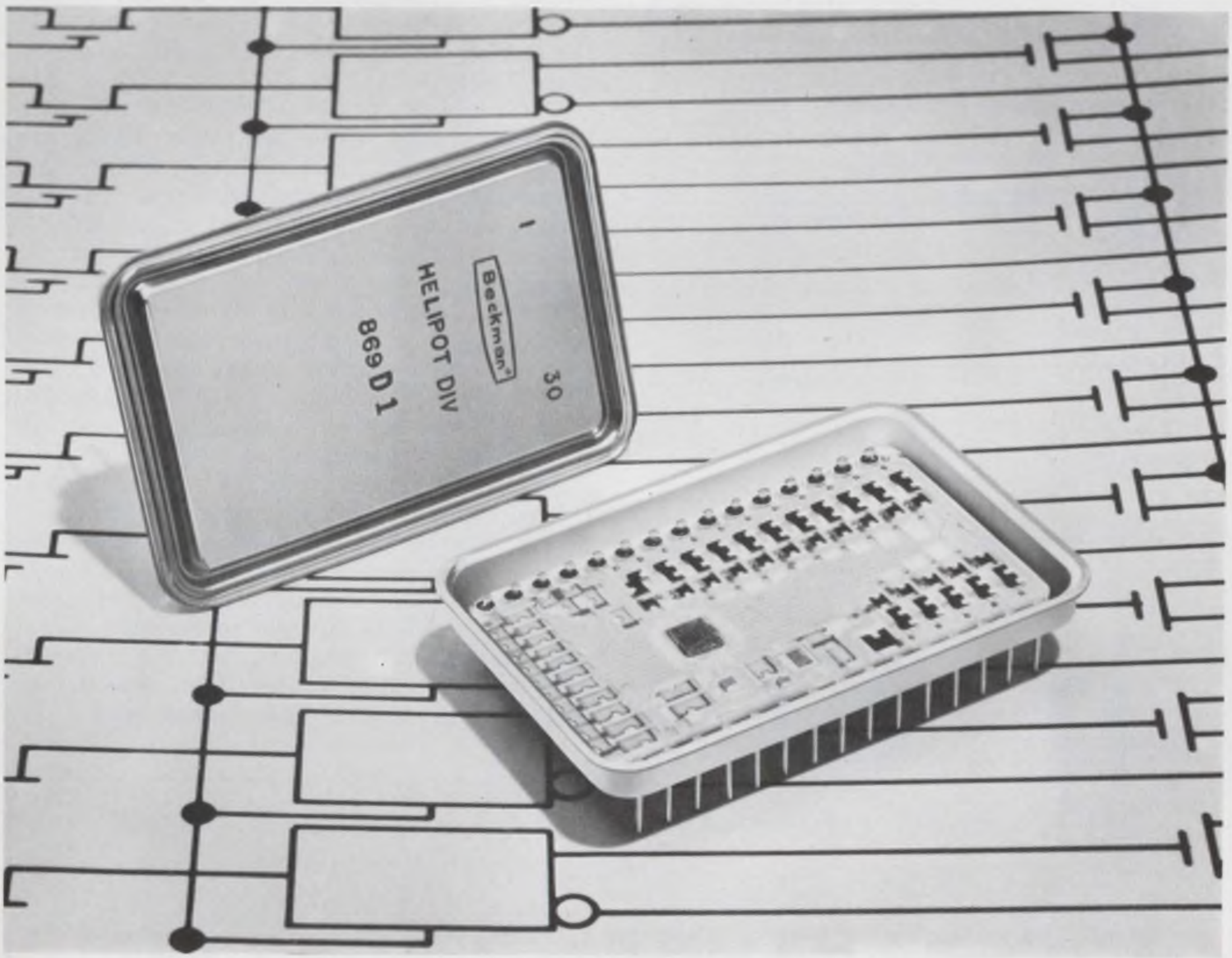
Thick films offer low cost and perhaps quicker delivery, because the hybrid maker generally makes his own thick-film resistors, but he may have to go outside for thin-film chip resistors. Thick-film resistors use a screen-printed cermet material, composed of precious metals, their oxides and suitable glasses. And thin-film resistors are usually sputtered or vapor deposited tantalum-nitride, nickel-chromium or chromium cobalt.

Connections between components are also made with film techniques. Thick-film conductors are printed, precious-metal alloys of gold, platinum, palladium and silver. And thin-film conductors are generally deposits of almost pure gold.

About 85% of the hybrids use thick-film technology, with the screen-printed resistors and conductors applied on a substrate of alumina (generally 96% Al_2O_3). The remaining 15% of the hybrids use thin-film technology, where resistors and conductors are deposited on glass alumina or silicon substrates. Semiconductor devices and chip capacitors are then added.

Active devices are usually mounted in die, or

Frank Ruegg, Chief Engineer, Microcircuits Engineering, Beckman Instruments, Inc., Fullerton, Calif. 92634.



These hybrid d/a converter packages combine many technologies. They include: MSI, bipolar and MOS ICs, linear ICs, thick and thin-film resistor networks and discrete chip devices. The newest and most advanced devices can be combined by hybrid methods and enclosed in high-density packages.

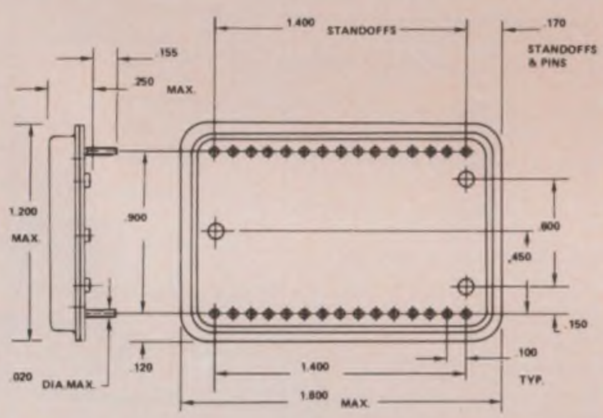
chip, form. Special capacitors (0.1 μF and up) and resistors also come in chip form. They are often connected to the deposited circuit by thermocompression or ultrasonic bonding methods. These processes are commonly called chip-and-wire construction. Chips are held to the substrate surface by remelting of the interface (eutectic bonding) or by use of epoxy or low-temperature cermets as adhesives. Both chip-bonding and wire-connecting are generally manual operations.

A number of chip forms have been developed to replace the chip-and-wire approach and to improve reliability. These include beam-lead and flip-chip devices.

Inductors and transformers are difficult to include within the hybrid and they generally are

Table 1. Some hybrid housings

Package Type	Method of Seal	Number of Terminals	Available Substrate Area (Sq. in)	Θ_{CA} (°C/W)	Power Rating (W)	Outline Drawing
Metal pin packages	Cold weld	10 20 30	0.465 0.850 1.250	60 30 20	2 4 6.5	A
	Cap weld	12	0.104	80	1.5	B
Metal ribbon-lead packages	Stitch weld	12 22	0.340 0.465	90 55	1.4 2.3	C
Dual in-line packages	Epoxy	14 16	0.086 0.098	80 80	1.5 1.5	D



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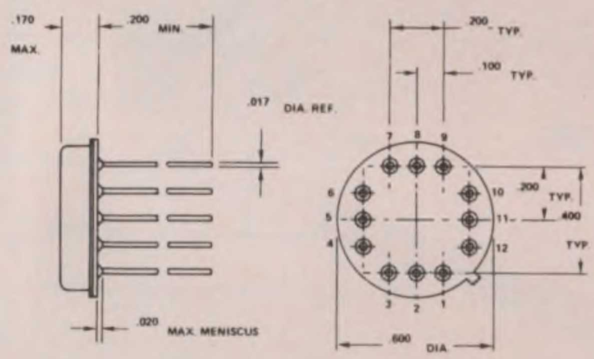

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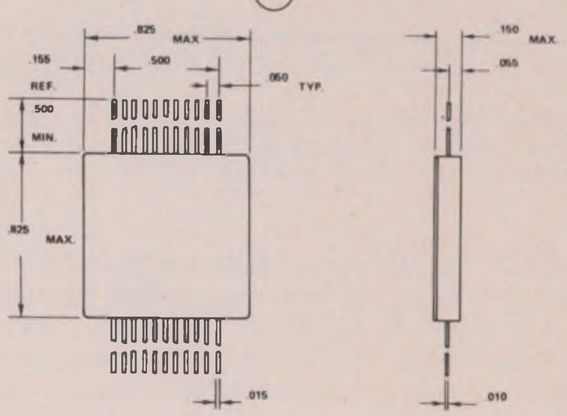

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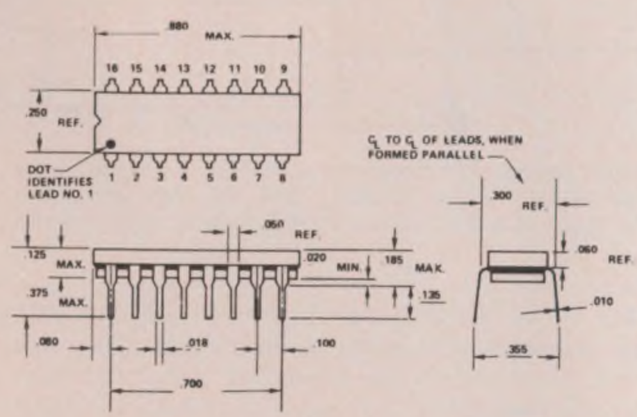

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designed out or mounted outside the package. Some low-inductance coils are now made in chip form, especially for high-frequency circuits. These coils can provide usable inductances with respectable Qs, and in sizes that are compatible with hybrid dimensions.

Resistors are the primary element

Of all the components, resistors are the primary circuit elements of hybrid technology. Resistors can be made inexpensively and in high density. Thus resistor-dependent circuits such as DACs are favored for hybrid packaging, where the number of capacitors and active devices is relatively small.

Power circuits of greater than 5 W are difficult to hybridize, unless the power devices can be left outside the package. And circuits that need many I/O pins or that have many internal connections can also be difficult to convert.

Though thick and thin-film assembly can accommodate a wide variety of component types and values, no process is completely void of restrictions. It is sometimes better to leave some devices—large capacitors, large power transistors and diodes, specially selected devices and large inductive devices—in discrete form outside the microcircuit package.

Conductors and crossovers must also be considered carefully. Fine-line screening techniques permit very narrow line widths, but Ohm's law prevails. High-current paths and low-impedance lines may require special layout considerations, and these should be brought to the attention of the manufacturer. High-conductivity materials with line resistivity of less than 0.01 Ω per square can be used for these applications.

Crossovers may affect the design because the bottom and top conductors form a small capacitor—of typically less than 2 pF. Insulating glass between the two conductors has a dielectric constant of approximately 8, and the actual capacitance value depends on the total area of the crossover. In most applications the placing of the crossover can be controlled so capacitance does not interfere with circuit performance, but the manufacturer should be told about circuits that are particularly sensitive to capacitive coupling. Critical circuit areas can be guarded by conductor patterns in addition to control of crossover design.

Hybrid housings are extremely varied; they range from simple leadless, polymer-coated assemblies to sophisticated multipin, hermetically sealed metal packages. The substrate can be a major portion of the housing, with a simple lid for mechanical protection, or it can be completely enclosed in an all-metal package. Many hybrids are made in all-ceramic packages, with polymer or glass seals. And hybrids can also be assembled simply as potted modules.

What to tell the manufacturer

Though many hybrid manufacturers are equipped to design and evaluate circuits, it's best if the customer supplies a working, properly toleranced design. Hybridization is primarily a packaging job, and this is what the manufacturers do best.

The circuit performance requirements must be precisely defined. Performance can be evaluated by either black-box specifications or a toleranced schematic. But the most meaningful description of circuit performance is a combination of the schematic diagram and a description of significant input/output parameters and their desired tolerances.

Black-box specs alone require engineering design and development by the hybrid manufacturer, and this will increase costs. A schematic diagram alone, even though the components are toleranced, does not always tell which performance parameters are critical.

The items normally categorized as black-box specifications are these:

- Power-supply voltage and current levels.
- Input parameters, such as voltage range, input impedance and input current.
- Output characteristics, such as output impedance, voltage range, slew rate and output current.
- Transfer characteristics, such as gain settings or logic truth tables.
- Maximum ratings, such as worst-case-voltage conditions, temperature-range limits, etc.

Note that each category may provide vital information not included in the schematic diagram.

Tell the hybrid manufacturer everything that may affect circuit performance. He can then take advantage of the special characteristics of some microcircuit manufacturing techniques. For instance:

- Resistors can use the same film material for close temperature tracking.
- Resistors can be functionally trimmed in the operating mode to eliminate the need for subsequent calibration procedures.
- Minimized conductor lengths can reduce capactive/inductive effects.

Passive component tolerancing should include the initial tolerance, power and voltage rating and any other parameter that will have a direct effect on circuit performance. The data might include such items as voltage coefficient, power factor, temperature coefficient, noise and high-frequency characteristics.

Semiconductor specifications should include the closest generic type, JEDEC number or the semi manufacturer's part number. It is not likely that all of these numbers will be directly available in chip form. But the hybrid manufacturer can generally come close to obtaining suitable substitutes. He normally purchases semiconductor devices to wafer-probed specifications and then lot-qualifies each type to other key parameters. However, it is not usually feasible to probe ac or temperature dependent parameters in this way. When such parameters are critical to circuit performance, the hybrid manufacturer must use semiconductor lots that have been selected by the semiconductor maker for the temperature or ac parameters.

Table 2. Component unit areas

Component type	Units per component
Resistors (cermet, thick film)	
General purpose (up to 100 mW)	1.0 Units
Capacitors	
Screened (cermet-270 pF)	1.0 Units
Chip capacitors 0.1" × 0.1"	2.0 Units
Diodes, passivated chip	
Signal switching	0.5 Units
Zener/reference	0.5 Units
Schottky/hot carrier	0.5 Units
Transistors, passivated chip	
Bipolar small siganl	0.5 Units
Bipolar medium power	1.0 Units
JFET	0.5 Units
Integrated circuits, passivated	
Linear (741, 710, 107, etc.)	2.0 Units
Digital (7400, etc.)	4.0 Units
MOS arrays (3101, etc.)	0.5 Units/Lead
MSI devices (74145, etc.)	0.5 Units/Lead

The hybrid manufacturer often has his own repertoire of semiconductor devices. If possible, the design should use these devices.

Housing the hybrid

The first step in selecting a hybrid package is to count the pins. The pin count may have more impact on package selection than the amount of circuitry. The next step can be defined only after these questions are answered:

- What size substrate is needed?
- Is the circuit complex, so that it requires partitioning into more than one package? Can the circuit be divided into individually testable functions?
- What style package should be used?
- Are there special mechanical and environmental requirements?

Try to use a package considered standard by the manufacturer and avoid costly, all-metal packages if true hermeticity isn't needed.

Table 1 lists some common standard package styles with their pin capacities, available substrate areas, power dissipation and thermal resistances.

You can estimate the substrate area you need, as follows:

Assume one unit of area is 0.015 $in.^2$ This is the area of a resistor. A component density of 0.015 $in.^2/unit$ is moderate and can be readily achieved, provided pin assignments are not fixed before the layout is designed. Assign a number of units to each component by consulting Table 2, and total the number of units for the circuit. Determine the substrate area:

$$A_s = (0.015\ in.^2) \cdot (U_t),$$

where U_t = total units. A package choice based on available substrate area can then be chosen from a listing such as Table 1. But the unit system is strictly a short-cut method. Common sense must be applied liberally.

Temperature is another constraint

Temperature rise is another important packaging constraint. The rise, T_R, is a function of the total power dissipation, P_T, of all internal circuit elements:

$$T_R = T_C - T_A = (P_T)\ (\theta_{CA}),$$

where T_C = case temperature, T_A = ambient temperature and θ_{CA} = case-to-ambient thermal resistance.

An approximate value of θ_{CA} for a packge in free air and with minimum heat conduction through pins is 35°C/W/$in.^2$. For example, a circuit that dissipates 1 W, rises approximately 35 C above ambient in a 1-$in.^2$ package, or 70 C above ambient in a 1/2-$in.^2$ package. This general rule is a conservative first approximation.

Though the case temperature may be safe, individual component temperatures may exceed safe limits. The maximum allowable junction temperature for silicon devices depends on the application, and in some cases it is limited by system specifications. The general rule is never to allow a junction to exceed 200 C. High-reliability applications often further limit temperature to 150 C.

Hybrid costs: $5000 and up

Hybrid manufacturers generally prefer making many (10,000 pieces) low-cost simple units to a few (1000) high-cost, complex ones. They're interested in jobs where the gross will exceed roughly $5000, if business is slow, and perhaps $20,000 when the backlog is long.

They generally charge for layout, tooling and fixturing. This is a one-time charge, and it can range from a few hundred dollars to several thousand.

Drawings and the 10 to 20 prototypes generally required to test the design take a minimum of six weeks. Special parts may add as much as eight weeks. And burn-in requirements and load-life testing can extend the delivery time even further.

Monolithics are another way

Monolithic technology in many cases offers most of the advantages of hybridization and the end product is even smaller in size. The main difference is an initial high tooling cost and the need to run a minimum of 100,000 units. If the circuit is primarily digital and the quantity large enough, the custom monolithic approach can offer a cost advantage. Monolithic tooling and start-up costs are roughly an order of magnitude greater than hybrid costs—typically $20,000 to $100,000—though parts costs in large volumes are significantly less.

Custom analog MSI or LSI monolithic designs are particularly difficult to execute, because the monolithic approach does not allow the experimenting and prototyping that hybrids allow at modest cost.

Hybrids provide greater circuit flexibility, less problems with parasitics and they have the potential for greater precision, long-term stability and greater freedom in component selection. And hybrids can usually handle higher-power circuitry than monolithics.

In addition to the above, the yield factors for custom monolithic devices are difficult to determine in advance. This is an important consideration in a packaging choice. ■■

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INFORMATION RETRIEVAL NUMBER 54

Improve ROM systems with pROMs. Here are two ways to use programmable ROMs to change words and increase memory size after a masked-ROM system is designed.

With two design techniques that use programmable ROMs—the pROM patch and the pROM wire scrambler—you can alter a masked-ROM system after you're committed to masks.

The pROM-patch method changes words and handles increased address fields in ROM. The pROM wire-scrambler technique expands memory size simply and by a factor of two through the use of memories that have the same pinout and model number of the PC-board ROMs.

System designers usually wait for the last minute to order masked ROMs. They know that custom ROM masks cost $300 to $750 each and cannot be changed. Moreover vendors typically quote an 8-to-12-week delivery and require a minimum order. The result of a scrapped mask and work-in-progress can often be a $20,000 error and a four-month delay.

Typically pin-compatible pROMs are used for prototype and first production systems. Programmable ROMs permit rapid design changes in the field. But their higher cost—three-to-five times that of ROMs—tends to make designers want to switch to ROMs as soon as possible.

A ROM/pROM compromise: The pROM patch

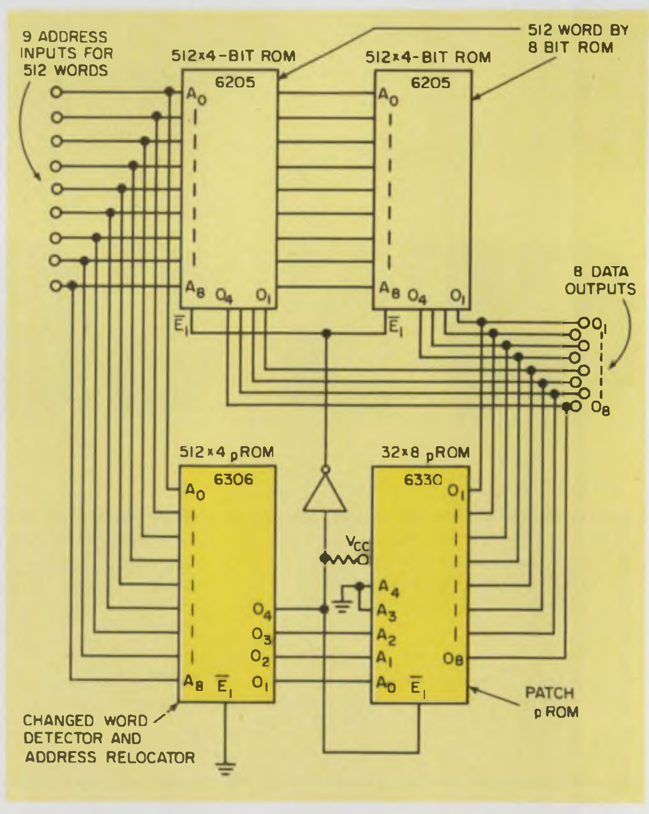
An example of the pROM patch appears in Fig. 1. Below the 512 × 8-bit ROM, consisting of two 512 × 4-bit ROM ICs, are two pROM circuits and a TTL gate not found or required in conventional 512 × 8-bit ROM systems. The additional 512 × 4-bit and 32 × 8-bit pROMs allow word changes.

The masked ROMs can be soldered into the board, since their contents don't change. The pROMs must be placed in sockets to simplify their removal for programming in conventional equipment.

The 512 × 4-bit pROM is programmed to detect the word that must be changed and to point to an address in the 32 × 8-bit pROM that contains the corrected data. Output O_1 of the larger ROM goes low only when its input detects a changed word. Then the masked ROMs are disabled and the 32 × 8-bit pROM is enabled. Outputs O_2, O_3 and O_4 of the larger pROM are programmed to point to word 0 of the 32 × 8-bit pROM for the first design change. Subsequent changes use the remaining words.

The smaller pROM contains the patch data. Its output is OR-tied onto the data-out bus of the masked ROMs. Patch data appear on the bus when the enable signals of the 512 × 4-bit ROMs go high, and the enable signal of the 32 × 8-bit pROM goes low.

Tables A and B illustrate a design situation that could benefit from a patch technique. ROM-word 71, part of a microprogrammed timing



1. **A patch pROM and changed-word detector** provide a 512 × 8-bit ROM system with the flexibility to change any eight of the 512 words before or after system shipment. The memory model numbers refer to circuits offered by Monolithic Memories.

Joseph J. McDowell, Systems and Applications Manager, Monolithic Memories, Inc., 1165 E. Arques Ave., Sunnyvale, Calif. 94086

generator, fails to pass final tests before customer shipment. To correct the error, the 512 × 4-bit pROM is removed from the socket and programmed to have "LLL" stored in word 71. The 32 × 8-bit pROM is then removed from its socket and programmed to have the new data "HLLLLHLL" in word 0. The patch corrects the design error.

After shipment, the customer wants to add a tape-reader option. This requires a one-word patch to disable the teletypewriter and enable the high-speed reader. This time word 74 is changed via a patch stored in word 1 of the 32 × 8-bit pROM. A serviceman in the field makes the change at the customer's facility.

Later, ROM technology makes possible higher speeds. The patch is now used to accommodate these higher speed ROMs. Shortly after that, the higher-speed ROM is found to have excessive noise sensitivity; two additional patches are installed in the field to overcome the problem.

The patch technique in the example saves six mask changes and considerable documentation change. It also permits rapid changes in the field without PC-board rework to remove the soldered-in ROMs.

Patch handles increased address fields

Still another variation of the patch technique permits the handling of address fields that are larger than the number of words in a changed-word detector (Fig. 2). A 4-to-1 multiplexer helps to reorganize the 512 × 8-bit pROM to look like a 2048 × 1-bit changed-word detector. The multiplexer trades off four outputs—O_1 to O_4—for two inputs—A_9 and A_{10}. Outputs O_5 to O_8 of the pROM point to an address in a second patch pROM (not shown) where the correct data are stored. Up to 16 changed words can be handled, since outputs O_5 to O_8 are wired to inputs A_0 to A_3 of the patch pROM.

To avoid ambiguous words, addresses A_9 and A_{10} are wired into the patch pROM as address inputs A_4 and A_5. Without this connection, the changed-word detector would not be able to tell at outputs O_5 to O_8, for example, whether the changed word is 511, 1023, 1535 or 2047, since

Engineering change #	ROM word (decimal) requiring change	Patch pROM word (decimal)	Reason for change
1	71	0	Design error
2	74	1	Tape reader option
3	24	2	Higher-speed unit
4	349	3	Customer requests field changes
5	495	4	
6	5	5	

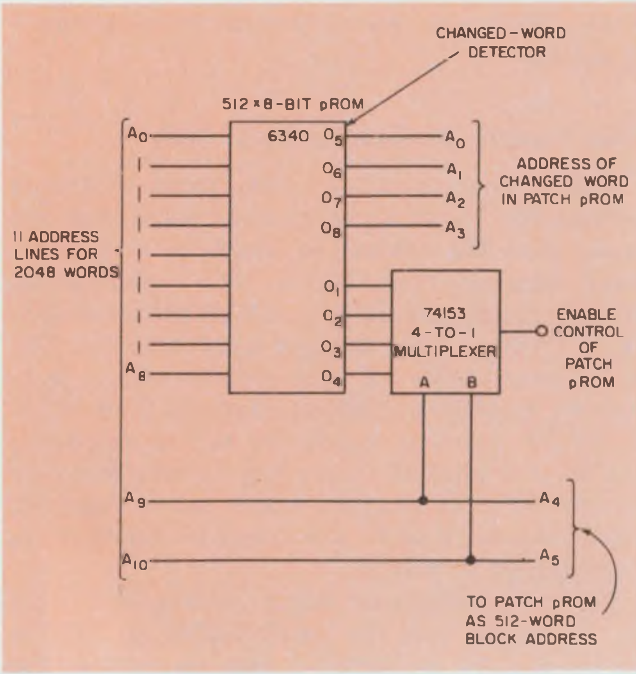
(a)

6306 Decimal address	6306 Contents				6330 Decimal address	6330 Contents							
	O_4	O_3	O_2	O_1		O_8	O_7	O_6	O_5	O_4	O_3	O_2	O_1
5	L	H	L	L	4	L	H	H	H	L	H	L	L
24	L	L	H	L	2	H	L	H	L	L	L	H	H
71	L	L	L	L	0	H	L	L	L	L	H	L	L
74	L	L	L	H	1	L	H	L	L	L	H	H	H
349	L	L	H	H	3	L	L	H	H	H	H	L	L
495	L	H	L	L	4	L	L	L	H	L	H	L	L
ALL OTHER WORDS	H	H	H	H	7	H	H	H	H	H	H	H	H

Note: 1. L = TTL LOW ≈ 0 V
H = TTL HIGH ≈ 3 V
2. Unprogrammed words have high outputs
3. The pROMs are activated when enable $\overline{E_1}$ goes low.

