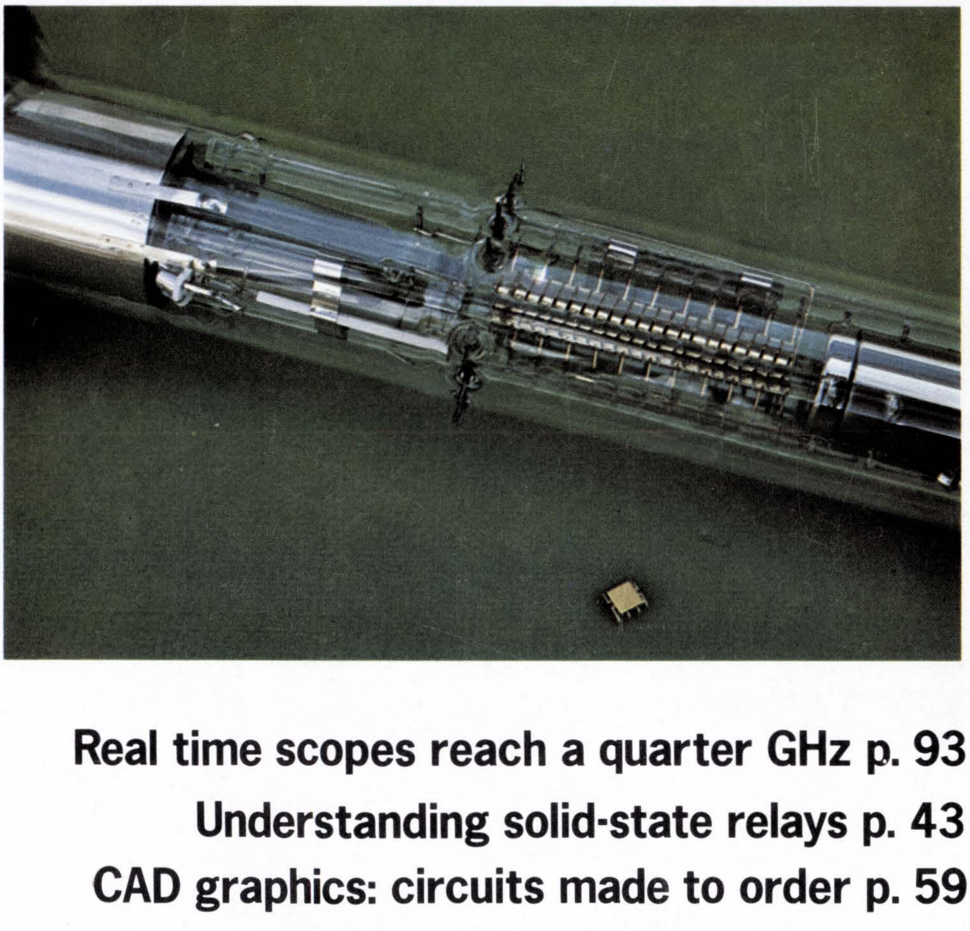
VOL. 28 NO. 8
AUGUST 1969

THE ELECTRONIC ENGINEER



Real time scopes reach a quarter GHz p. 93

Understanding solid-state relays p. 43

CAD graphics: circuits made to order p. 59

How to cable fast pulses p. 71

New, cheaper waveforms at WESCON p. 88

Not everyone needs a DVM that's good enough to calibrate other DVMs

Sure our Model 5700 is the most accurate DVM there is — 0.0025%. And the most stable — 0.0065% for a year. But if you don't really need a DVM that's good enough to calibrate other DVMs, don't buy it. Buy one of our 32 others instead.

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DANA®

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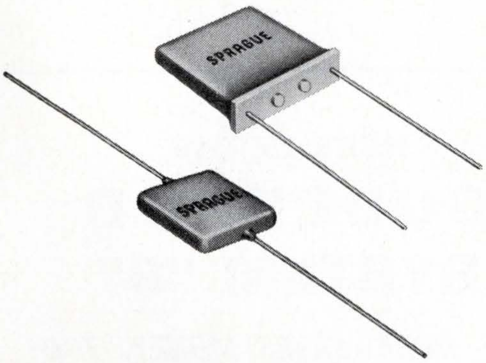
Investigate MONOLYTHIC® LAYER-BUILT CAPACITORS



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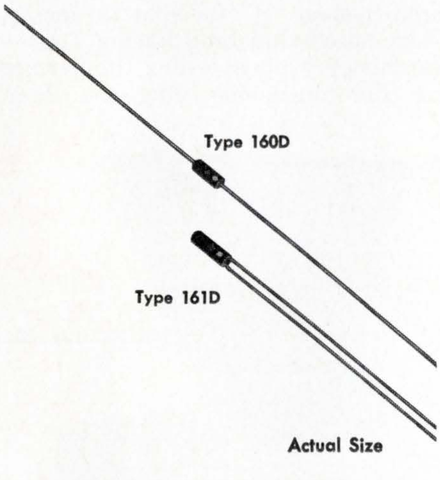
Made with alternate layers of sprayed ceramic dielectric material and screened metallic electrodes, fired into a solid homogeneous block. Coated with tough phenolic resin. Available in four formulations—082(N030), 075(N750), 067(W5R), 023(Z5U). Your choice of axial-lead or improved radial-lead construction. Radial-lead capacitors have new bossed terminal base which prevents resin run-down on leads, maintains uniform lead spacing, eliminates dirt and moisture entrapment around leads, permits degreasing fluid to flow freely between capacitor and board.