(b)

A typical record of engineering changes (A) that the patch method can handle. The truth table (B) gives the required programming of the 6306 pROM. The 6306 must detect the changed word and point to an address in the 6330 patch pROM, which is programmed with the corrected data.



2. **A 512 × 8-bit pROM can be reorganized** to appear as a 2048 × 1-bit changed-address detector with the aid of the multiplexer. The configuration also provides enable control and changed-word address for a patch pROM. Up to 16 changed words can be detected in each of the four 512-word blocks.

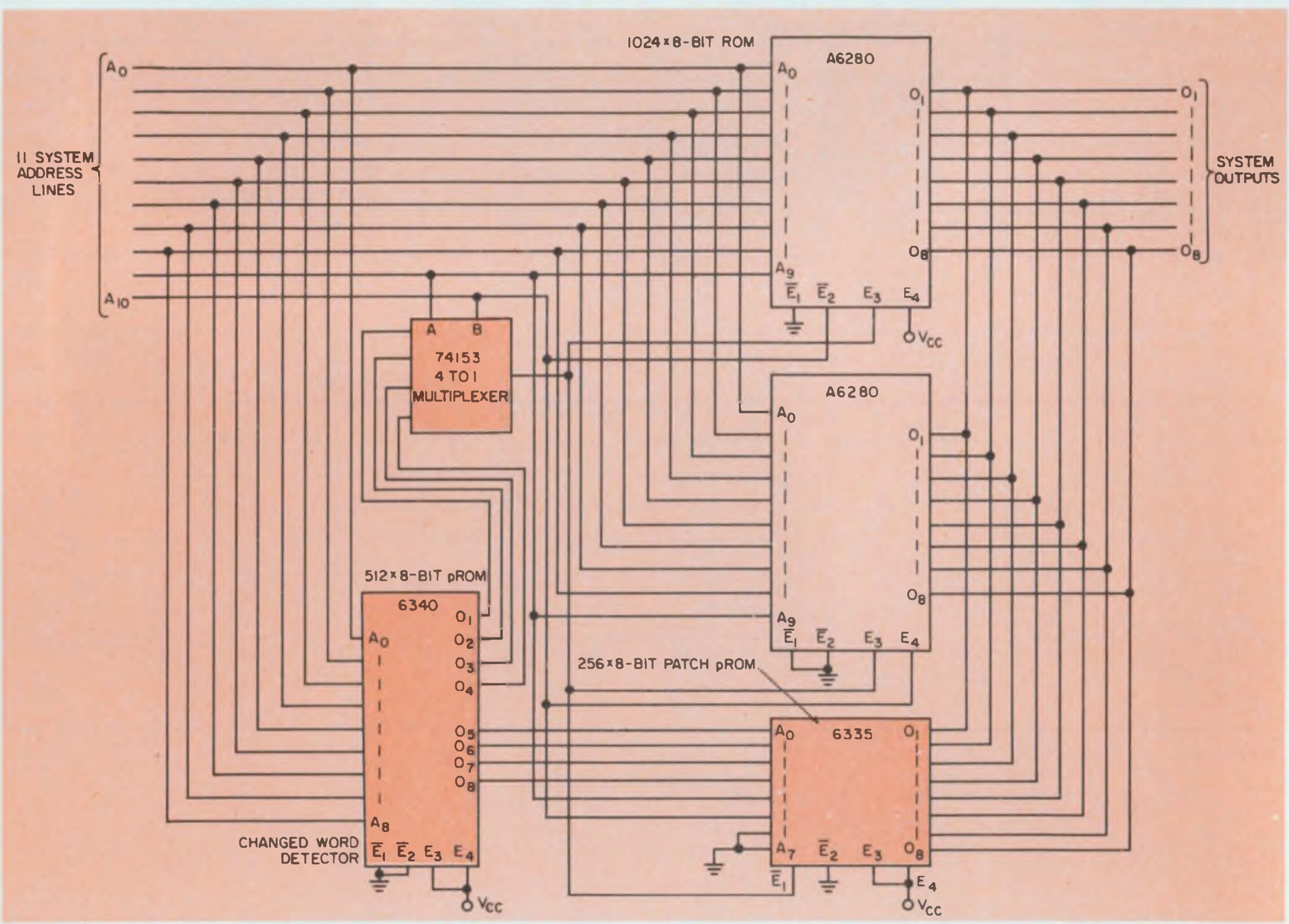
the detector is a 512-word device. Also, if word 511 is changed, you would not be able to change word 1023, 1535 or 2047, since only the low-order address bits—A_0 to A_8—go into the 512 × 8-bit pROM.

This technique doesn't allow 64 random changes, as might be expected from a six-address-input patch pROM. But the technique does permit a maximum of 16 words to be changed in each of the four blocks of 512 words.

A complete 2048 × 8-bit ROM system can have 16 words patched in each block of 512 words (Fig. 3). Two 1024 × 8-bit ROMs are used to make the 2048 × 8-bit ROM. Their outputs are wire-ORed, and system address A_{10} and the ROM's low and high active enables select a block of 1024 words.

When A_{10} is low, indicating the first 1024 words, and a changed word is not detected, the upper ROM activates; it has $\overline{E}_1$ and $\overline{E}_2$ low and E_3 and E_4 high, which constitute the enabling requirements. When A_{10} is high, indicating the last 1024 words, the lower ROM activates through E_3, and the upper ROM deactivates on the change of $\overline{E}_2$ to a high.

When a changed word is detected, the multiplexer output goes low and disables both ROMs



3. **This 2048 × 8-bit ROM system permits altering** of 16 words in each block of 512 words. Memory ICs are enabled when $\overline{E}_1$ and $\overline{E}_2$ go low and E_3 and E_4 go high. The ROM system uses two 1024 × 8-bit ICs.

when E_3 goes low. The 256 × 8-bit patch pROM, however, becomes enabled through $\overline{E_1}$, and it gates the patch data onto the output bus. Only 64 words of the 256 words in the patch pROM can be used. Hence A_6 and A_7 are grounded. It's possible to have a system that uses the spare words in the patch pROM to permit an additional level of patches. For that case, change the conditions on A_6 and A_7 to place the patch pROM into another of the four blocks of 64 words each.

A larger number of patch words can be obtained by use of multiple pROMs in the changed-word detector. And a larger number of patched outputs can be obtained by several patch pROMs driven in parallel.

Expand memory size with pROMs

The second design technique—wire scrambling—simplifies doubling of a memory's size at any time during development or after the system is shipped. Like-numbered ROMs and pROMs can be used, because they are generally pin-compatible, the key requirement of the technique.

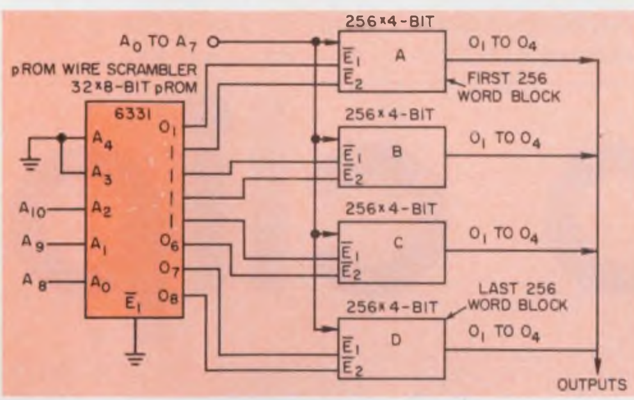
Newer bipolar 256 × 4-bit ROMs and pROMs and 512 × 4-bit pROMs are pin-compatible. The only difference between the pinouts of the 256 × 4 and 512 × 4-bit ICs is that the 256 × 4-bit circuit has two enables and the other has one. The 512 × 4-bit memories trade off the second enable for the required higher-order address line, A_8. Examples include Monolithic Memories' 6301 and 6306 memories, which are, respectively, pin-compatible 256 ×4-bit and 512 × 4-bit pROMs.

Many designers, aware of the pin-compatible feature among ROMs and pROMs, bring enable lines out to the board connector. This permits the signal to be used as a chip enable or a higher-order address line reserved for expansion.

This approach has several disadvantages: First, in larger memory systems that have several rows of packages on the board—say, 10 rows of 10 packages each—10 chip-enable lines (one per row) must be brought to the card connector. Hence 10 pins and board area are wasted. Second, the decoder that selects one of the rows to be activated must be placed off the printed-circuit board to avoid use of an elaborate on-board jumper system.

Finally the card-connector pins that convert a chip enable to an address must be rewired to double the memory size. The rewiring makes field changes costly and time-consuming.

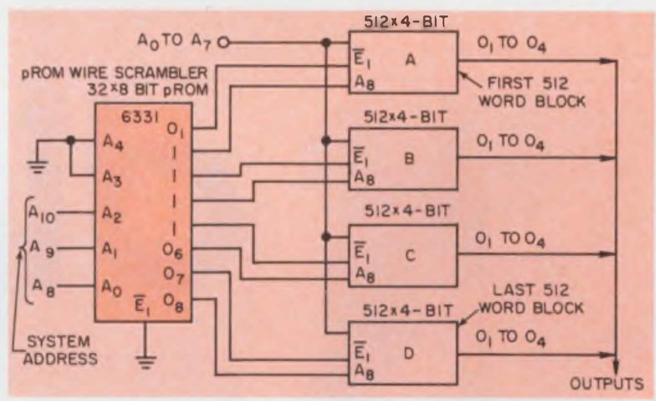
The situation is further aggravated when you



6331 Address			6331 Content							
A_2	A_1	A_0	O_8	O_7	O_6	O_5	O_4	O_3	O_2	O_1
L	L	L	H	H	H	H	H	H	L	L
L	L	H	H	H	H	H	L	L	H	H
L	H	L	H	H	L	L	H	H	H	H
L	H	H	L	L	H	H	H	H	H	H
H	L	L	H	H	H	H	H	H	H	H
H	L	H	H	H	H	H	H	H	H	H
H	H	L	H	H	H	H	H	H	H	H
H	H	H	H	H	H	H	H	H	H	H

L = TTL LOW ≈ 0 V
H = TTL HIGH ≈ 3 V

4. **A 32 × 8-bit pROM wire scrambler** handles the scrambling of address and enable signals for a 1024 × 4-bit system. Memories A through D can be ROMs or pROMs, and they are enabled when signals at $\overline{E_1}$ and $\overline{E_2}$ are low. The scrambler selects one of four rows.



6331 Address			6331 Content							
A_2	A_1	A_0	O_8	O_7	O_6	O_5	O_4	O_3	O_2	O_1
L	L	L	L	H	L	H	L	H	L	L
L	L	H	H	H	H	H	H	H	H	L
L	H	L	L	H	L	H	L	L	L	H
L	H	H	H	H	H	H	H	L	H	H
H	L	L	L	H	L	L	L	H	L	H
H	L	H	H	H	H	L	H	H	H	H
H	H	L	L	L	L	H	L	H	L	H
H	H	H	H	L	H	H	H	H	H	H

L = TTL LOW ≈ 0 V
H = TTL HIGH ≈ 3 V

5. **This 2048 × 4-bit system uses memories with the same pinout** as that of the 1024 × 4-bit system of Fig. 4. But the pROM scrambler is programmed differently, and address A_8 replaces enable line $\overline{E_2}$. The scrambler maintains the phase of address A_8.

expand from a 256 × 8-bit to a 1024 × 8-bit system. Address and chip-enable must be scrambled.

A solution is to use a pROM wire scrambler, as in Figs. 4 and 5. The two figures differ only in that Fig. 5 shows a 2048 × 4-bit system, while Fig. 4 shows a 1024 × 4-bit system. The tradeoff of address and enable lines is handled by different programming of the 32 × 8-bit pROM. Both systems use memories having the same pinouts, and they don't require board-connector rewiring or the accessibility of enable lines at the card connector.

Of course, the pROM should be in a socket, since it may be removed and replaced by another pROM, programmed differently to expand the system.

In the 1024 × 4-bit system of Fig. 4, eight words of the 32 × 8-bit pROM are programmed to form a 1-of-4 decoder. Unlike a TTL decoder, however, this puts out two low-level signals to select a row, since we must have both $\overline{E_1}$ and $\overline{E_2}$ low to select a row. In addition the pROM is programmed to ignore input A_{10} when it is high, because the maximum memory size with a 256 × 4-bit device is 1024 × 4-bits.

In Fig. 5 we also want to perform a 1-of-4 row select. But because the rows contain 512 words, address lines A_9 and A_{10} must decide which row to select. Note that in Fig. 4, addresses A_8 and A_9 make the row-select decision.

Also in Fig. 5, the pROM must change enable $\overline{E_2}$ of Fig. 4 into address input A_8. This is accomplished by programming of outputs O_2, O_4, O_6 and O_8 (wired to address A_8 of the 512 × 4-bit ICs) to agree in sense with input address A_8 (wired to pROM-address A_0). In the address/content table, whenever A_0 goes low (L), outputs O_2, O_4, O_6 and O_8 go low. And whenever A_0 goes high (H), outputs O_2, O_4, O_6 and O_8 go high. System address A_8 therefore becomes "wired through" the pROM, preserving its input phase. Addresses A_9 and A_{10} are decoded in the pROM to form a 1-of-4 decoder on outputs O_1, O_3, O_5 and O_7; address A_8 is ignored in this function.

The pROM scrambler has a disadvantage: increased access time. In the 2048 × 4-bit system (Fig. 5), for example, the pROM access time adds to the A_8 address path, which also includes the 512 × 4-bit ROMs. However, the pROM shown features an access of less than 50 ns, and it buffers the address input, which otherwise would usually require two TTL inverters to preserve the phase of the address. Hence the net speed loss is not severe. Moreover the pROM has three-state outputs that can easily drive a row of 10 ICs.

The same wire-through and scrambler-decoder techniques can be used to expand a 256 × 8-bit memory to a 1024 × 8-bit memory. ■■

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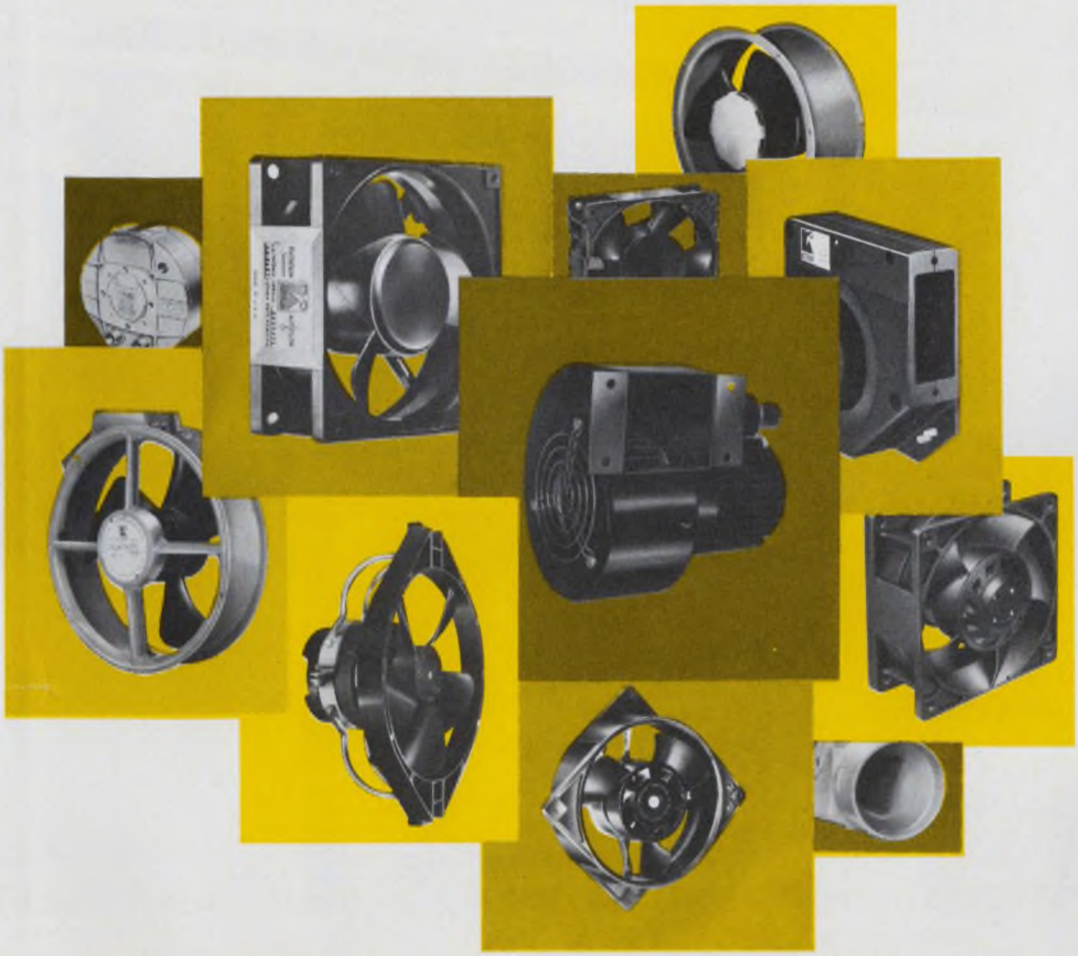

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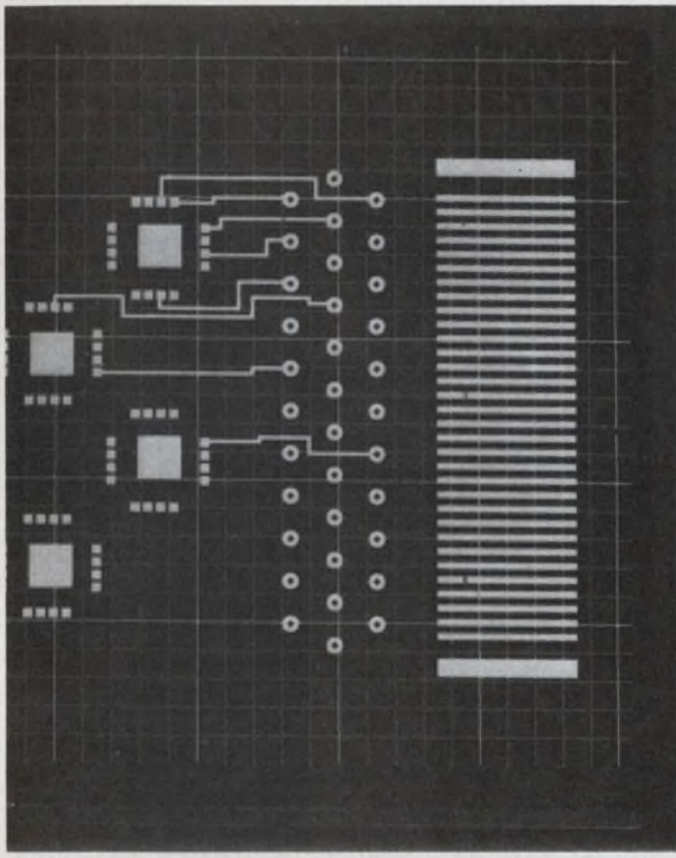
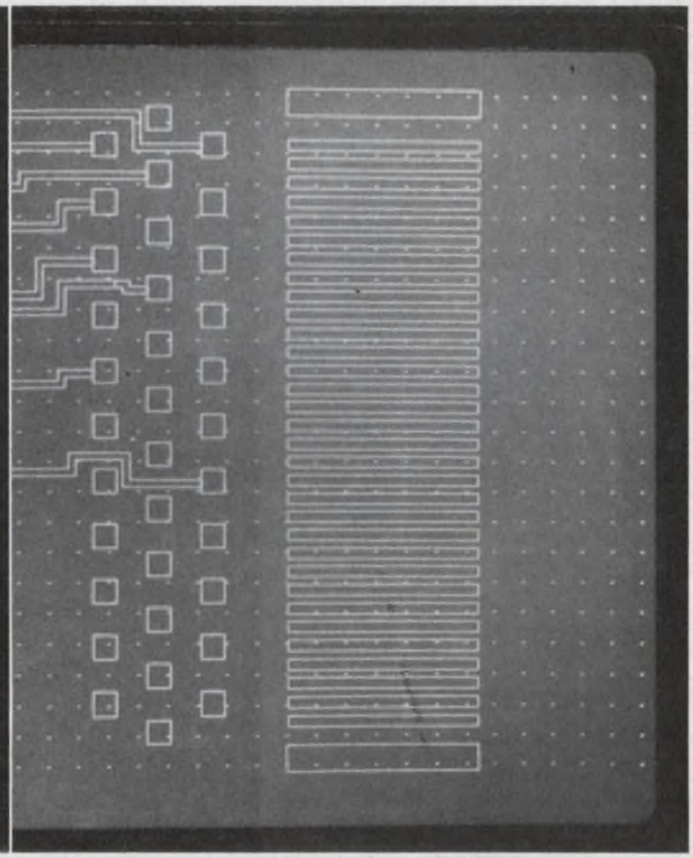


Unretouched time exposure of data displayed on a Digivue unit. Note high contrast picture, precise graphics.



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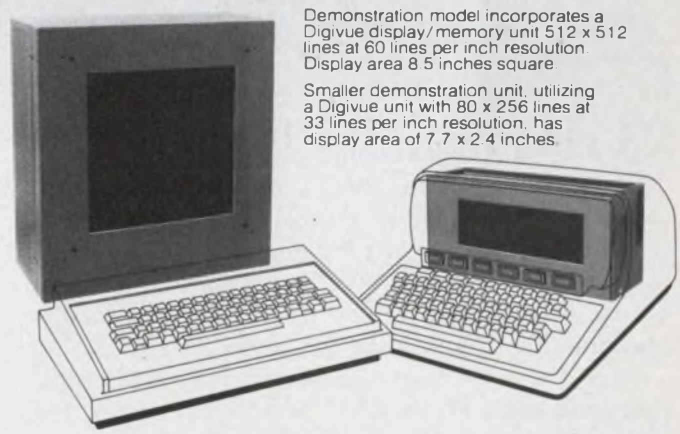

Demonstration model incorporates a Digivue display/memory unit 512 x 512 lines at 60 lines per inch resolution. Display area 8.5 inches square.

Smaller demonstration unit, utilizing a Digivue unit with 80 x 256 lines at 33 lines per inch resolution, has display area of 7.7 x 2.4 inches.

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Besides low losses, the technique offers other benefits: Switching frequency can go as high as 20 kHz, resulting in inaudible operation and in a considerable reduction of both magnetics size and capacitor values. Moreover efficiency improves over that of 60-Hz supplies, the forward-loop regulator is easily stabilized and complicated control circuitry isn't needed.

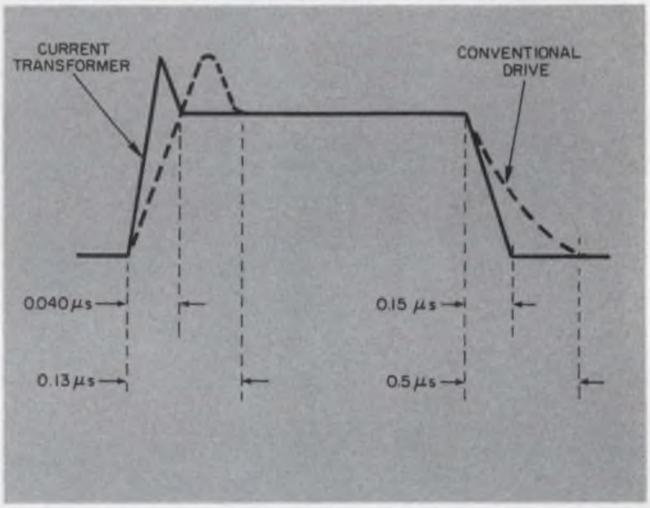
The key to high efficiency—possibly the highest attainable in 250-to-500-W supplies—lies in the constant volt-second characteristics of the saturating core, in which the product of "on" time and the difference between input and output voltage is maintained constant.

Saturating core keeps output steady

Thus if the input voltage E_{in} increases, t_{on} is reduced and the product $(E_{in}-E_{out})t_{on}$ remains constant. Note that the forward loop compensates for input-voltage changes more rapidly than does the conventional closed-loop design.

The current transformer provides a base drive that is proportional to the collector current and varies according to a predetermined ratio of I_c to I_b. If, for example, the load changes, and requires less current, then the base drive drops equivalently to minimize the drive losses.

Fig. 1 shows the collector-current switching characteristics of an SVT 300-10 transistor for both the conventional and the current-transformer approach. Switching loss with a conventional, or voltage source, base drive is 20 W at a power output of 350 W. By contrast, the current-transformer base drive reduces switching losses to 8 W.



1. **About three times faster switching occurs** when the switching regulator pass transistor is driven with a current transformer, rather than a conventional base drive. As a result, switching losses drop drastically.

Operation of the square-loop core for forward-loop regulation can be illustrated by a self-saturating dc-to-ac inverter (Fig. 2). When the circuit oscillates and Q_1 conducts, the supply voltage is dropped across the transformer primary winding N_1, as indicated by the equation:

$$E_{in} = N_1 \frac{d\phi}{dt} \times 10^{-8},$$

where $d\phi/dt$ is the rate of flux change in T_1.

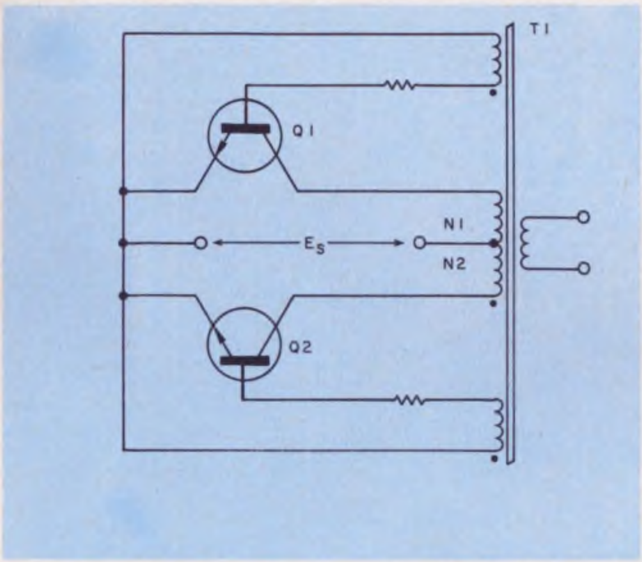
When the core approaches saturation, the induced voltage and, consequently, the base drive, are reduced. Because transistor Q_1 is turned off, the induced voltages across windings N_1 and N_2 are reversed. This, in turn, causes a reversal of bias, and transistor Q_2 turns on as Q_1 turns off. Then this cycle repeats.

A square-loop core used as a forward-loop regulator functions similarly, except that E_s differs for t_{on} and t_{off} (Fig. 3). In the figure, when Q_1 is on

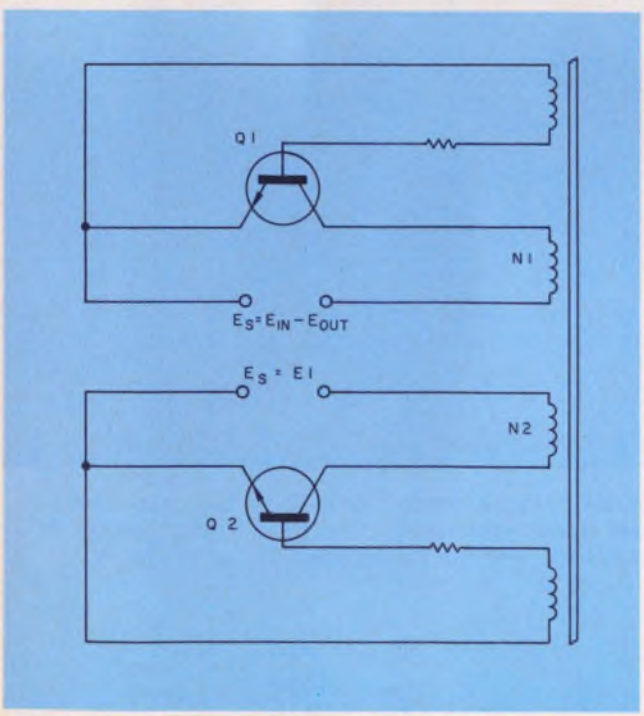
$$(E_{in} - E_{out})t_{on} = N_1\, d\phi \times 10^{-8}.$$

When E_{in} changes, t_{on} also changes and maintains the product of $(E_{in}-E_{out})$ and t_{on} constant. When Q_2 is on

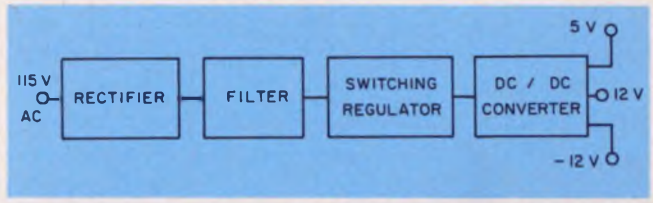
Jagdish Chopra, Applications Manager, TRW Semiconductors, 14520 Aviation Blvd., Lawndale, Calif. 90260.



2. **Self-saturating, square-loop-core inverter** forms the basis of a forward-loop regulator.



3. **Operation of the regulator** can be visualized more clearly when windings N_1 and N_2 are separated, and the circuit equations are written for alternate conduction of Q_1 and Q_2.



4. **Functional elements of the forward-loop supply:** The rectifier and filter are conventional designs. The converter switches at 20 kHz and delivers output voltages of +5 and ±12 V.

$$E_1 \times t_{on} = N_2\, d\phi \times 10^{-8}$$

This type of control reduces the 120-Hz line ripple by 33 dB.

Design includes dc/dc converter

The elements of a 300-W forward-regulated supply are shown in Fig. 4, and the complete schematic is given in Fig. 5. The rectifier and filter are conventional designs, with the filter rated at 100 V dc, 4 A.

The design, which includes a dc-to-dc converter, can operate from a 115-V, 60 or 400-Hz ac line. The switching regulator provides a 50-V output with input voltage variations from 80 to 160 V, and the dc-to-dc converter produces +5 and ±12 V dc from the 50-V output.

This supply has many applications; for instance, computer peripherals, minicomputers and avionics equipment. And of course, the bulky 400-Hz transformer so common in avionics equipment is eliminated.

From the basic switching-regulator equations,

$$E_{out} = E_{in} \frac{t_{on}}{t_{on} + t_{off}}$$

$$E_{out} t_{off} = (E_{in} - E_{out})\, t_{on}$$

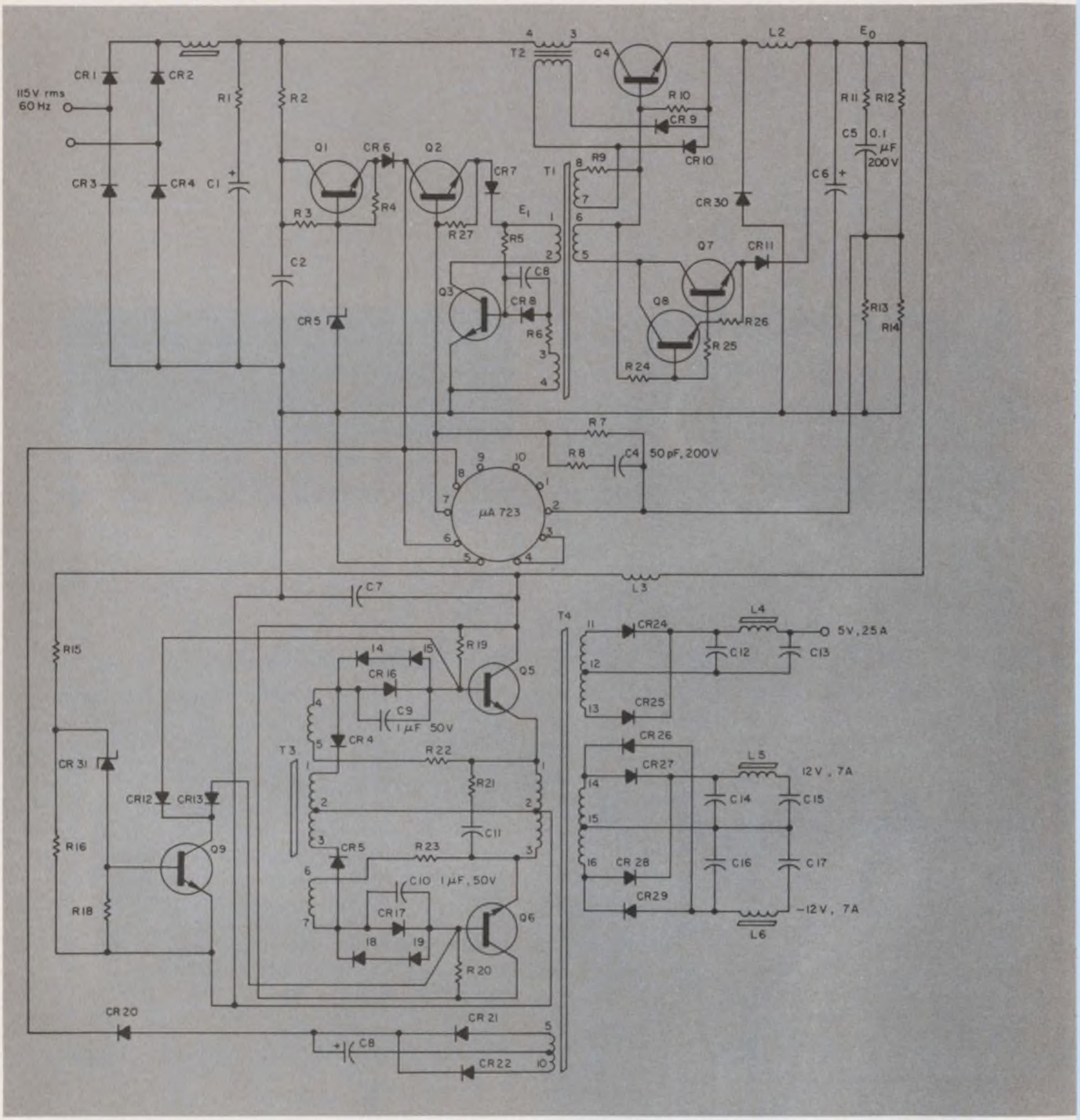
$$E_1 t_{off} = (E_{in} - E_{out})\, t_{on},$$

where $E_1 = kE_{out}$, and k is a constant. If the product of $(E_{in} - E_{out})t_{on}$ is maintained constant, and t_{off} is also constant, then the output remains constant. Operation of the regulator is as follows:

When Q_1 is on and Q_2 is off (or vice versa), the voltage across winding 6-5 is

$$E_{in} - V_{CE}(sat) + V_{BE} - E_{out}.$$

When Q_1 saturates



5. **Schematic of the complete supply.** Square-loop transformer T_1 switches at 20 kHz as transistors Q_3 and Q_4 conduct alternately. Transformers T_3 and T_4 form part of the dc/dc converter, while T_2 is the base-drive current transformer for Q_4. The triple-output delivers 300 W but the unit can be designed for up to 500 W.

$$E_{in} - V_{CE}(sat) + V_{BE} \approx E_{in}.$$

Transformer T_1 (winding 5-6) is designed to support the volt-second value and also to meet the minimum 20-kHz switching frequency. Other design criteria are:

$$E_{in}(\text{minimum}) = 80 \text{ to } 160 \text{ V}$$

$$E_{out} = 50 \text{ V}$$

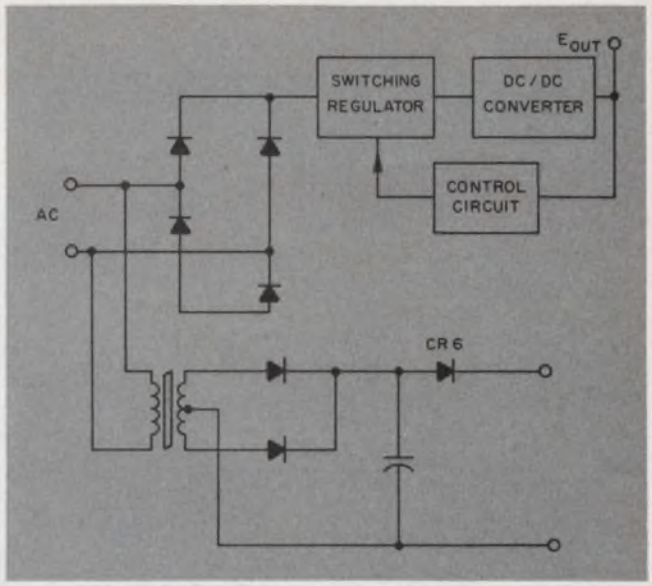
$$t_{on} = 32\ \mu s$$

$$t_{off} = 18\ \mu s.$$

Transformer T_1 is designed first; then the value of E_1 is chosen to meet the t_{on} and t_{off} requirements. When T_1 saturates, Q_4 turns off and

Component values

SYMBOL	PART NO.	DESCRIPTION
TRANSISTORS		
Q1, 2, 3, 7, 9	2N5326	80 V, 5 A
Q4, 5, 6	SVT300-10	300 V, 10 A
Q8	2N4305	80 V, 5A
DIODES		
CR1-4	1N3211	300 V, 15 A
CR5	1N5077	30 V ZENER
CR6-22	DSR5101	100 V, 5 A
CR24, 25	SD-51	Schottky 35V — 60 A
CR26-29	SVD100-12	100 V, 12 A
CR30	SV300-12	300 V, 12 A
CR31	LVA 68A	6.8 V ZENER
CAPACITORS		
C1	350 μF, 250 V dc	
C2	0.1 μF, 200 V dc	
C3	0.1 μF, 50 V	
C4	50 pF, 200 V	
C5	0.1 μF, 200 V	
C6	100 μF, 75 V dc	
C7	5 μF 100 V dc	
C8	22 μF, 50 V dc	
C9, 10	1 μF, 50 V dc	
C11	0.002 μF, 200 V	
C12	1 μF, 50 V dc	
C13	1000 μF, 10 V dc	
C14, 16	1 μF, 50 V dc	
C15, C17	1000 μF, 20 V dc	
RESISTORS		
R1	0.33, 5 W	
R2	2.5 k, 3 W	
R3	20 k, 1/2 W	
R4	10 k, 1/4 W	
R5	30 k, 1/4 W	
R6	2 k, 1/4 W	
R7	154 k, 1/8 W 1%	
R8	51 k, 1/4 W	
R9	300, 1 W	
R10	100, 1/2 W	
R11	4.22 k, 1/8 W 1%	
R12	21.5 k, 1/8 W 1%	
R13	5.11 k, 1/8 W 1%	
R14	S.I.T. 1/8 W 1%	
R15	10 k, 1 W	
R16	3 k, 1/2 W	
R18	10 k, 1/4 W	
R19, 20	10 k, 1 W	
R21	51, 1 W	
R22, 23	7.5, 5 W	
R24	10 k, 1/2 W	
R25	2 k, 1/4 W	
R26	600, 1/4 W	
R27	2 k, 1/4 W	
TRANSFORMERS		
T1—CORE	52000 — 1/2 D	MAGNETICS INC.
WINDING—1 — 2	50 Turns, #30	
3 — 4	25 Turns, #30	
5 — 6	130 Turns, #30	
7 — 8	25 Turns, #30	
T2—CORE	52402 — 1 D	MAGNETICS INC.
WINDING—1 — 2	40 Turns, #24	
3 — 4	4 Turns, #18	
T3—CORE	5200 — 1/2 D	
WINDING—1 — 2	180 Turns, #28	
2 — 3	Bifilar wound	
T4—CORE	52029 — 1 D	
WINDING—1 — 2	50 Turns, #18	
2 — 3	Bifilar wound	
4 — 5	5 Turns, #28	
6 — 7	Bifilar	
8 — 9	36 Turns, #32	
9 — 10	Bifilar	
11 — 12	7 Turns, #16 (Dual)	
12 — 13	Bifilar	
14 — 15	12 Turns, #16	
15 — 16	Bifilar	
INDUCTORS		
L1 = 6 mH @ 4.5 A		
CORE # E 1 625 SQ	— 120 Turns — #20	
L2 = 1.0 mH @ 7.5 A		
CORE # E 1 375 SQ	— 60 Turns — #18	
L3 = 130 μH @ 7.5 A		
CORE # 55120 — A2	— 70 Turns — #20	
L4 = 25 μH @ 25.0 A		
L5, 6 = 100 μH @ 8.0 A		



6. **For better regulation at the 5-V output,** the loop can be closed from the 5-V terminal instead of the 50-V point. When this is done, a modified start circuit keeps the output and input isolated.

Q_3 turns on in response to the regenerative characteristics of the core. Then t_{off} is determined by E_1 and winding 1-2 of transformer T_1.

Current transformer drives base

To complete the switching-regulator design, winding 8-7 is used to initiate turn-on of Q_1, and winding 3-4—along with R_5—turns Q_3 on and maintains it in the on state. Base drive is provided through the current transformer. During t_{off} the voltage across winding 8-7 resets the current transformer.

The output voltage is sensed and amplified via the μA 723 IC voltage regulator which, in turn, varies E_1. Capacitors C_5 and C_4 are selected for loop stability.

Frequency of the dc-to-dc converter (20 kHz) is controlled by saturating transformer T_3. The main transformer connects between the emitters of transistors Q_5 and Q_6. This connection turns the converter off, should the switching regulator short through the network composed of R_{15}, R_{16}, CR_{31}, Q_9, CR_{12}, and CR_{13}. This approach protects the power-supply load from overvoltage caused by the short. Rectification of the 5-V output is accomplished by Schottky diodes CR_{24} and CR_{25}, which have a forward drop at 25 A of about 0.5 V.

For certain logic circuits—those in which better regulation is required—the regulator loop can be closed if the output is sensed in any of the usual ways. Regulation to within 1% can be achieved. To retain isolation between the output voltage and the input line when the loop is closed, a modified start circuit can be implemented (Fig. 6). ■■

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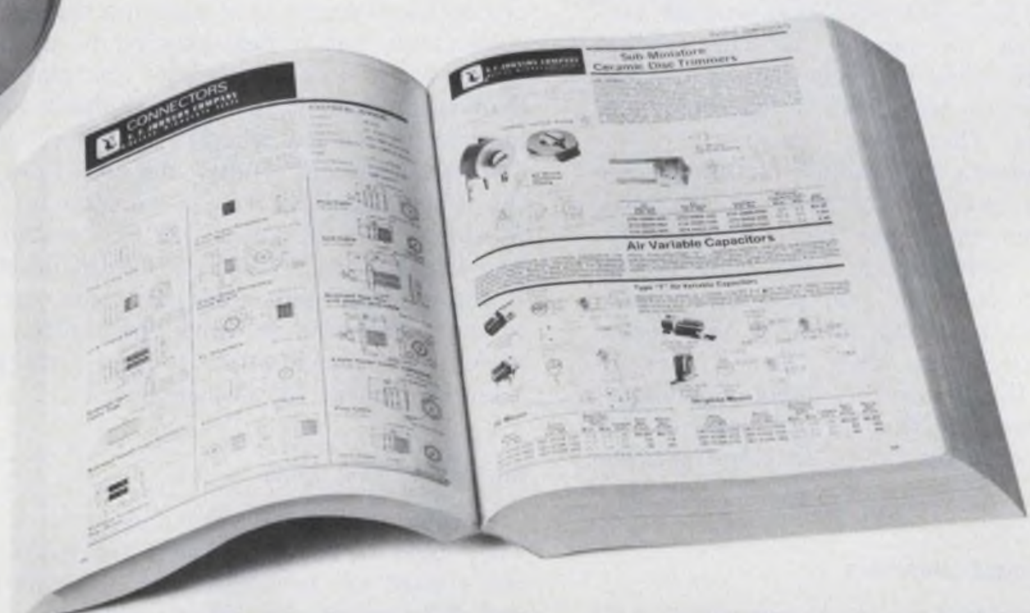

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GOLD BOOK

COMING JULY, 1974

Don't be a slave to a project schedule,

advises this manager, who believes that it's far more important to review a product constantly to test how practical it is.

They say there never has been a project completed on time and within budget. So what? No designer I know can develop his best product if his main concern is the schedule. His main concern should be how practical the product is—NOW, not when he started it. The market changes and the designer must constantly review his product to determine if it's worth developing further. That takes planning.

Some vital aspects of product planning have been ignored in most of the articles I've read, probably because these are hard to quantify. People tend to write about what they understand, even if it isn't the real problem. Charts and reports and planning methods proliferate and they're valuable to keep track of what's going on. But the danger in using established methods exclusively is that people use them to meet milestones directly and to develop the product indirectly.

Cross-fertilize project members

To keep my product design as current and as practical as possible during a project, I do the following at Sigma:

- Interface engineers with other disciplines.
- Review the specs constantly.
- Stick to my initial design approach most of the time.
- Solve the most difficult technical design problem first.

It's wrong to insulate engineering in a company. I've worked with a number of companies in many fields, and it seems to me that in a world that's increasingly technological the engineer knows some things that he should share. There should be cross-fertilization between engineering and sales, particularly when they're developing new products. New products are risky, and any input that can be shared by these two disciplines is vital to the success of the project.

Tom Beling, Vice President, Engineering, Sigma, Braintree, Mass. 02185.

Here the salesmen sit next to the design engineer. We even moved their desks together. The industrial engineers and applications engineers are also there. We feel that regular interface among these people is of extreme value. It sounds elementary, but it beats trying to communicate by memo. It does two things: It increases communication, and it increases understanding. It's hard to curse a guy when he's sitting next to you.

I also believe in sending my engineers out into the field regularly to see customers, explore problems, and discover the real world, as opposed to how we'd like it to be inside of Sigma. If the engineer sees some poor customer trying to get a machine to work, he'll often adopt a more responsive attitude toward field problems after he returns to the company.

Sticking to your guns

I watch the specs very closely on a project. They tend to be vague, so I try extra hard to get a good set to begin with. I want to make sure I know exactly what's needed.

I'll start out with a certain set of specs at the beginning of a project, but before it's finished, I'll usually end up with a completely different set. What happens is that I can't meet the specs, or I exceed them in some areas, or I find some aren't needed at all. Every time the specs are changed, I review the product again to determine if it's still practical.

All along the way you've got to ask production people what they think of the specs: Are they practical? From a company point of view, product design is the relatively cheap part of product introduction. After the product is designed, you have to make a decision on whether to go into the pilot run, production, sales and the whole business. All that usually costs more than the design itself.

Then there's the "should-I-start-with-a-new-approach" question.

You're working on a project and run into obstacles; if you don't, the project probably isn't worth doing. But when you do stub your toe, you always have this question: Do I push ahead

Tom Beling and Sigma Instruments

Tom Beling's career has the unmistakable mark of success; after serving in the U.S. Army Signal Corps for two years, he made a habit of steady advancement.

Between the time he was a designer of various portions of airborne radar at Farnsworth Electronics and Sigma's Vice President of Engineering, Beling worked as a systems engineer on Doppler Radar at Raytheon, as a division manager in instrumentation and audio research at United Research, Inc., and as vice president of engineering at Acton Labs.

In the middle of his career he attended Harvard Business School and earned an MBA to go along with the BSEE and MSEE he'd earned earlier at the University of Illinois.

Sigma Instruments, his present employer, was founded in 1938 to make sensitive relays, an area in which the company is still a leader. Other switching products now include general purpose relays, reed relays, and outdoor lighting controls, as well as hybrid and solid state relays. Electronic controls for electric utilities were added in the 1950's, and a line of digital stepping motors and associated electronics has been developed in the past few years. Beling is responsible for the design and development of all products at Sigma.

Beling's extracurricular activities include membership in IEEE and ARRL, published articles, and six patents. Special interests are camping and photography. He has probably had a lot of practice taking pictures since he and his wife have four children ranging in age from 11 to 18.

or do I start over with this new approach I just thought of? It doesn't matter what kind of project you're doing. After you do it, you think, "Man, if only I'd done such and such, I might be better off." It's very difficult to see the problems in a new approach, as opposed to the problems you already know about in the old approach.

I know of no solution to this problem. You can try to use good judgment and call the appropriate people together to review the situation carefully. But then you still have to face the decision alone. My philosophy is: I had a plan and I expected troubles . . . now what's really wrong with that plan? Sometimes that really sobers me up. But 70% of the time I'm better off sticking to my first approach.

I never base the decision on how much money has been spent; there's no way I'm going to get it back. I've tried both ways often enough, and most of the time I've found that if I try the second approach, the first approach starts looking pretty good again.

The ability to develop this kind of expertise and judgment is more important than trying to quantify and control something that is less susceptible to control the more difficult it gets. In our company we take only a few projects that are a gamble, and we don't cry very hard if we don't win.

Occasionally one reason I may doubt my initial project approach is because the first task I attack is finding the critical feasibility point. When I look at a project, I look first at the most difficult technical problems—there may be several. I assimilate that as quickly, honestly and realistically as I can, and try not to be blinded by my desire for it to work. I put all my energy on that problem at the beginning, rather than having an orderly project, where the tasks are done in sequence. I waste some time, but over the long haul I find out what products aren't practical early in the game.

Anatomy of a project

From the beginning to the end of a project, I maintain a constant and cold-blooded review of the product, to avoid putting more time, money and effort into it if it isn't going to be practical or if it's going to be too complex for the customer to use.

After I get a good set of specs, I contact everyone in my department who I think would be able to contribute an idea. Because of the nature of our company, I have people who do various kinds of engineering—electromechanical, relay, mechanical, electronic. I ask them how they would solve it, and I give them a day or two to mull it over.

I'll get diverse ideas for the solution, from which I'll try to synthesize an approach. Engineers in some companies work on the problems in cubicles. Other engineers find it difficult to use the expertise they have because they are in competition with other departments or divisions in the same company.

I like to "blue sky" the solution a bit. I don't want to have a preconceived notion of it. I'm not afraid of not knowing some phase of technology. I'll ask questions to find out about it; but we all pick and choose the better ideas, and I act as the catalyst. I never fault a project member for making a wrong decision, unless he has plowed forward after he has been proved wrong.

At this point we've spent about 5% of our budget, and we've decided that the design is technologically feasible. So we start forming detailed plans and charts. If we keep checking spec modifications (where we are and what we can do) and cost modifications, we can estimate what the cost is going to be and what we can sell it for. We're comparing cost and price constantly, playing them off the specs.

Maybe we'll get in the middle of the project and find that the cost is so high it'll be an engineering monument to finish. And maybe, even though the costs appear to be high, the product might look promising enough for us to press ahead and try to drop costs out later.

Testing theory against the project

Let me give you an example of how my theory worked on a project we had a couple of years ago.

The customer supplied the specs, and we supplied an overly enthusiastic idea of what could be done with the cost. Neither one of us knew what he was doing; we were breaking new ground. The customer gave us an optimistic set of specs to meet the requirement when we gave him an optimistic projection.

Soon it became apparent that a lot of things had to be done to the product other than the specs we'd received. Our plans were thrown out of kilter. We spent four or five times the amount of money that we'd estimated. But as we went along, we saw the product taking a positive shape.

Sometimes the engineer can come up with a product that's so good it's worthwhile even at twice the budget. Cost should never be the engineer's chief worry. He could develop a product at half the budget and never sell the first one.

Timing is important, too. An engineer could have invented the digital computer 200 years ago, and it wouldn't have done him any good. He might have been remembered as a genius, but he'd never be remembered as a millionaire.

When we had finished the product for our customer, we found that it performed more functions than we'd asked it to, opening up new markets for the customer. So, at the moment, it appears that this device, which cost us so much, is going to be a big winner, selling at about three times the original estimated price.

I've been 25% to 50% more successful with this project method than with any other I've used, but it was enough to make a PERT man blanch in horror. What we were doing along the way was holding back and seeing what we had and asking ourselves, "What can the product do now?" "Is there anything else it could do?" It took a lot of hard work and liaison with this particular customer to get the answers we had to have. ■■

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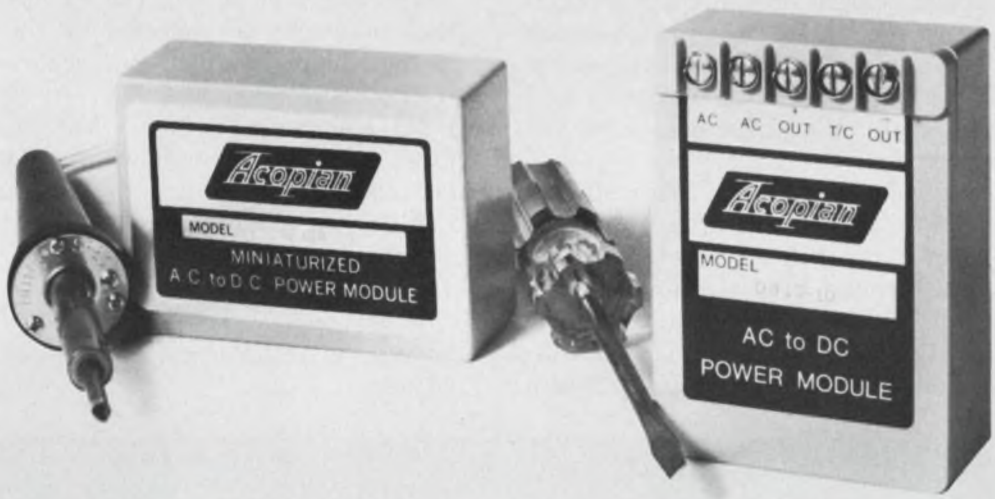

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300	3.5 x 2.5 x 1.63	105	DB15-30
350	3.5 x 2.5 x 1.63	110	DB15-35
500	3.5 x 2.5 x 2.38	135	DB15-50

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INFORMATION RETRIEVAL NUMBER 60

Low power at ohmmeter's probes allows safe usage on most sensitive components

Ordinary ohmmeters can damage tunnel diodes, MOSFETs and many transistors. The more sensitive components can be harmed even by so-called micro-power ohmmeters. However, the power used at the probes of the ohmmeter in the figure is so low that the ohmmeter can be used on the most sensitive components.

The circuit imposes only maximum voltage of 10 mV, a maximum current of 1 mA and a maximum power of 2.5 μW to the test probes—even on the lowest resistance scale. On the $\times 10$, $\times 100$ and $\times 1000$ scales, the maximum currents and powers are reduced further by factors of 10, 100 and 1000, respectively.

In the circuit, a voltage of 10 mV is maintained between point "A" and ground. This voltage is also across one of four selected fixed resistors, designated R_i (R_1 through R_4), which is in series with the unknown junction resistance R_x. Variable resistor R_v at the input to op-amp A_1 sets the voltage level that point "A" is forced to maintain via the circuit's negative feedback. R_v also serves as the ohmmeter's zero-set control.

With point "A" at 10 mV, the current through resistors R_f and R_x is

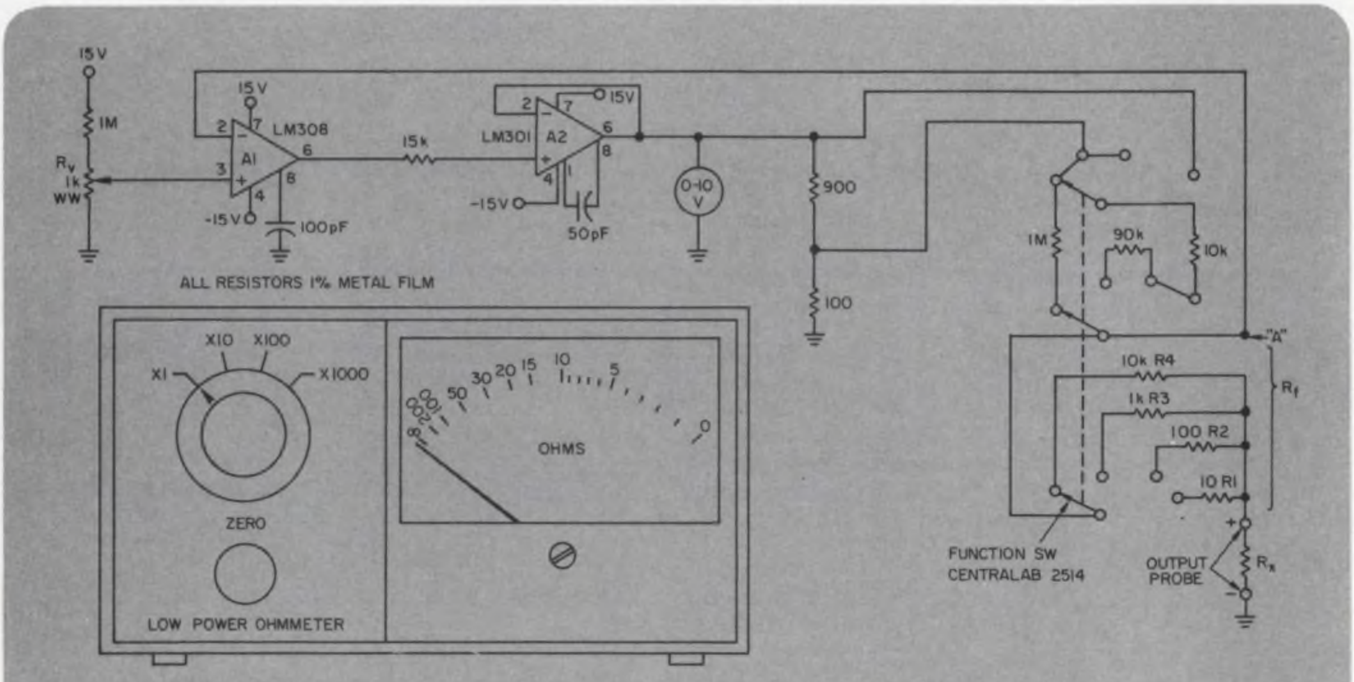
$$I = 10\ \text{mV}/(R_f + R_x).$$

The current is supplied by the output of A_2, whose output voltage is proportional to this current, or $1/(R_f + R_x)$.

The values of R_f and the resistors in the feedback networks are selected by the range switch so that the meter reads mid-scale when $R_x = R_f$.

The operational amplifier A_1 should have an input bias current that is less than 10^{-7} A that flows through the unknown resistance at the upper end of the ohmmeter's useful range. The LM308 has a rated bias current of only 7×10^{-9} A, which meets the criterion amply.

B. D. Wallace, Instrumentation Program, University of California, Santa Barbara, Calif. 93106. CIRCLE NO. 311



With a commercially available ±15 V power supply and about $60 worth of parts, you can build this low-power ohmmeter. The circuit delivers a maximum of 10 mV, 1 mA or 2.5 μW to the probe.

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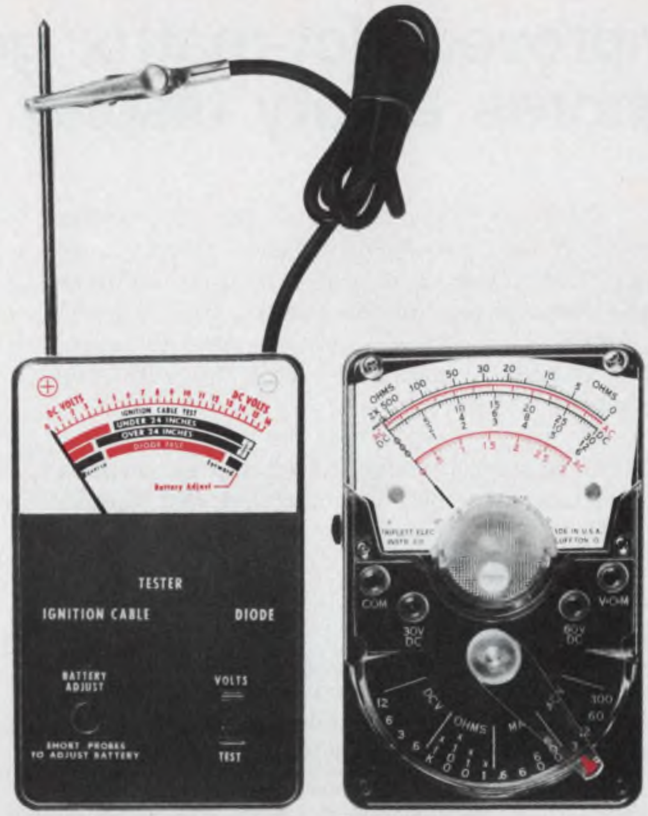
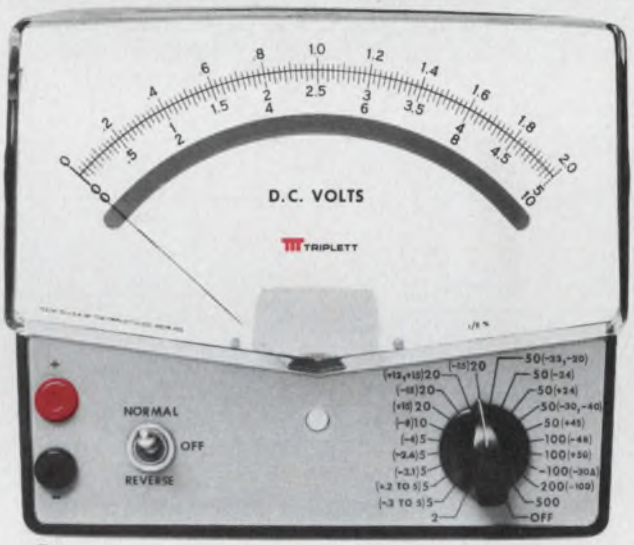


A B



C

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Tester B is a modification of a standard Triplett tester incorporating only the specific ranges needed by the field service engineers for whom it was designed.

Tester C has special ranges and special input connectors and cables to permit a single-point connection for trouble-shooting and servicing all the circuits of a complex business machine.

Several other buyers of standard Triplett test equipment request their company name on the dial to personalize their testers.

If you think a custom tester may solve some problems for you, contact your Triplett representative. He'll put you in touch with the Tester Designers and Engineers at Triplett who'll help you analyze the problem and suggest the optimum cost/result solution. Triplett Corporation, Bluffton, Ohio 45817

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INFORMATION RETRIEVAL NUMBER 61

Improved dot-matrix generator ignores empty display positions

IC character generators of the dot-matrix variety provide on/off information from an integral ROM. External X and Y registers address all the dot positions in the matrix. On the average only a third of these dots are used to represent a character in a given font. So why step through all states?

The circuitry shown avoids the need to advance position registers through states that correspond to blank areas in the character font. All Y-position addresses correspond to active dots.

When the ASCII code is first presented to the character generator, the unit outputs the first column on lines O_1 through O_7. To follow the circuit operation, assume initially that the input causes O_3 and O_6 to be activated and that the S-R latch is cleared. Then encoder gates G_6 and G_3 provide inputs to the priority encoder. The encoder ignores G_3 but it encodes G_6 for the correct Y position of the first bright dot. The decoder connected to the Y outputs activates line 6.

The leading edge of the clock pulse loads the encoder output to the Y-position register. The clock pulse also generates the intensity signal and its trailing edge strobes decoder gate G_{13} to set bit Q_3 of the latch. With Q_3 high, gate G_6 is disabled, and only line 3 remains active at the priority encoder.

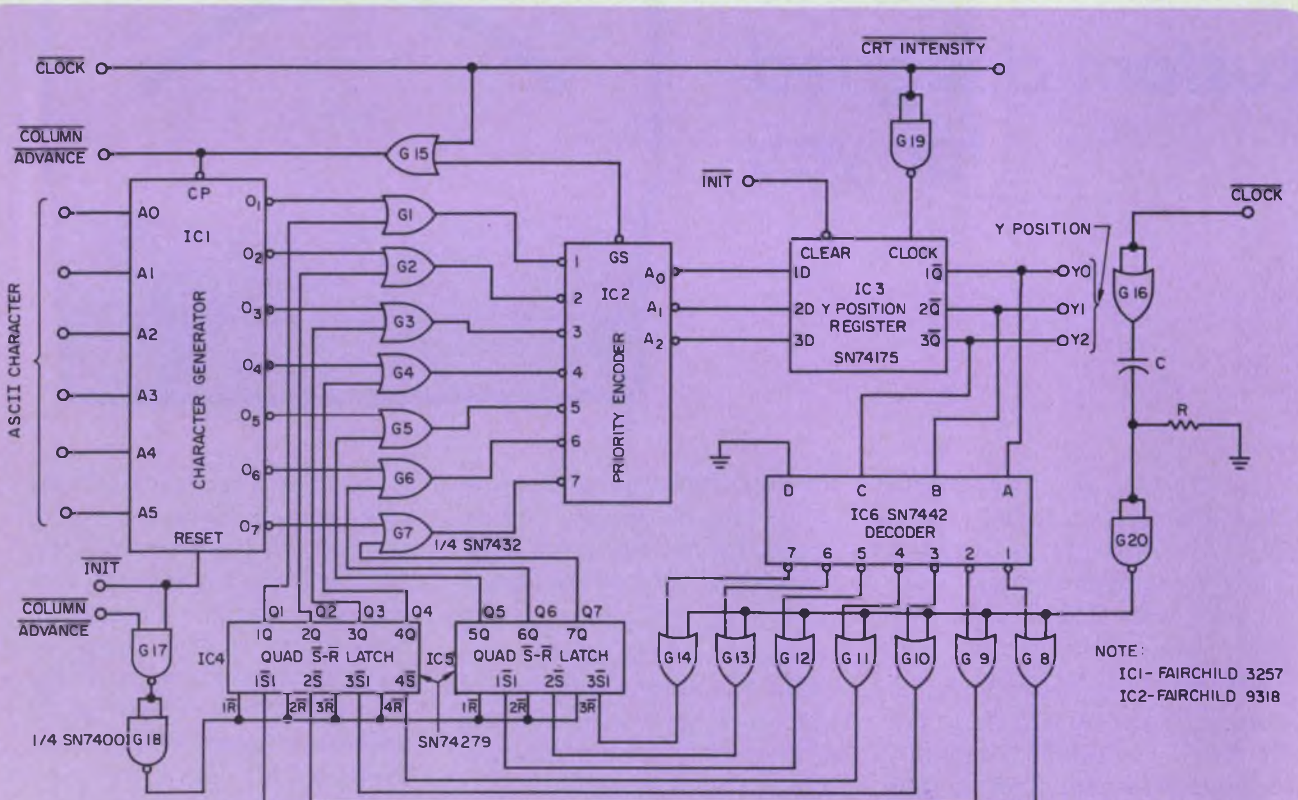
The next clock pulse outputs the dot as before; however, no more lines remain active at the priority encoder. Since all encoder inputs are inactive, the unit will generate signal GS to open gate G_{15}. The next clock pulse clears the latch and advances the character generator by one column. The circuit is now ready to output the next row of dots. An X position register (not shown) selects the display column.

The whole circuit is suitable for fabrication as a single IC. Use of a 7-bit S-R latch to store column information Q_1 through Q_7 would eliminate the need for gates G_1 and G_7.

Kruno Culjat, Senior Engineer, General Atomic Co., P.O. Box 81608, San Diego, Calif. 92138.

(This article was written when the author was employed by Ortec Inc., Oak Ridge, Tenn.)

CIRCLE NO. 312



Dot-matrix display skips empty column positions to reduce idle time. IC_2 selects and encodes active rows, one at a time, for each clock pulse. The decoder-latch combination disables previously encoded lines. The RC differentiator is used to prevent possible race conditions.

Combinatorial logic circuit calculates the absolute difference of numbers

The absolute magnitude of the difference between two positive binary numbers,

$$Z = |X - Y|,$$

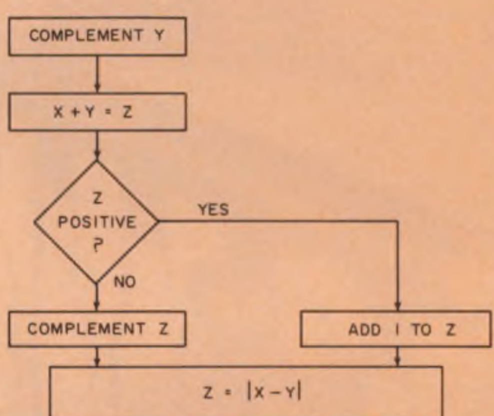
can be calculated with two SN74283 binary adders, two SN7486 EXCLUSIVE-ORs and one inverter. Many applications in digital design, such as in d/a converters, require this operation.

A flow chart of the required steps is shown in Fig. 1. Many computers perform these operations sequentially, but the simple combinatorial circuit in Fig. 2 does it for two 8-bit binary numbers, in less than 80 ns. When the ONE's complement, or inversion, of Y is added to X and a carry is obtained, the result is positive, and the carry must be added to the result to get the correct answer. This process is called the end-around-carry method—the equivalent of use of a TWO's complement of Y.

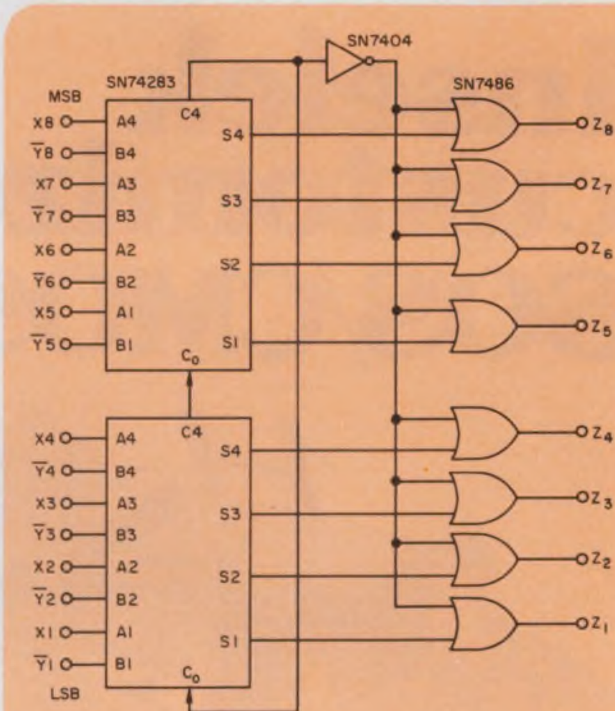
When no carry comes out of the highest-order adder, the SN7404 inverter applies a ONE to the EXCLUSIVE-ORs, and all the inputs are inverted in their outputs. Though the circuit shows only an 8-bit implementation, its extension to larger numbers is explained in Fig. 2.

Paul Jacobs, Principal Engineer, Raytheon Co., 6380 Hollister Ave., Goleta, Calif. 93017.

CIRCLE NO. 313



1. **All the steps to obtain the magnitude of a difference** are accomplished in 80 ns.



2. **To expand this subtractor** for larger binary words requires the use of one additional SN74283 and one SN7486 for each 4-bit input-word increase. Of course, loading limits on the SN7404 must be observed. An extra inverter should be added for about every 8-bit increase.

IFD Winner of March 1, 1974

Jerald Graeme, Manager, Monolithic Engineering, Burr-Brown Research Corp., International Airport Industrial Park, Tucson, Ariz. 85706. His idea "Bootstrapped RC Differentiator Performs Accurately Without Phase Inversion" has been voted the Most Valuable of Issue Award.

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INFORMATION RETRIEVAL NUMBER 63

international technology

Photodetector combines slim pulse with high gain

A photodetector tube that measures light pulses of only a few picoseconds and has high gain has been designed at the Philips Electronics and Applied Physics Laboratories at Limeil Brevannes in France. Such a device is needed in plasma research and in the measurement of laser signals.

The tube is basically a cathode ray with a photocathode in place of the normal cathode. The tube also contains an electron gun, an electron focusing system, a deflection unit, a microchannel plate and a fluorescent screen.

A light signal focused on the cathode is converted into an electron current proportional to the intensity of the illumination. The electron beam is accelerated and intensified by the tube's electron optical system. The resultant fluorescent-screen display has a light output proportional to the flux received at the photocathode. A control electrode in the electron gun synchronizes gating of the tube with an external signal.

Spiral scanning is applied to electrostatic deflection plates for observation of light phenomena. The scanning is produced by two 200-MHz, amplitude-modulated sinusoidal voltages. The spot speed is 2 cm/ns with a 200-V, peak-to-peak sweep voltage. The accelerating voltage is 2 kV. The time resolution of the tube is 10 ps. With a trialkaline photocathode, the photon gain is more than 10,000 for a wavelength of 0.5 μm.

CIRCLE NO. 315

Coil plus a/d converter monitors phone dialing

A monitor that can reveal the use of company telephones for personal calls has been produced by Telstop SA in Luxembourg.

An inductive coil picks up dialing signals from the telephone cord, and the signals are recorded on a magnetic-tape cassette. An a/d conversion system produces a paper printout of the numbers called.

The device cannot be used for wiretapping, since it picks up only the dialing signals. However, it must be approved by telecommunications authorities wherever it is used.

CIRCLE NO. 316

Photomultiplier gain soars to 15,000

Image intensifiers that have a gain of 15,000 and can operate in a gated mode are being built by Philips Eindhoven in the Netherlands.

Small channel photomultipliers, about 12 μm in diameter and 5-mm long, are fused side-by-side. This produces a thick plate with a sensitivity of 10^{-5} LUX. The image amplifiers are gated to enhance an image and to suppress light that is backscattered by fog or smoke.

The method—called Milkrokanal, or channel photomultiplier technology—employs a long laser pulse to illuminate the subject. But the gate opens only for a brief period at the precise time that light from the subject returns to the camera. Unwanted light, such as that reflected from suspended particles or even a curtain, arrives when the gate closes and is prevented from obscuring the image.

CIRCLE NO. 317

Higher sensitivity noted in varactor-diode amp

A parametric varactor-diode amplifier operates at room temperature with a sensitivity that the developer—Ferranti of England—says was attainable previously only through use of cryogenic techniques. It amplifies within the 7.25-to-7.75-GHz band.

The operating bandwidth is 500 MHz. Effective input-noise temperature is 100 K at 7.5 GHz. Ferranti says that improved semiconductor fabrication methods and a higher-than-usual pumping frequency—50 to 60 GHz, compared with 40 GHz—give the increased performance. Raising the operating frequency increases the ratio of pump-to-signal frequency. Therefore, Ferranti says, better noise performance can be obtained from a varactor diode.

CIRCLE NO. 318

System widens capability for patient monitoring

A new system for computer-assisted monitoring of patients not only checks physiological variables against norms but also analyzes them in relation to one another and to previously measured values.

Up to 32 patients can be monitored at one time. Patient data are updated every 30 seconds, and data can be stored up to 16 days.

The system, developed by Siemens of West Germany and called Simon, includes provision for immediate computer access to any information concerning individual patients. Hospital personnel communicate with a Siemens 404 computer and peripheral equipment, with video monitors and keyboards. The 404 includes control unit, operator console typewriter, tape reader, tape punch, data store and magnetic disc recorder.

CIRCLE NO. 319

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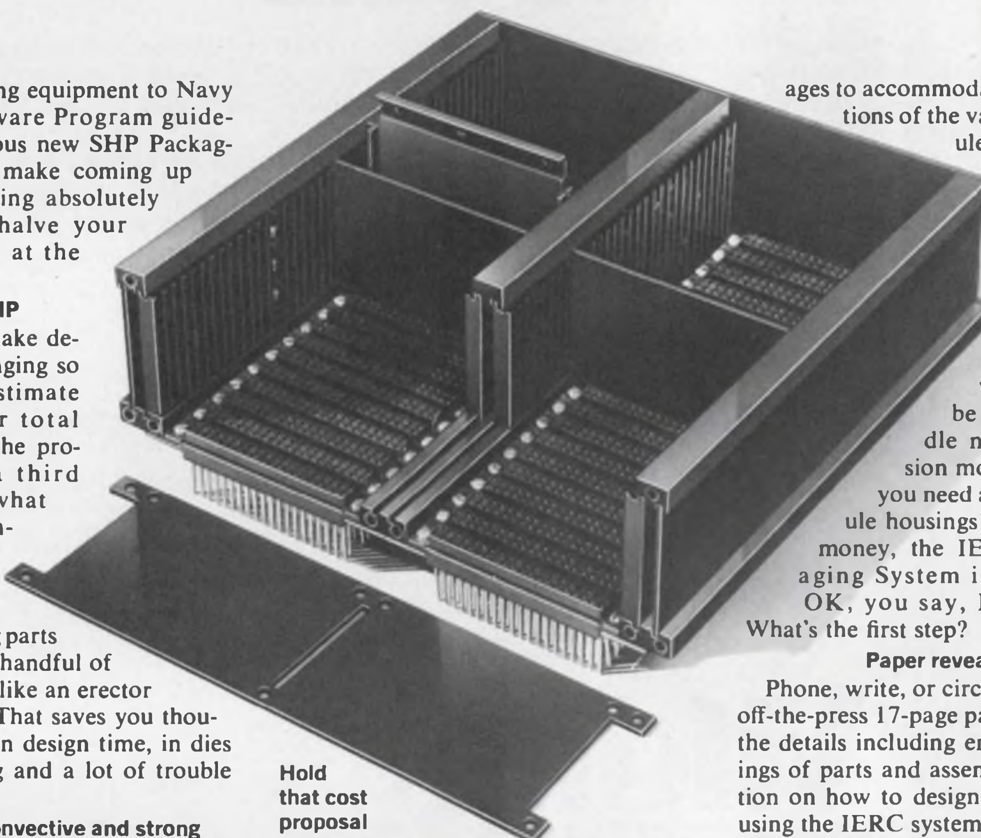
Viking Industries, Inc./21001 Nordhoff St./Chatsworth, Calif. 91311

INFORMATION RETRIEVAL NUMBER 64

Navy Standard Hardware Program packaging made easy and profitable



If you're supplying equipment to Navy Standard Hardware Program guidelines, our ingenious new SHP Packaging System will make coming up with the packaging absolutely simplistic and halve your packaging costs at the same time.

No sweat SHP

First off, we make designing the packaging so effortless we estimate you'll cut your total design load for the procurement by a third because that's what our first customers are experiencing.

Production consists of putting parts together — just a handful of different kinds — like an erector set. Only easier. That saves you thousands of dollars in design time, in dies and other tooling and a lot of trouble to boot.

Conductive, convective and strong

And when you get finished you'll have packaging for your circuitry with the high order of thermal efficiency you'd expect from industry's leading manufacturer of circuit heat dissipating devices. Plus mechanical integrity that's ready for the most demanding environments.

Packaging that cannot be individually produced for twice the price.

Hold that cost proposal

That's a pencil-sharpening fact you can ill afford to ignore if you're in the middle of preparing a proposal in response to an RFP that calls out SHP — or if you ever expect to bid an SHP program.

Here's how our new SHP Packaging System works:

We've designed six basic parts — plus a few specials for unusual configurations — with which you can build circuit module housings conforming to Navy Avionics Facility, Indianapolis, guidelines and dimensions for any of the common SHP-defined circuit modules using nothing but a screwdriver.

Ad infinitum

You can build these packages to accommodate any combinations of the various SHP modules, and the potential dimensions of the packaging in span and depth are for practical purposes limitless.

In fact, our system is so versatile it can be adjusted to handle non-SHP-dimension modules as well. If you need any kind of module housings and like to save money, the IERC SHP Packaging System is for you, too.

OK, you say, I'm interested. What's the first step?

Paper reveals all

Phone, write, or circle to get our hot-off-the-press 17-page paper that gives all the details including engineering drawings of parts and assemblies and a section on how to design SHP packaging using the IERC system.

If you're involved in SHP or ever expect to be, get involved with the IERC SHP Packaging System today.

Ask about our SHP module plates including our revolutionary Metal Core Circuit Board plates for extremely high power densities, too. International Electronic Research Corporation, a subsidiary of Dynamics Corporation of America, 135 West Magnolia Blvd., Burbank, Calif. 91502. (213) 849-2481.

IERC DCA

Heat Sinks/Dissipators

INFORMATION RETRIEVAL NUMBER 65

new products

Build your own curve tracer

Heath Co., Benton Harbor, Mich. 49022. $89.95 (kit); stock.

Used with an oscilloscope, the IT-1121 semiconductor curve tracer accurately displays operating parameters of virtually all types of semiconductors, such as bipolar transistors, diodes, SCRs, triacs, FETs, etc. Extra leads are provided for tests of larger devices or for in-circuit tests. All major controls are stepped in a 1, 2, 5 sequence for maximum parameter resolution.

CIRCLE NO. 250

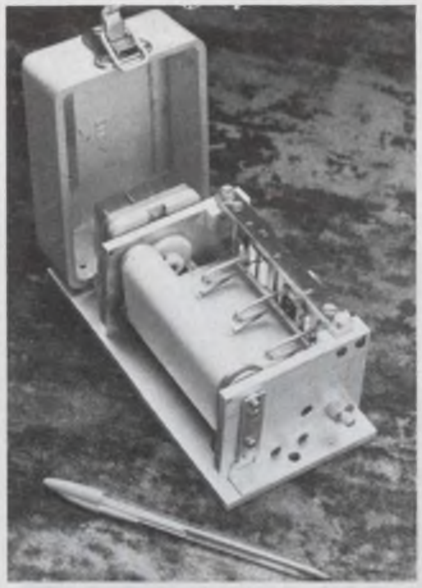
DPM changes range and function with plug-ins

Newport Laboratories, 630 E. Young St., Santa Ana, Calif. 92705. (714) 540-4919. $145; 4 wks.

Model 257 line-powered, 3-1/2-digit panel meter offers selection of full-scale range and function (dc volts or dc current) by substitution of a plug-in 16-pin DIP range-change module. Full-scale ranges from 19.99 mV (10 μV per count resolution) to 199.9 V, and from 1.999 μA to 1.999 A. Input impedance on the lower ranges is 1 GΩ and input bias current is as low as 0.1 nA.

CIRCLE NO. 251

Chart recorder runs six months by itself



Impact-O-Graph Corp., 181 Northfield Rd., Bedford, Ohio 44146. (216) 439-6116. $580; stock.

Model M chart recorder gives up to six months of recording without attention. Chart speeds available are 1/8, 1/4, 1/2, and 1 in./h. The 1/8 in./h rate provides six months of recording on a 45-ft roll of 4-in-wide pressure-sensitive paper. The unit is driven by a battery-powered electronic clock. The battery is rated for more than one year's operation before replacement.

CIRCLE NO. 252

3-in. scope boasts bag of service tricks

RCA Electronic Instruments, 415 S. Fifth St., Harrison, N.J. 07029. (201) 485-3900. $229 (optional price).

This 3-in. portable service scope, the WO-33B, also includes a built-in Quicktracer transistor-diode tester circuit complete with special probe (similar to the RCA WC-528B); a vectorscope function for color TV; and a "ringing" test function to check flyback transformers, yokes, coils and other inductances. Scope specs include a bw of 5 MHz and a max. sensitivity of 10 nV pk-pk/in.

CIRCLE NO. 253

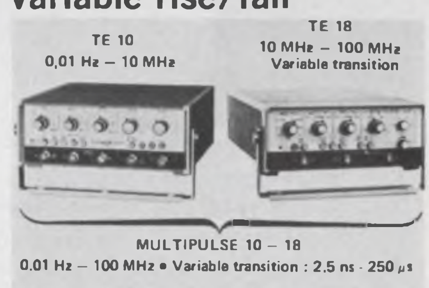
Test instrument wears many hats

UFAD Corp., 700 36th St. S.E., Grand Rapids, Mich. 49508. (616) 241-6000. $2275; 45 days.

Model 850, the "LAB-ALL," is a multifunction test/measurement instrument. Used with a multimeter, the "LAB-ALL" becomes a bandpass or band reject tracking filter, tunable notch filter, distortion analyzer, wave analyzer, and phase-sensitive voltmeter. With a scope the 850 becomes a servo analyzer, network analyzer and phase angle voltmeter. With a scope and function generator, the unit becomes a nonreal-time spectrum analyzer. The 850 measures phase, frequency, and amplitude of all signals having harmonic components between 30 Hz and 100 kHz. Accuracies range from ±0.25% to ±2%, depending upon function.

CIRCLE NO. 254

100-MHz pulser offers variable rise/fall



Tekelec-Airtronic, Cite des Bruyeres, Rue Carle Vernet, B.P.°2, N°376. France. (1) 626-02-35.

TE 18 pulse generator covers 10 to 100 MHz and features adjustable rise and fall times. Other specs include variable pulse width and delay of 5 to 50 ns, variable amplitude of 200 mV to 5 V into a 50-Ω load, variable rise and fall time of 2.5 ns to 250 μs.

CIRCLE NO. 255

High-power pulse gen sells for $1190

Velonex, 560 Robert Ave., Santa Clara, Calif. 95050. (408) 244-7370. $1190; stock to 30 days.

The Model 340 high-power pulse generator provides 5-kW peak power at 1% duty factor with pulse output of 1000 V at 5 A. The unit's fully recessed plug-in feature allows impedance matching between the pulse generator and load for any impedance between 0.1 and 20,000 Ω. Standard plug-in units also allow voltage isolation, polarity inversion and varying rise and fall time. Pulse widths range from 100 ns to 1 ms and rep rates from 1 shot to 100,000 pps. Amplitude is continuously adjustable from less than 100 to 1000 V.

CIRCLE NO. 256

Compact function gen works on batteries

Wavetek, 9045 Balboa Ave., San Diego, Calif. 92123. (714) 279-2200. $149.95; stock.

The Model 30 function generator features 2-Hz to 200-kHz simultaneous sine, square and triangle waveforms with internal linear or logarithmic sweep. External capacitors can be added for unlimited frequency down ranging. Sweep mode and voltage-control mode give a frequency change of 1000:1. Full voltage control requires only 0 to 1 V, either dc for programming discrete frequencies or ac for FM operation. This hand-sized battery-operated generator weighs less than 1-1/2 lb.

CIRCLE NO. 257

DMM samples, holds and controls remotely

California Instruments, 5150 Convoy St., San Diego, Calif. 92111. (714) 279-8620. $1740; 30 days.

Model 6653A is a four-digit, 10%-overrange multimeter designed to perform in data-acquisition systems. The unit offers such standard or optional capabilities as successive-approximation logic, three filter modes to provide optimum speed vs rejection and true-rms conversion. Functions include six ranges of dc V from 0.001 mV to 100 V, three ranges of dc/dc ratios from 0.0001:1 to 110:1, four ranges of true-rms ac V (50 Hz to 100 kHz) from 0.0001 to 1100 V and five ranges of resistance. Long-term accuracy is to ±0.01% of fs ±0.01% of reading.

CIRCLE NO. 258

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INFORMATION RETRIEVAL NUMBER 67

3-terminal regulators supply 100 mA

Fairchild Semiconductor, 464 Ellis St., Mountain View, Calif. 94042. (415) 962-3816. 50¢ to $1.05 (100-999); stock.

Three-terminal voltage regulators, the 78L series, provide up to 100 mA of output current. The 78L circuits are fixed positive voltage units that eliminate the need for external transistors and resistors and reduce circuit-board space. Available output voltages range from 2.6 to 15 V with tolerances of 5% and 10%. The series comes in TO-92 plastic and TO-39 metal-can packages.

CIRCLE NO. 259

Access improves in upgraded 1103s

Nortec Electronics Corp., 3697 Tahoe Way, Santa Clara, Calif. 95051. (408) 732-2204.

Three versions of the standard 1103, a fully decoded dynamic 1024 × 1-bit RAM—the NEC 1103, 1103-146 and 1103-1—come in either plastic or ceramic 18-pin DIPs. A fast 300-ns access time is a feature of the NEC 1103, with the 1103-146 accessible in 220 ns. The NEC 1103-1 has a 150-ns access time. Read cycle on the NEC 1103 RAM is 480 ns and write cycle is 580 ns. The new memories have a 2-ms refresh cycle and dissipate only 250 mW, primarily during precharge.

CIRCLE NO. 260

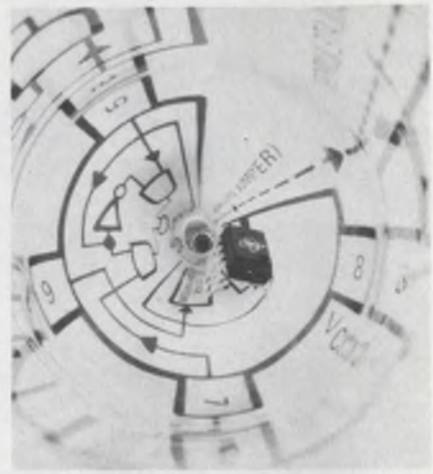
256 bit RAMs offer 30-ns access

Signetics, 711 E. Arques Ave., Sunnyvale, Calif. 94086. (408) 739-7700. $28 up (100); 4 wks.

Two 256-bit RAMs — the 82S16 with three-state outputs and the 82S17 with open-collector outputs —feature an access time of less than 30 ns. Write time for both models is 20 ns. Each RAM dissipates typically 1.5 mW per bit. Input loadings are 25 μA for a logic ONE and −100 μA for a logic ZERO. The memories operate from a single 5-V supply.

INQUIRE DIRECT

1024-bit static SR consumes 0.2 μW/bit

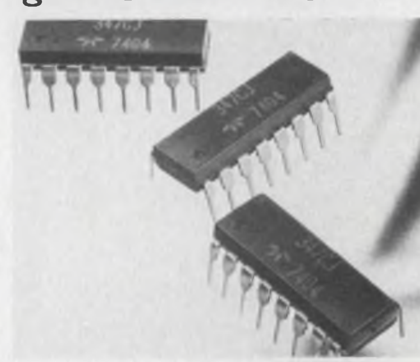


Texas Instruments, P.O. Box 5012, MS 308, Dallas, Tex. 75222. (214) 238-3741. $7.25 (100); stock.

A 1024-bit static shift register, the TMS3133, comes with two data inputs and a "stream select" control to simplify recirculation. It features a low dissipation of 0.2 μW per bit, TTL-compatible inputs and outputs, single TTL-compatible clock, dc-to-2-MHz operation and standard power supplies of 5 and −12 V. Push-pull output buffers can drive directly TTL and MOS loads.

CIRCLE NO. 261

Dual one-shot ignores transients



Teledyne Semiconductor, 1300 Terra Bella Dr., Mountain View, Calif. 94043. (415) 968-9241. $1.96 (100).

The HiNIL 347 dual retriggerable monostable multivibrator has a guaranteed minimum noise immunity of 3.5 V. It is offered in both 12 and 15-V versions. Each half of the 347 may be triggered or retriggered independently. Minimum input pulse separation is 300 ns. Output pulse times are set by external RC values.

CIRCLE NO. 262

All those little wires have been pushed around long enough.

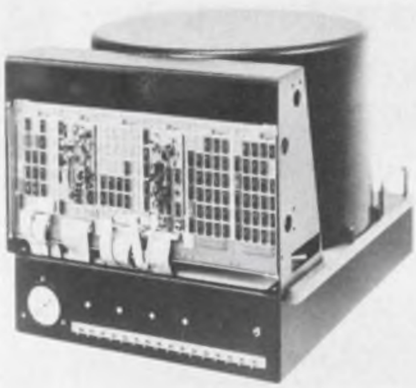
Paper tape reader has 300-char/s steady speed

Tally Corp., 8301 S. 180th St., Kent, Wash. 98031. (206) 251-5500. $546; 30 days.

A medium speed tape reader, the Model R2000, reads bidirectionally to 300 char/s and up to 200 char/s asynchronously. The unit reads tapes with up to 60% transmissivity and the tapes can have five, seven, or eight levels. Average error rate is 10^{-7}. A standard light bulb is used with this photoelectric reader and the electronics are DTL and TTL compatible.

CIRCLE NO. 263

Fixed-head disc drives offer 153 Mbit capacity



Digital Development Corp., 5575 Kearny Villa Rd., San Diego, Calif. 92123. (714) 278-9920. See text.

The A7310 and 9110 series head-per-track disc memories offer storage capacities from 6.7 to 153 Mbits. Average access times range from 8.5 to 17 ms. Each model includes the necessary circuitry to write, read, select tracks and generate timing signals. The modular system uses read/write heads in groups of 64 that service up to 1024 tracks. The design life of these systems is said to be 10 years minimum. The cost—about 0.25 cents a bit.

CIRCLE NO. 264

CRT displays printed for less than two cents

Alden Electronic & Impulse Recording Equipment Co., Alden Research Center, Westboro, Mass. 01581. (617) 366-8851. From $795.

A 400 or 600 "Push to Print" Recorder interfaced to a scan converter gives frame-by-frame hardcopy. The converter (not included in the price) converts standard 525 TV line frames into slow TV frames suitable for transmission over voice grade telephone lines and/or direct to graphic printout on the recorder. Higher resolutions are available with different scan converters. There are two systems available. One provides a resolution of 1300 TV lines per diameter equivalent to 80 characters a line. The other system provides 750 TV lines per diameter or 50 characters a line. Either system works with CRT displays. Single copies cost less than two cents.

CIRCLE NO. 265

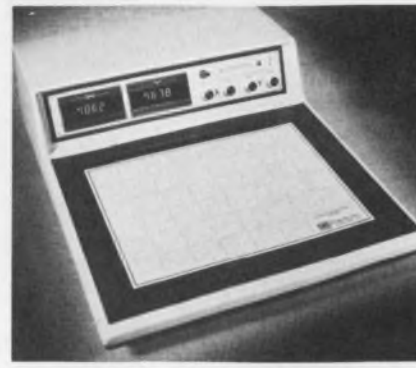
Compact serial printer operates at 110 char/s

Okidata Corp., 111 Gaither Dr., Moorestown, N.J. 08057. (609) 235-2600. $900; 60 days.

The Model 110 is a serial desktop printer that produces 80 columns of 5 × 7 dot-matrix characters at 110 char/s. The print head moves in both directions and pauses only at the end of each line. An 80-character buffer holds the print line. The 64-character ASCII set is standard, others can be furnished as an option.

CIRCLE NO. 266

Graphic digitizer has low error



Elographics, P.O. Box 388, Oak Ridge, Tenn. 37830. (615) 482-4039.

Model E241 is a graphics digitizer that generates X,Y coordinates with pressure from a ball-point pen or similar stylus. The work area is 15-by-11 in. and the standard error is better than 0.02-in. Coordinates require 125 ms for digitization. Dual 3-1/2-digit displays show the X and Y coordinates. Interfaces are available for programmable calculators or data terminals.

CIRCLE NO. 267

Plug-in CPU designed for process control

Process Computer Systems, 5467 Hill 23 Dr., Flint, Mich. 48507. (313) 744-0225. From $2950; 90 days.

The CM4400 CPU module includes six 8-bit registers, 8-bit accumulator, 8-bit parallel arithmetic unit, 16-bit program counter, 16-bit stack pointer, and a 2-MHz clock. The I/O concept used permits arithmetic/logic operations directly with the I/O devices, and allows the use of re-entrant software. Four different associated CM4500 memory modules may be used in any combination for up to 64 k bytes of read-only and random access-memory. A wide array of standard modules provides all the facilities needed for process control requirements.

CIRCLE NO. 268

Tape cartridge unit meets MIL specs

E S L Inc., 495 Java Dr., Sunnyvale, Calif. 94086. (408) 734-2244.

The Model P830R is a ruggedized magnetic tape cartridge unit designed for use in military and other applications that require reliable operation under adverse environmental conditions. The P830R uses the 3M DC300A data cartridge as the storage media. It is capable of writing or reading digital data at a rate of 160-k bit/s when all four tracks are used simultaneously; these tracks are electronically deskewed for simultaneous read operations. Each of the four tracks can also be used independently in accordance with ANSI specification X3B1. Recording density is 1600 bit/in. on each track, and the cartridge capacity is greater than 20×10^6 bits. The tape speed for read or write is 25 in/s; the search and rewind speed is 90 in/s. All cartridge loading and unloading operations are sequenced automatically. Mechanical and environmental specifications for the P830R meet applicable requirements included in MIL-STD-167B, MIL-STD-810B, and MIL-E-5400.

CIRCLE NO. 269

Weight printed by electronic printers

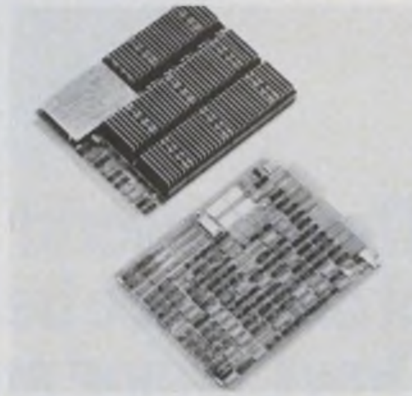
Streeter Amet Div., Dept. M3, Mangood Corp., Slusser and Wicks St., Grayslake, Ill. 60030. (312) 223-4801.

Two precision, high-speed printers for electronic weighing systems, Model 301 and 302, are designed to accept and print weight information. They can be installed either as permanent rack-mounted units or as portable instruments. The two printers have modular plug-in circuit boards for ease of servicing. They print on paper tape, pressure-sensitive tape or multicopy tickets, as required. Model 301, the more versatile of the two, provides a positive sprocket paper advance; is designed for longer operating life between servicings. Model 302 is a more economical unit for use in weighing applications that require only tape output.

CIRCLE NO. 270

DATA PROCESSING

16-bit microprocessor debuts on PC board



General Automation, 1055 S. East St., Anaheim, Calif. 92805. (714) 778-4800. Under $1000 (200 quan.).

For a cost of $1000 a board you can now have a 16-bit mini-on-a-card, the LSI-16. In fact a 7.75-by-11 in. board holds CPU and 32 k words of 1.8 μs MOS memory. The LSI-16 replaces the SPC-16 mini and uses a two-chip silicon-on-sapphire technology to build the CPU. One chip, the arithmetic logic unit contains the equivalent of 8000 transistors in a chip 0.2-in. square. The other chip is the control memory. In addition, the company offers a 32-k word MOS memory on the same size board.

CIRCLE NO. 271

Low-cost computer terminal has own coupler

MITS, 6328 Linn, P.O. Box 8636, Albuquerque, N.M. 87108. (505) 265-7553. $595; 60-90 days.

Priced below most computer terminals, the Comter 256 can store 256 characters and display a 32 character line. A Burroughs Self-Scan display is used. A built-in acoustic coupler makes computer hookup very simple. And the operator can transmit material line-by-line instead of character-by-character. ASCII coding is used with 110/300 baud transmit/receive rate. Terminal storage is expandable to 1024 characters.

CIRCLE NO. 272

Extra processor used in graphics terminal

Digital Equipment Corp., 146 Main St., Maynard, Mass. 01754. (617) 897-5111. $17,500.

The GT42 graphics terminal can be used as a stand-alone graphics system or as a terminal that interacts a variety of host computers. The terminal is configured around the PDP-11/10 mini and features a hardwired display processor that drives a 17-in. CRT. The display processor performs the most used graphical techniques and minimizes CPU overhead. The terminal's 10-bit resolution (1024 × 1024 addressing) in X and Y is precise enough to allow overprinting. Standard equipment includes a light pen, ASCII keyboard and character set with 31 special mathematical and scientific symbols, and a serial communications interface.

CIRCLE NO. 273

Disc controller handles 400-Mbyte system

Data Systems Design, 1122 University Ave., Berkeley, Calif. 94702. (415) 849-1102. See text.

Both PDP-8 and PDP-11 minicomputers can be equipped with 400 Mbytes of disc storage with the Model 240. The controller plugs directly into the PDP-8 bus or mounts inside a PDP-11. Up to 8 discs can be accessed and the unit is compatible with either machine's operating system. The controller has a 16-word buffer and can read or write any format and preamble under program control. The price of a memory system is $2500 for the controller plus the cost of the disc drive used.

CIRCLE NO. 274

Hughes heat pipes. Order 'em hot off the shelf.

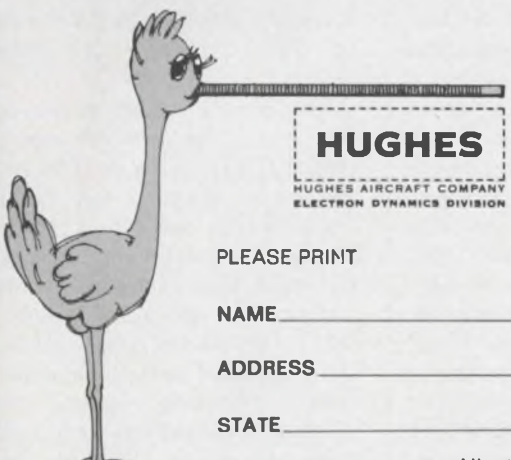
Now you can order heat pipes just like you order nuts and bolts. Because now Hughes stocks heat pipes in a variety of standard, off-the-shelf sizes and thermal capacities. (If you have a heat transfer problem that calls for a custom solution, we solve those, too.)

1333H STAINLESS STEEL AND AMMONIA
Thermal transport capacity: 50 watts with evaporator 90° below condenser, 15 watts horizontal operation, 7 watts with evaporator 90° above condenser. Recommended operating range: −80° to +90°C. Weight: 8 grams. Active Length: 5.69 inches. Diameter: 3/16". $37.00.

1370H COPPER AND WATER
Available in diameters of ¼", ½", and 1" at $37.00, $40.00 and $50.00, respectively, with thermal transport capacities of 345, 750, and 6000 watts with the evaporator 90° below condenser; 115, 250 and 2000 watts horizontal operation; 38, 60, and 500 watts with evaporator 90° above condenser. Recommended operating range: +50° to +150°C. Weight: 21, 70, 550 grams. Standard Active Length: 6, 6, 12 inches.

1350H STAINLESS STEEL AND METHANOL
Available in diameters of 3/16" and ¼" at $37.00 each and ½" at $40.00. Thermal transport capacities are 55, 75, and 180 watts with evaporator 90° below condenser, 17, 25, and 60 watts horizontal operation, and 6, 10, and 20 watts with evaporator 90° above condenser. Recommended operating range: −40° to +120°C. Weight: 8, 11, and 38 grams. Standard Active Length: 6 inches.

1361H FLEXIBLE STAINLESS STEEL AND METHANOL
Available in active lengths of 7" and 8" at $75.00 each, with thermal transport capacities of 20 watts with the evaporator 90° below condenser, 7.5 watts horizontal operation, 2.5 watts with evaporator 90° above condenser. Recommended operating range: −40° to +120°C. Weight: 20 grams. Diameter: ¼".



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For detailed information, or if you have a hot requirement and want one now, just fill out and send in the coupon. Hughes Electron Dynamics Division, 3100 W. Lomita Blvd., Mail Station 2124, Torrance, California. (213) 534-2121.

PLEASE PRINT ☐ **SEND INFORMATION.** ☐ **SEND QUICK ORDER FORM.**

NAME__________ **COMPANY**__________

ADDRESS__________ **CITY**__________

STATE__________ **ZIP**__________ **TELEPHONE**__________

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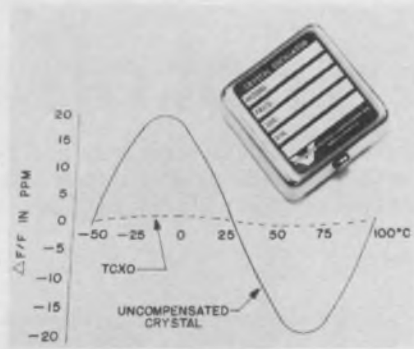
ED-7

INFORMATION RETRIEVAL NUMBER 77

TCXOs have stabilities of ±2 × 10⁻⁷



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

The CO-254 series of vhf temperature compensated crystal oscillators achieves a stability of $\pm 2 \times 10^{-7}$. The unit meets this stability over the 0-to-50-C temperature range, and $\pm 2 \times 10^{-6}$ over −55 to +85 C. They are available at frequencies up to 140 MHz. Long term stability (aging) is better than 1×10^{-8} per day and 2×10^{-6} per year. The TCXOs use a built-in oven that has a low (20 mA) power drain. The CO-254 series units operate from any desired supply voltage in the 5-to-32-V-dc range and provide sine or Schottky TTL compatible outputs. Low frequency models are available with CMOS compatible output with frequencies as low as 60 Hz.

CIRCLE NO. 275

FET-input op amp gives ±45 V output swings

Optical Electronics, P.O. Box 11140, Tucson, Ariz. 85734. (602) 624-8358. $62 (10 to 29); stock.

The Model 9736 high-voltage FET input op amp is completely protected against input overvoltage drive and output short-circuit conditions. The 9736 is packaged in a 1.125-in.-square-by-0.44-in. high module. Some of its specs include 90 dB open loop gain, 110 dB minimum common-mode rejection, ±40 V common-mode voltage, ±45 V at ±10 mA minimum output voltage swing, ±30 V/μs minimum slew rate, 10 MHz minimum gain-bandwidth product, ±20 μV/°C maximum input offset-voltage drift and 50 pA maximum bias current.

CIRCLE NO. 276

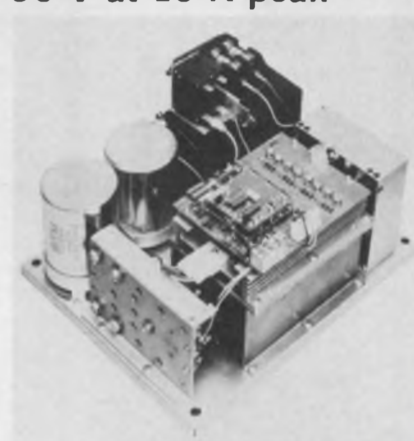
D/s converter modules are accurate to ±4 min.

Computer Conversions, 6 Dunton Ct., East Northport, N.Y. 11731. (516) 261-3300. Under $400; 4 to 6 wk.

A series of 14-bit digital-to-synchro converter modules provide ±4 minute accuracies when driving CTs, CXs or CDXs. The 2.6 × 3.1 × 0.82 in. units accept a 14-bit natural binary angle and convert it into three-wire synchro or four-wire resolver signals. The output is short-circuit protected and loading of 1 or 2 VA is available. Standard output voltages are 90 or 11.8 V rms L-L, 60 or 400 Hz. Digital inputs are TTL/DTL compatible and the synchro output and reference is fully transformer isolated. Part No. DSC40-L requires a 26 V reference and +15 at 135 mA, −15 V at 100 mA and +5 V at 85 mA. Operating temperature ranges are 0 to 70 or −55 to 85 C.

CIRCLE NO. 277

Servo amplifier delivers 90 V at 15 A peak



Westamp, 1542 15 St., Santa Monica, Calif. 90404. (213) 393-0401. $750.

The Model A6286 servo amplifier is a pulse-width-modulated unit that can drive dc motors with ratings of up to 1 hp. The maximum output voltage is 90 V and the peak output current is 15 A. The unit contains a power transformer for operation from 115/230 V, 50/60 Hz lines. Other features include: servo compensation, current limiting, output circuit breaker, and ability to handle regenerative loads. The unit is compact, only 10.5 × 13 in.

CIRCLE NO. 278

NEW Simpson 360 Digital VOM

Handy and rugged enough for the field — accurate and versatile enough for the lab. And its simplicity and readability make it perfect for production line testing.

- 3-1/2" digit, non-blinking, auto-polarity 0.33" LED display
- AC line or battery operation
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- Analog indicator for scanning nulls and peaks
- Analog output signal permits interfacing with recorders and other instruments
- Up-down integration analog/digital conversion assures superior stability, accuracy and noise immunity

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INFORMATION RETRIEVAL NUMBER 73

LED photoelectric control is coaxial

Scientific Technology, 1157 San Antonio Rd., Mountain View, Calif. 94040. (415) 965-0910. $137.65.

The 2010-series of LED coaxial photoelectric controls uses a patented optic system. Range of the 2010-series is up to 35 ft. (11 m) using a single 3 in. diameter (8 cm) reflective target. Increasing target size increases range. The 2010-series is completely self-contained in a cast aluminum Nema housing, 5.3 × 7.5 × 2.5 in. (13.4 × 19 × 16.4 cm). Standard input for the 2010-series is 115 V ac, and power consumption is less than 5 W.

CIRCLE NO. 279

Solid-state time delays handle currents to 0.8 A

Polytron, P.O. Box 984, Elkhart, Ind. 46514. (219) 294-3748. $2.95 (100-up).

The PCT-31 series of time delay modules are rated at 0.8 A. Voltage ratings are 12, 24 and 120 V dc. The time delay can be factory set from 0.1 to 15 s. Units have two terminals connected in series with the load. Modules with higher current and other voltage ratings are also available.

CIRCLE NO. 280

DAC handles either TTL or CMOS logic levels

Analog Devices, Rte. 1 Industrial Pk., P.O. Box 280, Norwood, Mass. 02062. (617) 329-4700. $84 (1 to 9); stock.

The DAC1009 12-bit d/a converter has positive true logic inputs. It is 2 × 2 × 0.4 in. and it can interface with both TTL/DTL and CMOS logic systems and provide either current or voltage outputs. The DAC1009 can do two-quadrant multiplication when its reference input is supplied by a unipolar analog signal source. When used as a multiplier, the DAC1009 has a small signal bandwidth of 950 kHz. With appropriate external circuitry, the feedthrough is less than 1 LSB at 50 kHz. The unit settles to 0.01% in 4 μs and has a gain temperature coefficient of 11 ppm/°C. Its differential linearity error of 4 ppm/°C provides monotonicity over a 0-to-50-C temperature range.

CIRCLE NO. 281

Four-quadrant drives span 5 through 150 hp

Cleveland Machine Controls, 7550 Hub Parkway, Cleveland, Ohio 44125. (216) 524-8800.

The Series 400 is a four-quadrant regenerative drive for use on three-phase, 50/60 Hz, 230 or 460 V lines. It will be made available from 5 through 150 hp, overlapping the horsepower range of the company's already established Series 300 adjustable-speed drives which are available from 40 through 500 hp. A variety of options required for machine tool applications are available. Some of the standard features include N/C input, overspeed and tach-loss protection, zero speed sensing, tool change and percentage set speed permission. Additionally, standards will also include adjustable current limit, armature voltage only or voltage and field control and test meter.

CIRCLE NO. 282

85 amp DO-5

The ratings are back and even we're a little amazed at the fantastic results. We knew our upgraded DO-5 was a honey, but an 85 amp rating is (to say the least) a major breakthrough in power semiconductors.

Here's how it tested:

- Dimensions as per JEDEC DO-5 outline.
- Maximum Recurrent Peak Reverse Voltage . . 100-1600 volts.
- Maximum Average Forward Current, Single Phase Half Wave Rating at 115°C. Case Temperature . . . . 85 amps.
- Maximum Surge Current (One Cycle) . . . . . . 1500 amps.
- Θ JC 0.6

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

FMC Special Products

INFORMATION RETRIEVAL NUMBER 75

Electronic speed control works with 3.5 kW loads

Brush Electrical Machines, P.O. Box 18, Loughborough, Leics, LE11 1EZ, England. Stock.

The type 10A variable speed motor controllers are suitable for any application requiring a variable speed drive. They can handle a power requirement of up to 3.5 kW (approx. 5 hp). The 10A has a closed (double) loop control circuit which uses an error actuated speed servo. A separate current servo, connected in parallel with the speed loop, provides overload and stalling protection. The units are available either as plate-mounted assemblies for fitting within customers own equipment or as self-contained units encased in styled steel enclosures. There are four output ratings of 9, 12, 18 and 28 A available, which are capable of controlling motors rated for 1.12, 1.5, 2.25 and 3.5 kW, respectively.

CIRCLE NO. 283

Control tachometer has up to four set points

Airpax, 6801 W. Sunrise Blvd., Fort Lauderdale, Fla. 33313. (305) 587-1100. From $180.

The Series 300 control tachometer has up to four switch points to control industrial processes. It will accept signals from any type sensor. The set points are adjustable from 0 to 100% of full-scale range. Other set point options are available for special application requirements. The input frequency ranges from dc to 20 Hz and the input sensitivity is 50 mV rms. Over-all accuracy is ±0.5% and the industrial output variations are 1 to 5, 4 to 20 or 10 to 50 mA or 0 to 10 V dc. Power requirements are 120 V ac or 24 V dc.

CIRCLE NO. 284

Proportional controller uses zero angle firing

Barber Colman, Rockford, Ill. 61101. (815) 877-0241.

Both single-phase (Series CB41) and three-phase (Series CB43) zero crossover proportioning power controllers handle loads from 15 to 75 A. The CB41 series spans a voltage range from 120 to 480 V ac while the CB43 spans 208 to 480 V ac. These units provide stepless power control for resistor heating elements that have a maximum cold to hot resistive change of 1 to 1.15, respectively. The three phase models are insensitive to phase sequence reversals and will handle four-wire Wye connected loads.

CIRCLE NO. 285

Solid-state relays have wide choice of options

Process Automation, G-7402 Fenton Rd., Grand Blanc, Mich. 48439. (313) 738-2340.

The 0666 series ac control modules are solid-state relays that can control ac or dc voltages. Options available include: zero crossing control, phase control, full cycle control, on/off control, control voltage 3 to 240 V (ac/dc), I/O isolation up to 1500 V, NO/NC outputs, output voltages 120/240 V ac or 24/48/150 V dc, load current of up to 140 mA/2 A/8 A and three output filters. Zero-crossing and phase-control options can be combined to allow conduction angle control from zero crossing (full cycle) to less than 10°. Full cycle control forces the relay to stay on or off for N-full cycles. NO or NC outputs allow selection of fail-safe, control power off, conditions.

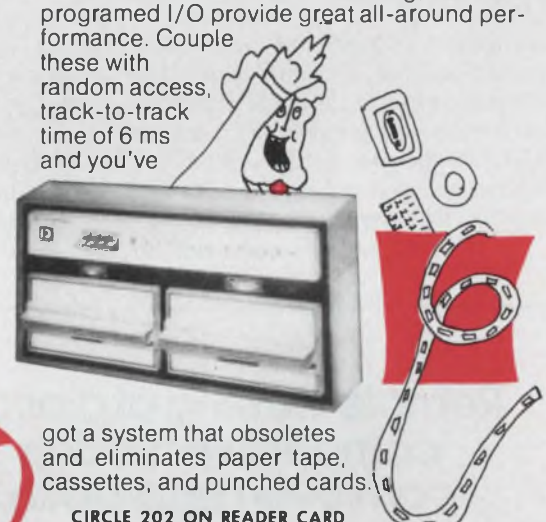
CIRCLE NO. 286

DIVA Mini Maximizer Systems.
The lowest co$t/byte in the industry.

The big ones. Large-capacity disc systems: 29, 58, 100, 116 Mbytes/spindle, up to 8-spindles/controller. Mini or IBM format. Systems are complete with controller interfaced to specified CPU, all interconnecting cables, diagnostic software, formatter program, and technical manuals. Optional I/O handlers are available for most mini software systems.

CIRCLE 201 ON READER CARD

The eliminator. Floppy disc: 3.1 Mbits/drive unformatted, up to 4 drives controller, IBM compatible. Big disc drive features like initial program load, overlapped seek (option), logical unit select switches, disc sectoring, DMA or programed I/O provide great all-around performance. Couple these with random access, track-to-track time of 6 ms and you've got a system that obsoletes and eliminates paper tape, cassettes, and punched cards.



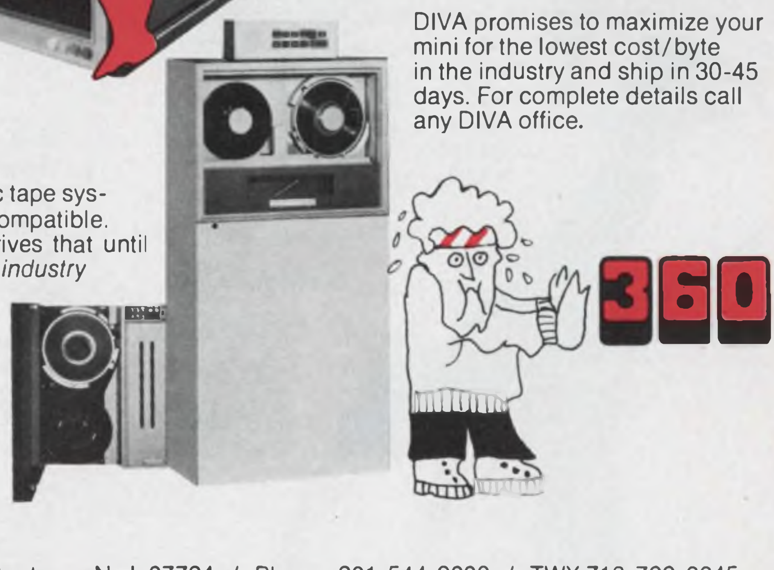
CIRCLE 202 ON READER CARD

Our little devil. Cartridge disc: 1,288,000 words/drive. Ideal for small-to-medium-size systems. An inexpensive replacement for DEC's RK 11/RD 02 and RK 05 cartridge disc drives. Software compatibility is provided through optional I/O handlers for most DEC, Interdata, Data General, and DCC software systems. Controller operates up to 4 drives.

CIRCLE 203 ON READER CARD

DIVA promises to maximize your mini for the lowest cost/byte in the industry and ship in 30-45 days. For complete details call any DIVA office.

Move over, maxi. DMT-1000 and DMT-1001 magnetic tape systems: 125 or 200 ips; 800 or 1600 bpi; 9 track; IBM compatible. DIVA controllers interface minis to these big tape drives that until now were usable only with big computers. Use any *industry compatible* ½-inch tape reels — from minis to 10.5-inch reels, as well as IBM wrap-around tape cartridges. 320 Kbytes/sec transfer, 500-ips rewind, 7-sec automatic load, photoelectric sensing, vacuum column guidance, air bearings, single capstan drive, and software compatibility are a few main features.

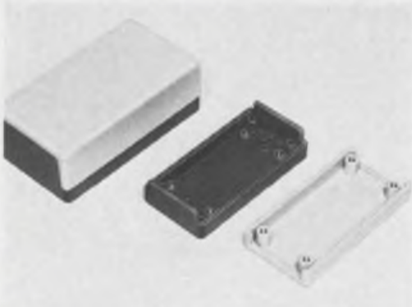


CIRCLE 204 ON READER CARD

Mini maximizer systems

DIVA, Inc. 607 Industrial Way West / Eatontown, N. J. 07724 / Phone: 201-544-9000 / TWX 710-722-6645
REGIONAL SALES OFFICES: California: 213-889-4180 / Massachusetts: 617-275-1436 / Texas: 713-626-1390 / Washington D.C.: 703-370-5211

Plastic box interlocks, houses electronic devices

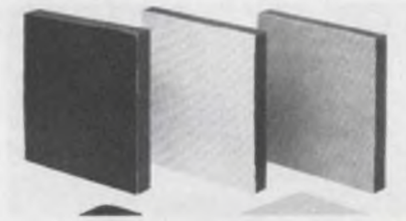


Vero Electronics, Inc., 171 Bridge Rd., Hauppauge, N.Y. 11787. (516) 234-0400. $2.16 to $4.04; stock.

An interlocking two-piece box, with a two-tone plastic body, is suited for either pocket or desk electronic devices. Two sizes are available. There are provisions for switches, sockets and other elements as well as cable inlets. Imbedded into the lower section are screw threads for mounting assembled component groups. The two halves are grooved for close fit and screws lock them together.

CIRCLE NO. 287

Noise-absorption foam easily cut

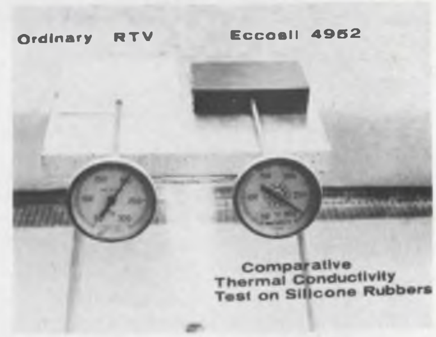


Ferro Corp., 34 Smith St., Norwalk, Conn. 06852. (203) 853-2123.

Ferro Cousti-Headliner noise-absorption material consists of high noise-absorption polyurethane foam bonded to a facing of a tough, perforated, reinforced PVC film with a leather-grain texture. The facing resists oils and greases and is easily washed with any vinyl cleaner recommended for automotive interiors. Standard colors are white, black and beige. The material is available in standard 1/2 and 1 in. thicknesses and can be easily cut with scissors, dies or any textile cutting equipment. It is also available with an optional backing of pressure-sensitive contact adhesive.

CIRCLE NO. 288

Silicone rubber has high thermal K



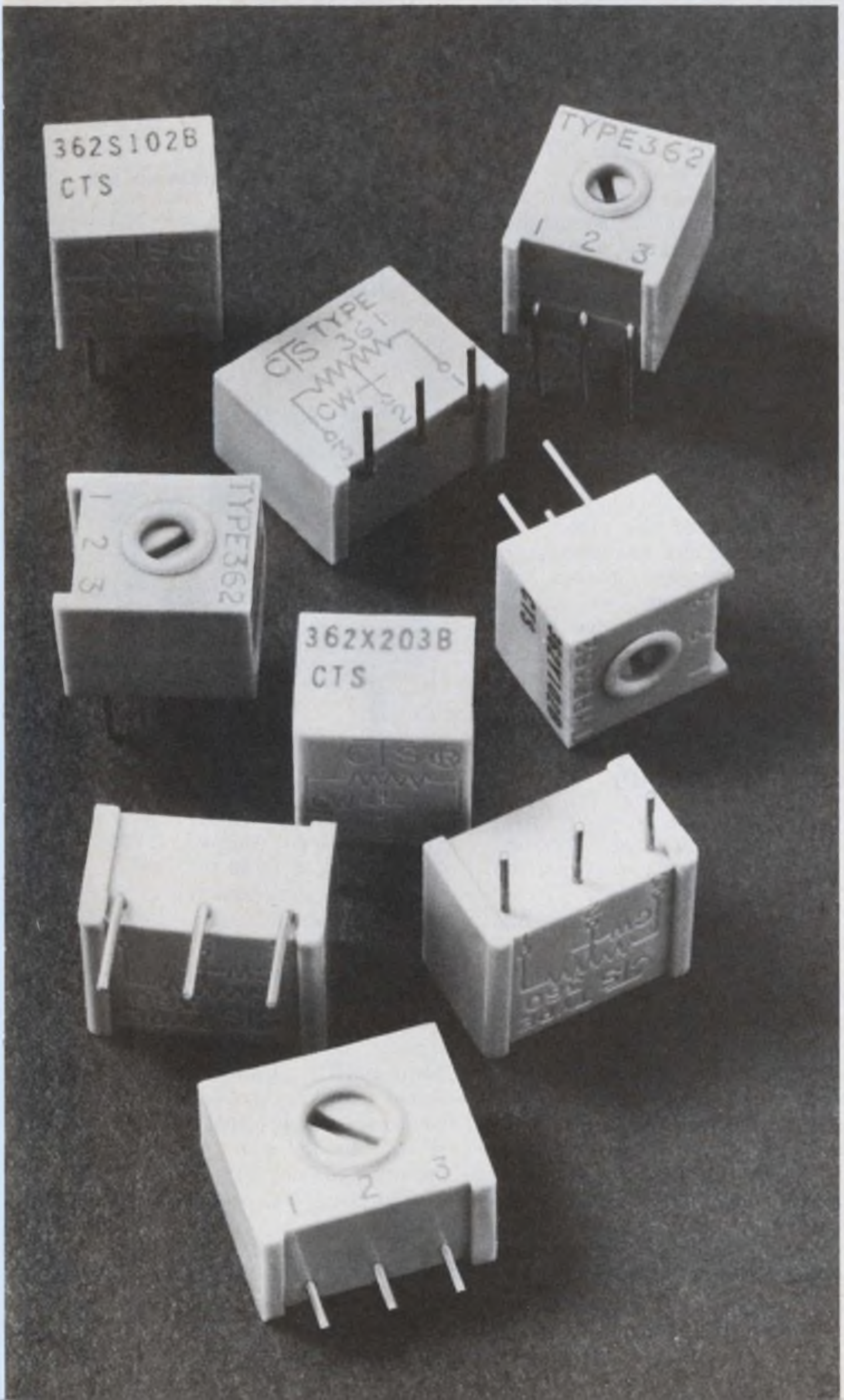
Emerson & Cuming, Inc., Canton, Mass. 02021. (617) 828-3300. $3.45 per lb ($18 lb up); stock.

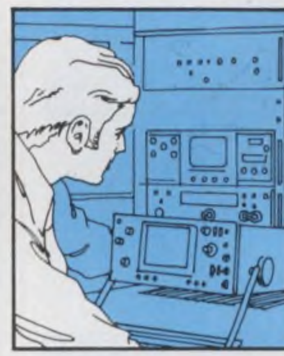
Eccosil 4952 is a silicone rubber formulation with the high thermal conductivity of 7.5 BTU-in/hr-ft^2 °F. This is about four times the thermal conductivity of ordinary RTV silicones. Thus Eccosil 4952 is recommended for encapsulating components that would otherwise tend to overheat. And because of its flexibility, it also provides protection from vibration and shock. The material can be used to temperatures of 500 F.

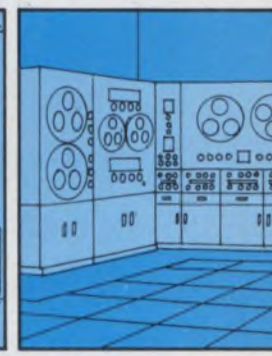
CIRCLE NO. 289

INFORMATION RETRIEVAL NUMBER 80 ▶

From instrumentation to computers, demanding OEMs turn to CTS for the best cermet trimmer values







CTS is the "engineer's choice" for quality cermet trimmers. CTS delivers proven performance, uniformity and reliability . . . at economical prices. The best known calculators and all types of fine tolerance instruments incorporate CTS trimmers. Our industrial 360 Series satisfies a wide range of critical OEM applications.

Nine popular styles give you the pin spacing you need. Choose from top and side adjust .100", .125", .150" and TO-5. Plus top adjust .200" grid, too. Units are flux sealed, and feature a low TC cermet element. Settability: 0.03%.

- 1 watt power @ 25° C., ½ watt @ 85° C
- 1.5% average ENR noise resistance
- 0.5% average CRV

Available off-the-shelf from CTS Industrial Distributors. CTS of Berne, Inc., 406 Parr Road, Berne, Indiana 46711.
Phone: (219) 589-3111.

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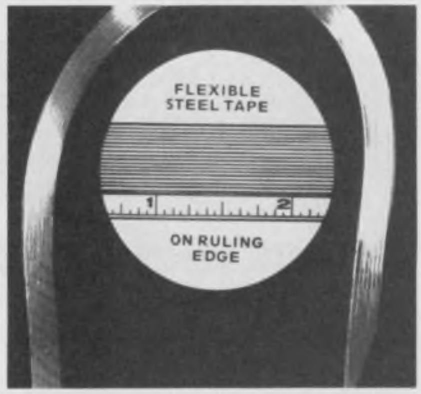
PACKAGING & MATERIALS

Adjustable curve has measuring scale



Hoyle Engineering Co., 302 Orange Grove, Fillmore, Calif. 93015. (805) 524-1211. $10.50: 22 in., $14.90: 32 in.; stock.

A versatile curve-drawing and measuring instrument incorporates a steel measuring tape in a grooved channel on its outside edge. This calibrated curve is made up of 12 interlocking strips. The individual strips are extruded from a clear butyrate plastic. Friction between the strips locks the curve into position after it has been shaped with the fingers. The measuring tape enables the user to accurately determine lengths along the perimeter of the curve. Calibrated curves are available in 22 and 32-in. lengths divided into 1/16-in. increments, or in the metric system, in 55 and 80 cm lengths divided into mm increments.

CIRCLE NO. 290

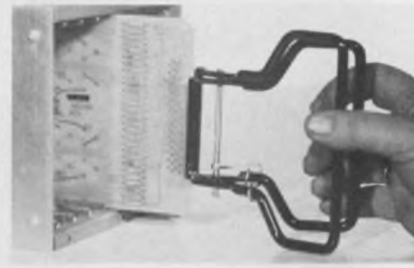
Heat pipe flexes to 1-1/8-in. radius

Hughes Electron Dynamics Div., 3100 W. Lomita Blvd., Torrance, Calif. 90509. (213) 543-2121. $75 (unit qty); stock

Model 1361H stainless steel and methanol heat pipe, for use where there is relative motion between the heat source and the heat sink, is available in 7 and 8-in. lengths. The pipes can be bent to a minimum 1-1/8-in. inside-radius curve. Flexing can occur in all radial directions without wick bunching problems. Thermal transport capacity of the flexible pipe for horizontal operation is 7.5 W max and thermal resistance is 1.6 C/W. Weight is 18 g for the 7-in. model and 20 g for the 8-in.

CIRCLE NO. 291

Card puller needs only 1/8-in. grip

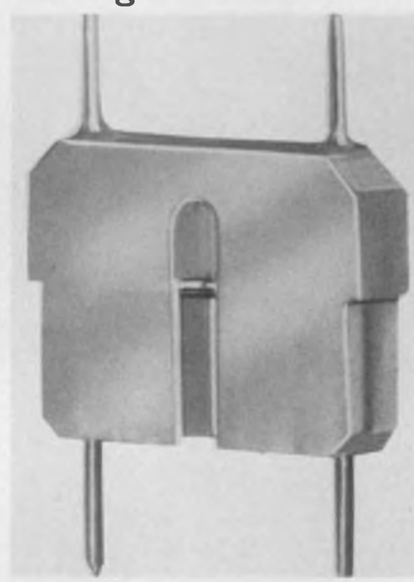


Calmark, 1820 San Marino Ave., San Marino, Calif. 91108. (213) 576-1838. Stock.

Series 112 PC-board puller features a positive gripping action. A sturdy wire-form design uses only 1/8 in. of board surface for gripping. Grips boards up to 1/8-in. thick. The unit is vinyl coated.

CIRCLE NO. 292

Plug-in patch programs DIP logic circuits



Aries Electronics, Inc., P.O. Box 231, Frenchtown, N.J. 08825. (201) 996-4096. $0.15 to $0.50; stock.

Individual programming of DIP sockets is possible with the new Aries Dipatch. For the ON position, the pins are inserted into the opposing socket contacts. For storage in the OFF position, the Dipatch is simply turned upside down and the plastic ears are inserted into the socket contacts. The device stacks on 0.100-in. centers; it is 0.400-in. wide; and it fits any conventional DIP socket. Pins are 0.018-in. dia., gold-over-nickel plated. The body is made of nylon and it is available in colors for color coding.

CIRCLE NO. 293

Fresh from the Factory. Yet These Cars Should Be Recalled.

Because they're missing something. Like an ignition system built for today's driving.

Factory electronic ignitions were okay for yesterday. (All they do is eliminate the points and condenser, you know.) But today...with fuel shortages, the ever-growing cost of maintenance, power-robbing smog control devices, etc.... there's a crying need for something better.

That something better is a Delta Capacitive Discharge Ignition System... the low-cost "now" system that really makes sense. Means up to 20% better gas mileage. 75% fewer tune-ups. Three to 10 times longer plug life. Instant starts... even at –40°. Better acceleration and performance. Easy to install on any automobile engine, too; even goes on in minutes right over the factory electronic system with no rewiring.

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303-242-9000

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Enclosed is $____ ☐ Ship ppd. ☐ Ship C.O.D.
Please send:____Mark Ten B assembled @ $64.95 ppd.____Mark Ten B Kit @ $49.95 ppd. (12 volt negative ground only____Standard Mark Ten assembled, @ $49.95 ppd.____6 Volt: Neg. Ground Only____12 Volt: Specify____Pos. Ground ____Neg. Ground____Standard Mark Ten Deltakit* @ $34.95 ppd. (12 Volt Positive or Negative Ground Only)

Car Year____ Make____

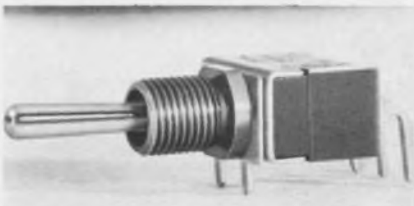
Name____

Address____

City/State____ Zip____

INFORMATION RETRIEVAL NUMBER 82

Toggle switches mount sidewise on PC board



American Switch Corp., Sadler St., Gloucester, Mass. 01930. (617) 281-2224.

With five electrically different single-pole options, Model ST1 toggle switches are designed for side mounting on PC boards. A special restraining bracket adds rigidity to the unit after assembly. They are suitable for use in dry circuits, and the ratings for this line are 0.4-W max at 28-V max ac or dc. The units occupy approximately 1/2 by 5/8 in. of board space and they have a profile that doesn't exceed 0.3 in.

CIRCLE NO. 294

Relay rated 10-A claimed half size of other types

Eagle Signal Industrial Controls Div., 736 Federal St., Davenport, Iowa 52803. (312) 329-9292. $2.50 (100 up).

A 10-A, DPDT enclosed relay, designated the 14 Series, is only half the size and cost of existing models of similar capabilities, according to its manufacturer. The relay is rated at 10-A, 1/10 hp, 120 V ac and 10 A, 24 V dc. The relay is also available in 6, 12, 48, 110-V-dc and 6, 12, 24 and 48-V-ac models. All models measure 7/8 × 1-7/16 × 1-1/8 in. and weigh 1-1/4 oz.

CIRCLE NO. 295

Glass trimmer capacitor adjusts two ways

Sprague-Goodman Electronics, 371 Willis Ave., Mineola, N.Y. 11501. (516) 746-1385.

Glass trimmer capacitors are now adjustable both by the conventional screwdriver slot at the bushing end of the capacitor and by means of a hex socket broached into the piston end of the capacitor. A standard No. 2 (0.035-in.) Allen hex tool can be used for adjustment in the hex socket, which is recessed to make it easy to locate in blind-hole situations. The hex socket modification is available on all open-end Pistoncap capacitors made by Sprague-Goodman Electronics.

CIRCLE NO. 296

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We design and manufacture complete electronic systems of various kinds for business, industry and government. It is our practice to hire very able people and then put them to work doing what they most like to do.

Because we are a large company, we offer a total career growth-potential that is as big as we are. And because we work in relatively small product-oriented divisions, your abilities and contributions are highly visible from the time you join us, with prompt recognition of superior performance.

Whether you work for us in California, New York, Ohio, Florida, Kansas or Delaware, you'll find yourself looking forward to coming to work in the morning. And your technology won't become obsolescent in 5 or 10 years, because, to remain a leader, we must continue to work on the far edge of the current state of the art.

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Circuit protector stops nuisance tripping

Transtector Systems, Div. of Konic International Corp., 532 Monterey Pass Rd., Monterey Park, Calif. 91754. (213) 283-9278.

Transtector System's new dual-function protectors eliminate nuisance tripping that is experienced with many high-speed protectors by clamping and absorbing the energy of transients in 50 ns. If the transient develops into an over-voltage condition, the unit then shunts the line to a safe level within 500 ns. It continues to draw sufficient energy to open the circuit's fuse or breaker. Upon removal of the power source, the unit automatically resets itself. The protectors have surge-current capabilities to 2000 A, choice of voltage trip points from 5 through 200 V dc and nominal current ratings from 1 through 100 A. The units are available in hybrid, radial-lead, 14-pin DIP or discrete cases.

CIRCLE NO. 297

Optical proximity sensor uses pulsed infrared

Electronic Products for Industry Corp., 1241 Birchwood Dr., Sunnyvale, Calif. 94086. (408) 734-8235. $95 (unit qty).

Infrared optical sensor transmits a pulsed, narrow beam and detects reflected light from any object at ranges up to 60 in. from noncooperative targets, or as far as 30 ft with a retroreflector. A LED generates the light at a frequency of 10,000 pulses per sec in high-energy pulses of 10-ns and 50-mW peak power. The receiver frequency is phase locked to the emitter for synchronous operation and, therefore, rejects ambient light. A large aperture, f/1.0 lens provides high optical efficiency.

CIRCLE NO. 298

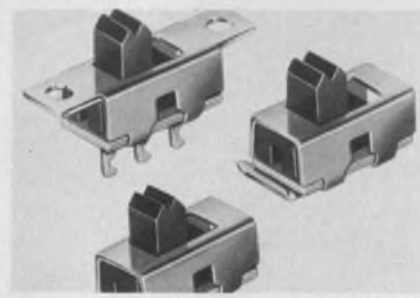
PC transformers have two secondary windings

Dale Electronics Inc., East Highway 50, Yankton, S.D. 57078. (402) 665-9301. $2.10 (OEM qty).

Designed for easy PC mounting, the new PL-12 transformer line is built to UL specifications and rated at 1.5 W. Currently, 17 standard models are available, and with an input of 115 V at 60 Hz, they cover outputs from 8 to 230 V. Transformer secondaries may be series or parallel-connected for twice the voltage or twice the current rating. Operating temperature ranges from −55 C to 105 C. Their six terminal pins form a 1 × 0.312-in. grid. Maximum height above board is 1-3/16 in.; maximum length is 1-29/64 in.; and maximum thickness is 1-1/8 in.

CIRCLE NO. 299

Slide switches feature miniature size



Alco Electronic Products, Inc., 1551 Osgood St., North Andover, Mass. 01845. (617) 685-4371. 30 to 60 days.

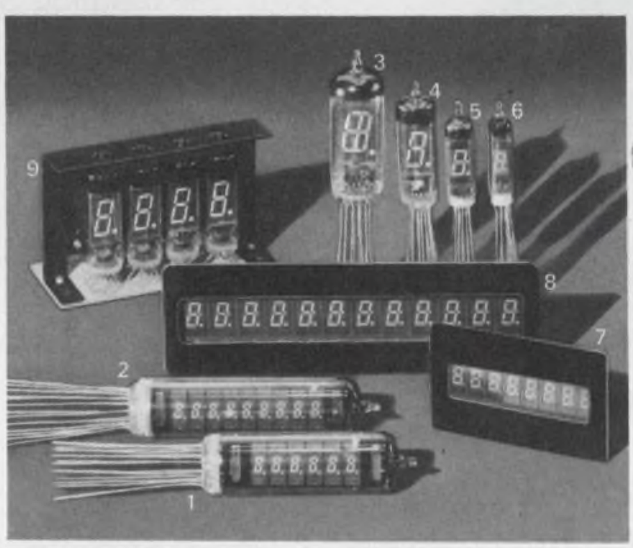
New subminiature SPDT slide switches for calculators and test instruments feature a ball-and-spring-detent mechanism, contacts with wiping action and an improved tactile feel. The basic switch is available in three styles with dimensions of only 0.433 L × 0.213 W × 0.197 H in. Model SLS-121M has tabs for panel mounting; SLS-121M-1 is identical, except it doesn't have the mounting tabs; and Model SLS-121M-RA has 90-degree bent terminals for right-angle mounting. All models have silver-plated brass terminals and contacts encased in a corrosion-protective steel frame. Actuators are black thermoplastic resin. Normal life expectancy exceeds 10,000 operations. The switches are rated 0.3 A at 125 V ac.

CIRCLE NO. 300

Frame them any old way

Or any new way.

Then sit back and watch your Ise display electronics get your ideas across. Beautifully.
In an eye-easy fluorescent green glow.
At the same time, they're low on voltage and current drain.
High on stability.
Pick the readouts that offer more of everything, including variety, for a whole host of digital display ideas.
They're a difference you can see.



1. DP60A
2. DP90A
3. DG19E
4. DG12H
5. DG10F1
6. DG 8F
7. DP 89A
8. DP127F
9. DMCL12H (NEW)

Display module w/counter & latch
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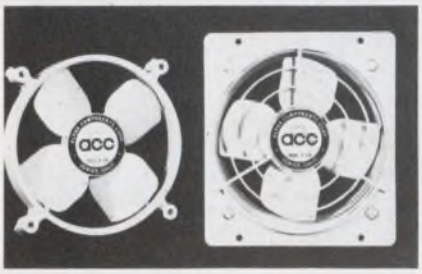
INFORMATION RETRIEVAL NUMBER 87

Cooling fan runs on 12-V-dc brushless motor

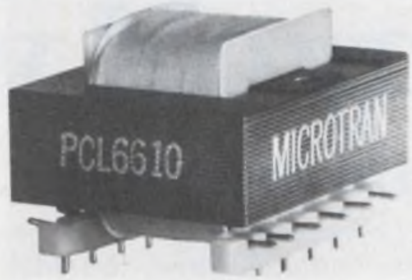


Alpha Components Corp., 115 Eucalyptus Dr., P.O. Box 947, El Segundo, Calif. 90245. (213) 322-7780. $16.40 (1000 up); stock.

Model D-12 cooling fans operate from a nominal 12 V dc that is normally available in many electronic systems. The motor requires only 2 A. The fan supplies 130 cfm of air at 12 V and 150 cfm at 14.4 V. The unit weighs only 24 oz., complete with grille and venturi, and it is 5-in. diameter by 2-3/8-in. deep. The new unit mounts on 4.125-in. standard mounting centers.

CIRCLE NO. 301

Miniature xformers mount on PC boards



Microtran Co. Inc., 145 E. Mineola Ave., Valley Stream, N.Y. 11582. (516) 561-6050. Typical $4.50 to $5.50 (100 up); stock.

A new series of 35 plug-in PC power transformers allows the construction of low cost, miniaturized, regulated and unregulated dc power supplies to provide outputs of +5 and ±15 V dc. Low-profile and miniature construction permit close stacking of PC boards. Precision spaced plug-in terminals also provide fixed mounting centers. The units are designed for 115 and 115/230-V, 50/60-Hz input. Output current ratings from 12 to 2000 mA dc are available.

CIRCLE NO. 302

Gas-tube arrestor offers low breakdown voltage

Signalite, 1933 Heck Ave., Neptune, N.J. 07753. (201) 775-2490. $1 (5000 up).

Signalite's CG-75 Comm Gap arrestor has a dc breakdown voltage of 75 V ±20%, when subjected to a slowly rising dc voltage, and a pulse breakdown voltage typically between 400 and 600 V, when subjected to a fast rising voltage of about 5 kV/μs. The unit is of rugged ceramic-metal construction with a length of 0.265 in. and a diameter of 0.380 in. max. Typical capacitance is 1.4 pF. Life may be millions of operations, depending on pulse-current amplitude and duration.

CIRCLE NO. 303

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HAS WHAT IT TAKES TO BE
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IN RF POWER SEMICONDUCTORS...
THE LINE – THE BOOK – THE BOARDS.

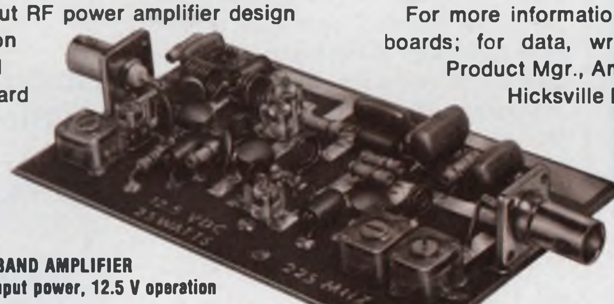
Amperex is going all out to support its state-of-the-art line of RF power semiconductors with a state-of-the-art program of applications engineering assistance.

The line is a broad one with an RF power semiconductor to fill virtually any RF amplification need in fixed and mobile transmitting equipment—from 30 MHz single sideband through 960 MHz UHF FM.

At the heart of the program is a 640-page applications manual containing 24 detailed engineering reports. This manual, available to communications design engineers, will cut RF power amplifier design time and cost to a fraction of that normally required between the drawing board and the production line.

The engineering assistance doesn't end with the applications manual—it only starts there. You won't even have to build the prototypes to get these circuits into production! We will supply sample boards, built for you, here in the Amperex applications laboratory. Use them to test, to evaluate, to demonstrate your system. Typical of the sample boards now being made available to Amperex customers, is a 25 watt, 225 MHz Class E Citizens Band Amplifier (illustrated at left) with 50 mV input power and 12.5 V operation.

For more information... on the line, the book, the boards; for data, write to Marty Burden, Group Product Mgr., Amperex Electronic Corporation, Hicksville Division, Hicksville, N.Y. 11802. Telephone: (516) 931-6200.



CLASS E, CITIZENS BAND AMPLIFIER
25 W output, 225 MHz, 50 mV input power, 12.5 V operation

P out (watts)	SSB 30 MHz 28 V	VHF 175 MHz FM 13.5 V	VHF 175 MHz FM 28 V	UHF 470 MHz FM 13.5 V	UHF 470 MHz FM 13.5 V Ampl. Modules	UHF 470 MHz FM 28 V
2.0				BLX65		
2.5			2N3553	BLX66		
3.0		2N3924		BLX67		BLX92
4.0		BFS22A	BFS23A		BGY22	
6.0			2N3375			
7.0		2N3926		BLX68	BGY23	BLX93
8.0	BLX13	BLY87A	BLY91A			
12.0		2N3927				
13.0			2N3632			
15.0		BLY88A	BLY92A		BGY24	
20.0				BLX69		BLX94
25.0		BLY89A	BLY93A			
40.0						BLX95
60.0	BLX14	BLY90	BLY94			
150.0	BLX15					

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North American Philips Electronic Component Corporation

INFORMATION RETRIEVAL NUMBER 90

Tetrode has improved cathode structure

Varian, 611 Hansen Way, Palo Alto, Calif. 94303. (415) 493-4000. About $40; stock.

The Model 4CX250BC/8957 tetrode can replace the 4CX250B in broadcast applications. The new tetrode, featuring an improved cathode structure, is capable of high emission over an extended period of time. A modified screen grid virtually eliminates the possibility of negative screen current. Maximum plate dissipation is 250 W and maximum input power is 500 W.

CIRCLE NO. 304

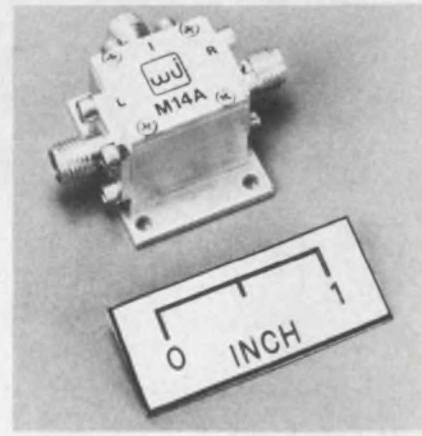
Switch line housed in flat packs

Sanders Associates, Inc., Microwave Div., Grenier Field, Manchester, N.H. 03103. (603) 669-4615. $40 up; 2 to 4 wks.

The DS-10000L Series of octave and multioctave-band switches comes in standard flat packs for ground or airborne applications from 5 to 4000 MHz. The switches offer up to 60-dB isolation with insertion losses as low as 0.5 dB, and they feature typical switching speeds of about 100 ns. The switches are available in either SPST or SPDT configurations, and with or without the TTL-compatible integral drivers.

CIRCLE NO. 305

C-to-Ku-band DB mixers isolate to 35 dB

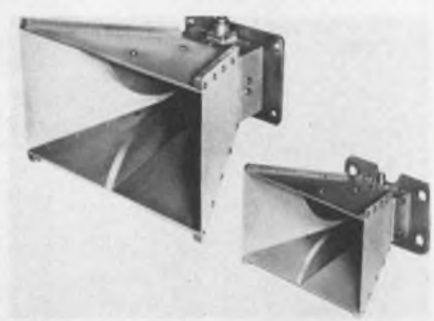


Watkins-Johnson Co., 3333 Hillview Ave., Palo Alto, Calif. 94304. (415) 493-4141. $350 to $500 (1-4); stock.

Two double-balanced mixers, having a frequency coverage up to 16 GHz, specify the following with a 7-dBm drive: a 5-to-6-dB noise figure, a 30-to-35 dB isolation and a VSWR of less than 2:1. Called the WJ-M14 (which can accept signals from 4 up to 9 GHz) and the WJ-M14A (which can accept signals from 4 up to 16 GHz), the new mixers also feature an i-f response of dc to 2 GHz, insertion loss of 2 to 3 dB, loss tracking of 0.2 dB and phase tracking of ±1 to 1.3 degrees.

CIRCLE NO. 306

Linear horns spec multioctave range



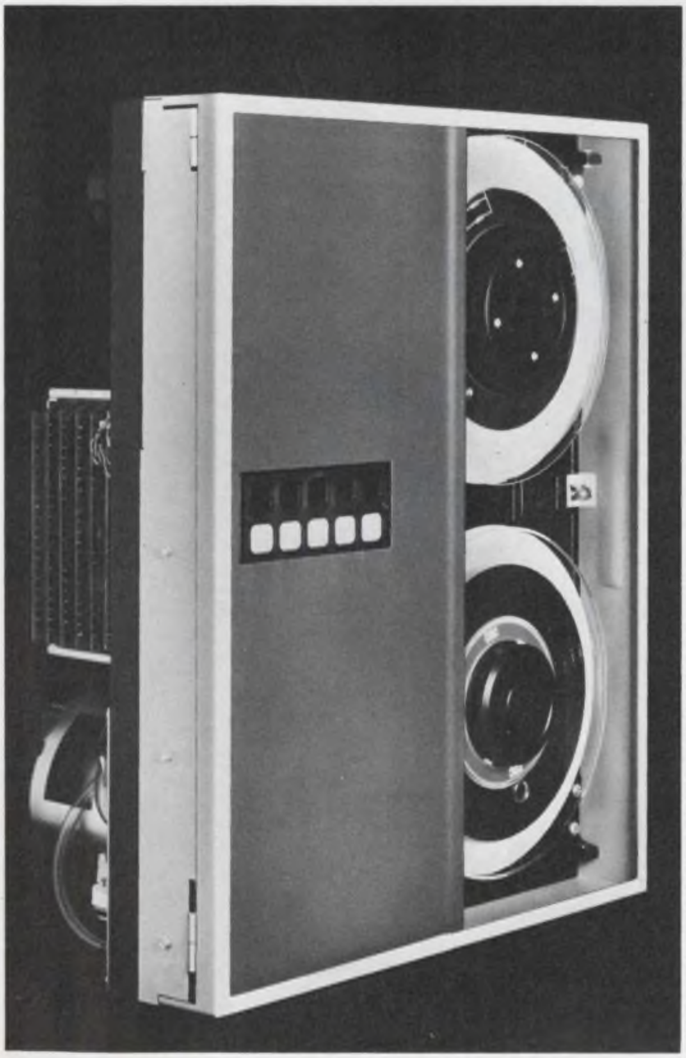
American Electronic Lab., Inc., MS/1123, P.O. Box 552, Lansdale, Pa. 19446. (215) 822-2929.

The Model H-1479 and H-1498 linearly polarized horns combine multioctave coverage with compact size. These coaxially-fed double-ridged horn antennas have an essentially constant gain of 11 dB. They cover the 1-to-18-GHz frequency band in overlapping ranges of 1 to 12 GHz and 2 to 18 GHz.

CIRCLE NO. 307

OEM Buyers take note:

CDC® Model 92000 Magnetic Tape Transport for best price/performance.



The CDC® Model 92000 Series Transports are rack mounted, budget priced, reliable, 25 and 50 IPS single capstan units compatible with ANSI standards.

These transports are used on our own systems and feature exceptional data and mechanical reliability.

- Vacuum column operation for improved tape handling
- Digital tachometers provide precise tape control
- Programmable clip levels for enhanced reading capability and improved error recovery
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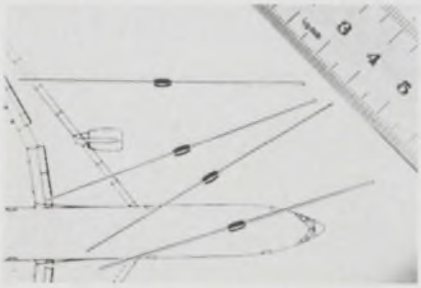
☐ I want to hear more about the CDC Model 92000 Series Tape Transports.

INFORMATION RETRIEVAL NUMBER 92

Transient protectors handle bipolar signals



Semtech Corp., 652 Mitchell Rd., Newbury Park, Calif. 91320. (213) 628-5392.

A silicon bipolarity transient suppressor provides symmetrical voltage transient protection. These devices have breakdown voltages of from 10 to 110 V ±10%. They can withstand peak power pulses (1 ms duration) of 500 W and will respond in 1 ps. The dynamic impedance of these transient protectors varies from 1.5 to 70 Ω. These devices have diameters of 0.14 in. and are 0.165 in. long.

CIRCLE NO. 308

LED numeric display has 0.25 in. high digits

Bowmar Canada Ltd., 1257 Algoma Rd., Ottawa, Ontario K1B3W7. (613) 746-3100.

The B-27R is a 0.25 in. high single digit LED numeric display. It gives off a highly visible bright red light (660 nm) from a GaAsP material. Luminance is typically 0.3 millicandela and the power required for nominal brightness is 125 mW.

CIRCLE NO. 309

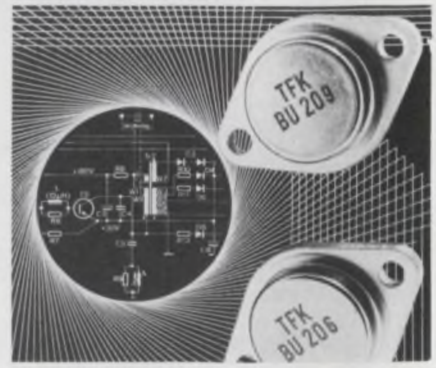
S-band power transistor delivers 10 W

RCA, Box 3200, Somerville, N.J. 08876. (201) 722-3200. $200 (25 to 99); stock.

The RCA2310 microwave transistor can supply 10 W cw at 24 V for operation at 2.3 GHz. The device has been designed for S-band (2.2 to 2.3 GHz) telemetry service. It uses 22-to-24-V supplies and is housed in a flanged ceramic-metal package, designated HF-46.

CIRCLE NO. 310

High voltage transistors work at 1700 V



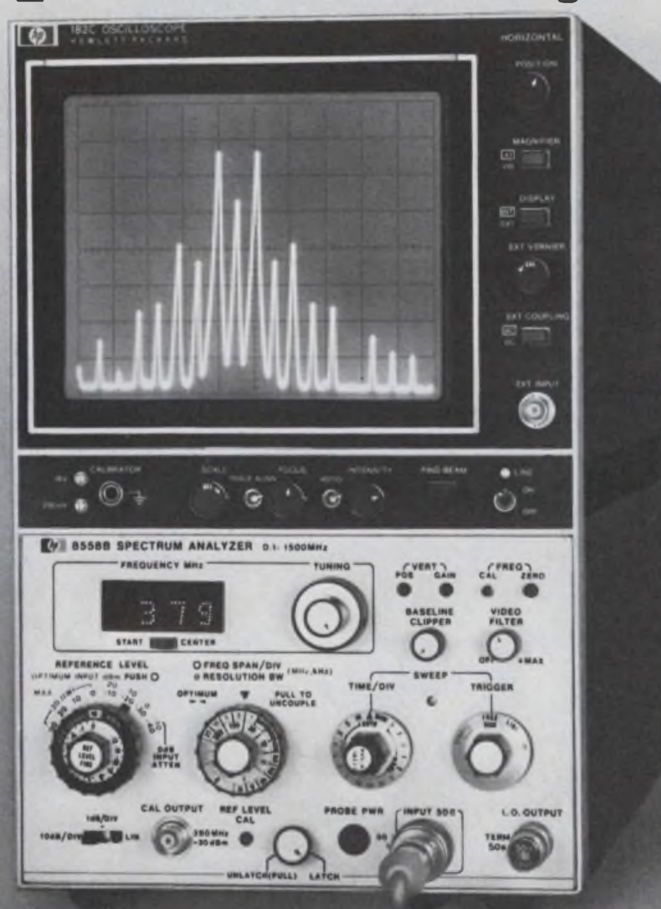
Energy Electronic Products, 6060 Manchester Ave., Los Angeles, Calif. 90045. (213) 670-7880. BU-206; $4.65 (100 pc. price); stock.

The BU204 through BU209, power transistors are silicon npn devices that can handle up to 1700-V peak voltage (collector-base) at 4 A (BU209). The BU204 and 207 can handle 1300 V, the 205 and 208 1500 V and the 205 and 209 1700 V. The 204, 205 and 206 can handle collector currents of 2.5 A average while the 207, 208 and 209 can handle 5.5 and 4 A, respectively.

CIRCLE NO. 320

FOR NEW STANDARDS IN SPECTRUM ANALYSIS, THINK HP

Affordable spectrum analysis



A new 1500 MHz plug-in for HP 180 series Scopes

Just $3900. The 8558B Spectrum Analyzer plug-in is priced low enough to make it practical for every workbench; no need to "timeshare" the expensive analyzer. And since it's part of the HP 180 Scope family, the mainframe can do double-duty using the wide selection of other 180 plug-ins.

Lab Grade Performance. Compare the 8558B's frequency and amplitude accuracy against any other analyzer and you'll quickly see how good it is. Frequency response over the full 0.1-1500 MHz range is ±1 dB, and there's an LED display of frequency with ±5 MHz accuracy. Distortion free dynamic range exceeds 70 dB. Signal levels from +30 dBm to −117 dBm can be measured. Resolution bandwidths from 1 KHz to a wide 3 MHz are provided.

Domestic USA prices only.

Three Control Simplicity. For most measurements, you simply set two frequency and one amplitude controls. Resolution bandwidth and sweep time are automatically optimized. Panel markings guide you to control settings that minimize the possibility of errors from signal overloading.

For full information on this tremendous value in spectrum analysis, call your nearest HP field office. Or write.

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INFORMATION RETRIEVAL NUMBER 95

new literature

Keyboards

"Applications Unlimited," a four-page two-color brochure, provides data on keyboards and suggests imaginative use of keyboard technology. A companion six-page full-color folder provides color reproductions of all 17 colors in which key-tops are available and the five colors of the anodized aluminum bezels or key-top containers. Bowmar, Fort Wayne, Ind.

CIRCLE NO. 321

IEEE computer publications

The latest edition of the IEEE Computer Society Publications 16-page catalog covers its full line of computer technology books. Computer Society, Publications Offices, Long Beach, Calif.

CIRCLE NO. 322

High-voltage assemblies

Fabrication and construction techniques for the company's custom high-voltage assemblies employed in military, aerospace instrument and industrial applications are described in a four-page brochure. Microsemiconductor Corp., Santa Ana, Calif.

CIRCLE NO. 323

Relay data

The K167 relay test system, which performs all major tests of a relay in any sequence with only one device insertion required, is described in a 22-page brochure. Data include lot summary sheets, data logged parameter values and readily interpreted statistical information, all automatically gathered and presented on CRT display or on hard copy. Teradyne, Boston, Mass.

CIRCLE NO. 324

Electron tubes and devices

An EEV/M-OV abridged data book details all of the company's products in one publication. A comprehensive equivalents index lists over 3000 types of tubes. English Electric Valve, Chelmsford, CM1 2QU, England.

CIRCLE NO. 325

LEDs

A LED lamp for panel lighting, film annotation, circuit-status indication, numeric and alphanumeric displays and visual indicators is described in a brochure. Dialight, Brooklyn, N.Y.

CIRCLE NO. 326

Instrument CRTs

A 16-page catalog provides data on instrument cathode ray tubes with diameters of from 1 to 7 in. Specifications include electrical and physical characteristics, maximum ratings, typical operation, phosphor characteristics, socketing, basing and shielding requirements, mounting considerations and safety precautions. RCA, Harrison, N.J.

CIRCLE NO. 327

Test equipment

An electronic test equipment catalog includes a complete listing and description of the company's rental equipment. Prices are included. The catalog discusses the advantages of renting equipment and defines the rental, rental/purchase and leasing services available. Rental Electronics, Lexington, Mass.

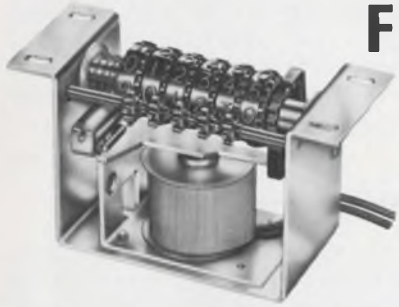
CIRCLE NO. 328

Finger strips and rings

An eight-page catalog is devoted to finger strips and rings, microprocessed from beryllium copper for use in RFI-EMI shielding. Specifications with schematic drawings are included. Tables indicate attenuation factors at various frequencies. Instrument Specialties, Little Falls, N.J.

CIRCLE NO. 329

A COMPLETE PRINTER FOR ONLY $10⁰⁰?



Well, maybe...

ENM has another All-American made counter that might enable you to add that printer you've always wanted on your product.

All it takes is a little imagination and ENM's Model EP1 printing counter module. Since it only costs $7.06 in 1,000 lots, you have about $3.00 to spend for your own hardware and printing method.

The electric Model EP1 has six large direct reading raised digits for impact, roller, or ballistic printing on self-contained paper, i.e. action paper or carbon card sets. Its flanged open frame construction makes mounting easy, and you have a choice of 24V DC, 24V AC, and 115V AC.

If you want to try one for test, send us $10.00 and we'll ship one to you out of stock.

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ENM COMPANY

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INFORMATION RETRIEVAL NUMBER 97

THE COMPATIBLES

Spectrum Technology is your one source for frequency control devices that are compatible with the high technology logic of the Seventies. Standard, modified or custom designs include subminiature hybrid circuit crystal oscillators, dual in-line low profile hybrid circuit logic clocks, low cost crystal oscillator IC logic clocks, and TCXO's. Write or call for details.

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15 VDC @ 1.5A TO 15A

24 VDC @ 1.2A TO 12A

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± 12 VDC OR ± 15 VDC

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± 12 VDC OR ± 15 VDC

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Holsapple & Associates, 6840 E. Washington, Indianapolis, Indiana 46219, (317) 899-2890

Rave 1, 3131 Stemmons Parkway, Dallas, Texas 75247 (214) 638-6575

Digital Sales Associates, 9 Spring St., Waltham, Mass. 02154 (617) 899-4300

Burtis Power Dist., Inc., 6324 Variel, Bldg. 'E', Woodland Hills, Calif. 91364, (213) 887-1360

POWER-ONE

531 DAWSON DRIVE
CAMARILLO, CA. 93010
(805) 484-2806

INFORMATION RETRIEVAL NUMBER 99

Power conversion equipment

A 12-page catalog describes ac-dc regulated converters, ac-dc regulated power supplies, dc-dc regulated converters, dc-sine wave inverters and miniature power transformers and inductors. A "design-as-you-order" section provides instructions and technical information to specify custom power conversion systems from standard catalog modules. Arnold Magnetics, Culver City, Calif.

CIRCLE NO. 336

Microwave diodes

A 32-page microwave diode catalog lists signal generation diodes, multiplier diodes, p-i-n diodes, devices for IC applications, tuning diodes, parametric amplifier diodes, reliability screening and case styles. Varian, Beverly Div., Beverly, Mass.

CIRCLE NO. 337

Circuit breakers

Two hydraulic circuit breakers are covered in a brochure. The Bendix Corp., North Hollywood, Calif.

CIRCLE NO. 338

Tachometers

A catalog lists 64 types and models of electronic tachometers including industrial tachometers, stroboscopes, magnetic pickups, photoelectric counters, photoelectric pickups, torquemeters and pulse generators. Prices are included. Power Instruments. Skokie, Ill.

CIRCLE NO. 339

Sputtering systems

The latest in sequential sputtering systems is described in a brochure. The brochure contains a selector chart of available models, along with specifications. Materials Research Corp., Orangeburg, N.Y.

CIRCLE NO. 340

Cable-harnessing systems

An illustrated eight-page brochure features cable-harnessing systems and heat-shrinkable components. Raychem, Menlo Park, Calif.

CIRCLE NO. 341

Chromatograph system

The application of a process-computer chromatograph system is described in a 12-page brochure. Honeywell's Process Control Div., Fort Washington, Pa.

CIRCLE NO. 342

Hardware and assemblies

A 57-page catalog describes electronic hardware and assemblies. The brochure contains information on terminal strips, telephone plugs and receptacles and circuity terminations. Each of three sections shows dimensional drawings, specifications, photographs and model types. A fourth section is a quick-reference manual. Malco, Chicago, Ill.

CIRCLE NO. 343

High-voltage relays

An eight-page, two-color catalog describes over 88 high-voltage relays for custom applications. The catalog includes photos, dimensional drawings, specifications, prices and ordering information. Magnecraft, Chicago, Ill.

CIRCLE NO. 344

Data-transmission system

A 32-page technical bulletin provides information for the type 25C data-transmission system. GTE Lenkurt, San Carlos, Calif.

CIRCLE NO. 345

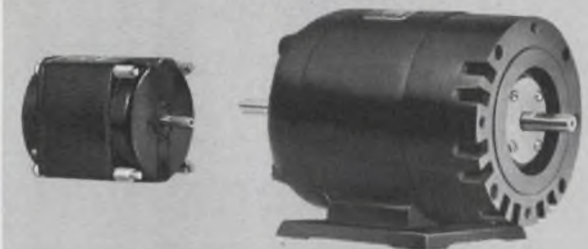
EMI filters

Information on EMI filters for residential, commercial and industrial use is given in a 16-page catalog. Cornell Dubilier Electronics, Newark, N.J.

CIRCLE NO. 346

now, A-C torque motors from stock

Bodine fhp reversible torque motors are ideally suited for a variety of holding, positioning, tensioning and winding applications.



■ Four models from our popular Type "K-2" and "N" lines ■ For intermittent locked rotor operation at rated voltage and continuous locked rotor duty at reduced voltage ■ Four wire connection arrangement for servo operation ■ Variable voltage power supplies can be used to achieve an infinite number of speed settings ■ Four frame sizes: from 2.405" diam. in the KCI-26 motor to 5.68" in the NCI-55.

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ELECTRIC
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Write for bulletin MTQ-CI.

Bodine Electric Co., 2554 West Bradley Place, Chicago, Illinois 60618

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- ☐ 0.1-500 MHz
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- ☐ Micro-miniature case

$2.95 10 piece quanities
Some models $3.45

ONE WEEK DELIVERY!

Impedance ratios of standard models are 1:1, 2:1, 4:1, 9:1 and 16:1. MCL kit TK-1 includes 2 units of each type and sells for $32.

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A Division Scientific Components Corp.
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(212) 252-5252 Int'l Telex 620156

INFORMATION RETRIEVAL NUMBER 103

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A NEAT TWIST

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INFORMATION RETRIEVAL NUMBER 102

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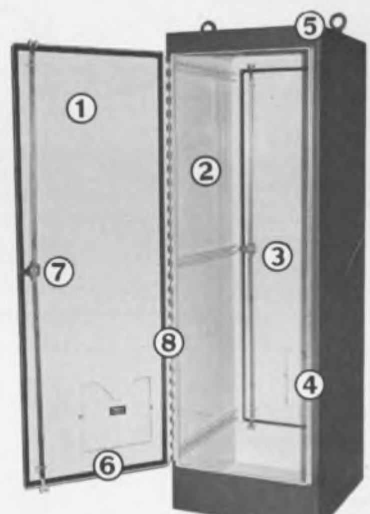

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Division of Federal Cartridge Corporation
Anoka, Minnesota, Dept. ED-75

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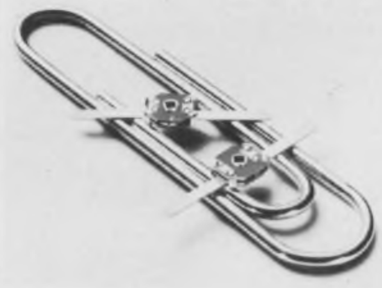
quick ads

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



Thin-Trim variable capacitors provide a reliable means of adjusting capacitance without abrasive trimming or interchange of fixed capacitors. Series 9401 has high Q's and a range of capacitance values from 0.2-0.6 pf to 3.0-12.0 pf and 250 WVDC working voltage. Johanson Manufacturing Corporation, Boonton, New Jersey (201) 334-2676.

INFORMATION RETRIEVAL NUMBER 181

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 182

Silicon Bridge Rectifier. Fast Recovery: 300 ns. 15 Amp. 50 to 1,000 V. Single phase. Full wave. Heat sink and chassis mounting. Underwriter Lab component recognition. $4.00 in quantity. Electronic Devices, Inc. 21 Gray Oaks Ave., Yonkers, N.Y. 10710. (914) 965-4400.

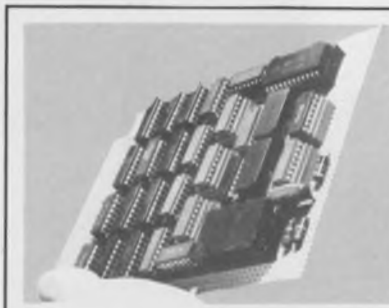
INFORMATION RETRIEVAL NUMBER 183

PM Synchronous Motor. Low cost motor provides torque to 10 oz-in at 300 RPM rotor. Electric reversibility, instant start/stop, quiet operation, and compact size—2-1/4" dia. x 1-1/8" long. For computer peripherals, control devices, chart drives, etc. ECM Motor Co., 1301 E. Tower Rd., Schaumburg, Ill. 60172. 312/885-4000.

INFORMATION RETRIEVAL NUMBER 184

Module catalogs—FM Telemetering-VCO's discriminators, oscillators, mixers, pressure transducers. Converters — voltage-to-frequency, frequency-to-voltage, phase-to-voltage, signal isolators. Choppers, relays, frequency, sensitive, time delay, analog. Phone or wire. Solid State Electronics Corp. 15321 Rayen St., Sepulveda, CA 91343. (213) 894-2271.

INFORMATION RETRIEVAL NUMBER 185

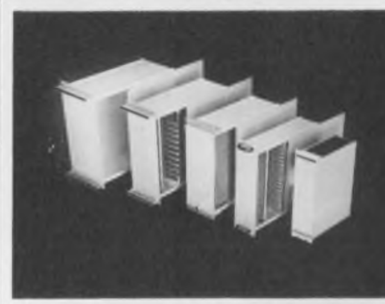


DIGITAL MATCHED FILTERS CORRELATORS CONVOLVERS. Ltd. quantities Model 328 (32 word x 8 bit) and Model 2561 (256 word x 1 bit) correlators available. Also custom units built to order. Inputs: Two digital signals, sampling/clock signals, 5V. Output: Correlation product. $2/word x bit FOB ARO 90 days RCS ASSO., INC. (714) 624-1801.

INFORMATION RETRIEVAL NUMBER 186

New miniature D/A's exhibit settling time as low as 15 nanoseconds under "worst case" conditions. Both the MDS and the MDP Series offer a complete range of 8 and 10-bit converters with 15mA, or +1.5V; or ±7.5mA at ±1.1V output. COMPUTER LABS, INC., 1109 South Chapman Street, Greensboro, N. C. 27403. Phone (919) 292-6427.

INFORMATION RETRIEVAL NUMBER 187



Precision-engineered prefab modular rack-mounting chassis units, card cages, cabinets & accessories assemble in many configurations to meet your space requirements. Kits & parts are in stock, ready for shipping. Free catalog includes prices. Techmar Omniclosure, 2232 S. Cotner Ave., Los Angeles, CA 90064, 213-478-0046.

INFORMATION RETRIEVAL NUMBER 188

Custom made cases, cabinets and enclosures. Exceptionally rugged construction, laminated Formica-wood-Formica. Internally reinforced corners. Attractive wood grain or solid color exteriors. Superb workmanship, competitive prices, small or quantity lots. W. A. Miller Co., Inc., 306 Mingo Loop, Oquossoc, Maine 04964. Telephone: 207/864-3344.

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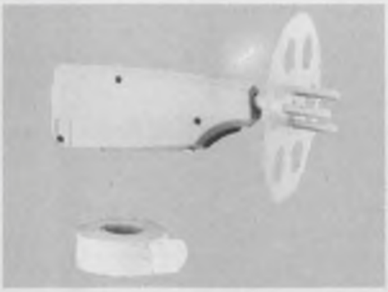

Hi-Speed Cordless Paper Tape Winder is light weight, portable and powered by its own internal battery pack. When not in use winder is attached to battery charging stand. Model 1000-1. $50. A-B Supply Co., P.O. Box 5609, China Lake, Calif. 93555 (714) 375-1385

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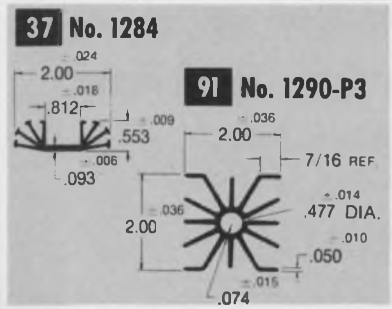

Heat Sink Extrusions Wall Chart on 99 dimensioned shapes with Surface Area/Inch; Thermal Resistance in °C/W per 3" length Nat. Conv.; Lbs/Ft; Scale 1/4" = 1". 2 Tech Articles also be sent: "Treat the Heat Sink as a System" & "Liquid Cooling High Power Semis." WAKEFIELD ENGINEERING, INC., Wakefield, Ma. 01880

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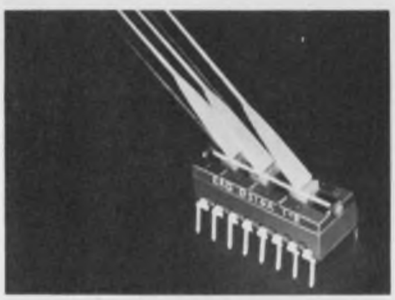
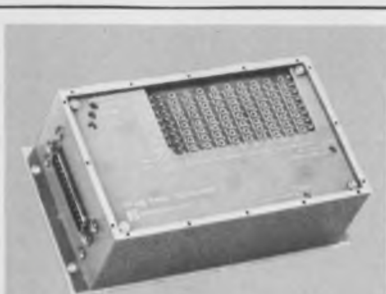


DILswitch 16, dual-in-line switch. Rated at 28V 250mA (240V and 2A carry) with gold on nickel plating for low level circuits. Sixteen standard types stocked including 1p/8w, 2p/4w and 4p/2w. Prices from about $1.40 (100 rate). Erg Components, Luton Road, Dunstable, Bedfordshire, LU5 4LJ, England. Telex 82349. Telephone Dunstable 62241.

INFORMATION RETRIEVAL NUMBER 191

Don't count down. Use SX-1 10 kHz - 300 kHz Quartz Crystals • 20 stock frequencies • 0.185" high TO-5 • 1000g shock & 50g vibration • $2.00 ea. in 1000 qtys. (±0.01% accuracy) • STATEK CORP. • 1233 Alvarez Ave. • Orange, Calif. 92668 • (714) 639-7810 • Telex 65-5430.

INFORMATION RETRIEVAL NUMBER 194



Timing programmer—Activates 8 external relays in a preprogrammed sequence or relative to the starting time. Timing selectable in 0.25, 0.5, or 1 second increments to over 1000 seconds. Applications include rocktes, missiles and aircraft.—BAYSHORE SYSTEMS—Springfield, Va.

INFORMATION RETRIEVAL NUMBER 192

Digital to synchro converters—14, 12 or 10 bit input, 11.8/90V, 400 or 60Hz transformer isolated output, accuracy ±4, ±15 or ±30 min. Driving 1VA, 2VA (2.6" x 3.1" x 82"H module) or 5 VA loads (4½" x 9¼" pc card). Price from $350 in qty. Computer Conversions Corp., East Northport, N.Y. 11731. (516) 261-3300.

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CIRCLE NO. 171

Federal Scientific Corp.
An affil. of Nicolet Instrument
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Giant Free Catalog! 4,500 Unusual Bargains

New 164-page catalog! Packed with 1,000's of hard-to-find buys in Optics, Science, Electronics. Loaded with optical, scientific, electronic equipment available from stock. Rare surplus buys. Many "one-of-a-kinds". Ingenious scientific tools. Components galore: lenses, prisms, wedges, mirrors, mounts, accessories. 100's of instruments: pollution test equipment, lasers, comparators, magnifiers, microscopes, projectors, telescopes, binoculars, photo attachments, unique lighting. Shop, save by mail! Request free Catalog "DA"

CIRCLE NO. 172

Edmund Scientific Co.
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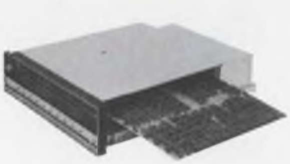

The 306/MFFT Fast Fourier Transform Processor is delivered with all control programs and plugs directly into any Data General Nova computer. It offers a complete Fourier Transform capability including Forward and Inverse FFT, Spectral magnitude, Hanning Weighting, and Complex Multiplication. Arrays from 16 to 16,384 real samples can be processed. An array of 1024 real samples is transformed in only 139 ms.

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Editor
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50 Essex Street
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Electronic Design

Advertising Sales Staff
Tom W. Carr
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Rochelle Park, N.J. 07662
Robert W. Gascoigne
Daniel J. Rowland
(Recruitment, Quick Ads, Classified)
50 Essex Street
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**Advertisers in non-U.S. edition*

product index

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new literature

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by avoiding cigarettes?

by keeping weight normal?

by serving tasty, low-fat foods?

by seeing your doctor regularly?

by not being a TV athlete...

but by exercising moderately instead?

Help your children form good living habits now
to reduce their risk of heart attack later.

Help your Heart... Help your Heart Fund

Contributed by the Publisher

Reed Relays in Stock with Long Life & Versatility

READY REEDS

The Ready Reeds are ready for you! Over 290 high quality types of reed relays are in stock for immediate delivery. A wide variety of hermetically sealed contact combinations and packaging techniques are available. Versions offered include; dry, mercury-wetted, sensitive, latching, power, high voltage, time delay, electro-statically shielded, and dual-inline-package DIP's.

Magnecraft's reed relays can provide almost everything that a designer would want in order to accomplish a high speed switching function. The versatility of the relay is so great that it can be custom-fitted to almost any application at a lower cost in dollars and power and in a smaller space than almost any other device, conventional or solid state.

The photo above portrays the reed relay packaging characteristics available: epoxy encapsulated, axial leads, plug-in, eight and fourteen pin dual-inline-package, open styles, and standard, miniature, and micro miniature printed circuit packages.

Our nationwide network of distributors and Chicago plant stand ready to serve your applications. But, if you don't find what you need in stock we will make if for you!

Free!
STOCK CATALOG

To help specify all your relay needs, ask for Magnecraft's new 1974 Stock Catalog with the most diversified line of over 1060 relays. A 68 page Designers Handbook and Catalog of Reed and Mercury Wetted Contact Relays with specific data drawings, and photos on all the various relays will accompany the Stock Catalog.

Find Magnecraft Relays in EEM sec. 4500.

Magnecraft ELECTRIC COMPANY

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INFORMATION RETRIEVAL NUMBER 244

The flat-as-a-pancake TV. If you want to design one tomorrow, we're ready with your linear IC's today.

Whatever the idea you put on paper, we can probably help bring it to life.

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