4SC-9105

Tiny in size...Giants in volume efficiency!

Type 160D, 161D Solid-Electrolyte Tantalex® Capacitors

for hearing aids and ultra-miniature circuits



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Tiny Type 160D/161D Tantalex Capacitors are sealed within a polyester film tube with tightly-bonded epoxy fill, so the assembly is both electrically insulated and highly resistant to moisture. They are available with axial leads as well as in single-ended construction.

Offering extremely high capacitance per unit volume (for example: 0.25 μF @ 20 VDC in a case only .065″ D. x .125″ L.), Tantalex Hearing-aid Capacitors let you select from a broad range of ratings in five different case sizes.

4SC-9125

For complete technical data on Monolythic® Capacitors, request engineering bulletins. For the full story on Type 160D/161D Capacitors, write for Engineering Bulletin 3515D. Address Technical Literature Service, Sprague Electric Co., 233 Marshall St., North Adams, Mass. 01247.

SPRAGUE®

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THE BROAD-LINE PRODUCER OF ELECTRONIC PARTS

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Using spot ties for wire harnessing?

HERE IS THE
GUDEBROD SYSTEM "S"

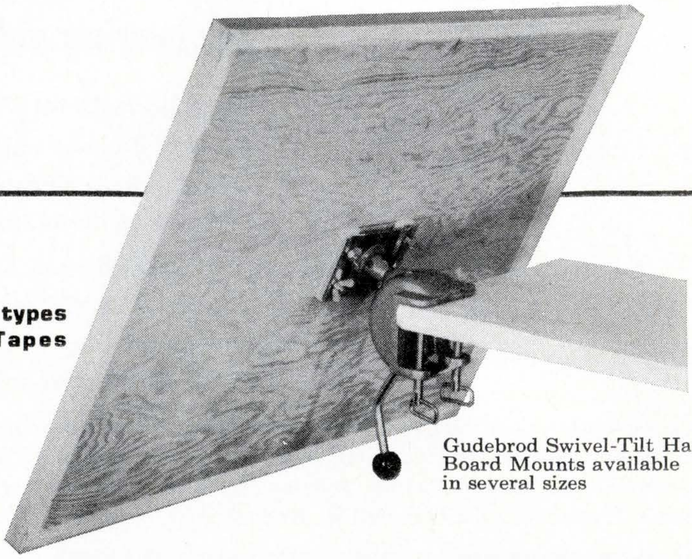
—SPEEDS THE WORK—SAVES MONEY, TOO!

GUDE-TIES CUT LENGTHS—Specifically produced for spot knotting these handy cut lengths of Gudebrod Flat Braided Lacing Tape are dispenser packaged for one hand, speedy withdrawal. Available in 6″, 8″, 10″, 12″, 15″, 18″, 20″ and 22″ lengths (other lengths on order). Meet or exceed MIL-T Specs, no-slip knots hold firmly without cutting insulation.

GUDE-SNIPS—These palm-of-the-hand snips cut cleanly, easily. For right or left hand use, spring action, DuPont Teflon bearing. Allow operator to have free use of fingers without constant reaching for knife or shears. Save motion, save time.

GUDEBROD SWIVEL-TILT HARNESS BOARD MOUNT—Balanced, two dimensional action brings every section of the harness within easy reach. No stretching, no straining. Knots are tied in an easy, natural position. Cuts fatigue—speeds work.

Here you have the Gudebrod System "S" for spot tie lacing, based on the high quality, high speed Gudebrod Lacing Tape—if you're interested in saving money while speeding the harness work, get in touch with us. (For continuous tying, ask about System "C".)



Gudebrod Swivel-Tilt Harness
Board Mounts available
in several sizes

Available also in other types of Gudebrod Lacing Tapes

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Electronics Division

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Circle 5 on Inquiry Card

THE
ELECTRONIC
ENGINEER
August 1969 Vol. 28 No. 8

The undergraduate . . . or how come we can't talk to one another? 35

A farce on engineers and communication, complete in one act.
By Roger D'Aprix

Understanding solid-state or static relays 43

Surprisingly, they are not in competition with other relays, but rather they created their own unique applications.
By Michael Joyce

Calibration curves for temperature sensors 49

These graphs show the characteristics of thermocouples for high and low temperatures and of resistor thermometers for cryogenic temperatures.

Temperature measurement guide 51

What are the calibration points for heat sensors? What instrument will be best for a given temperature range? The answers to these questions and many more are contained on this multi-colored wall chart. Remove your copy now, lest you forget.

CAD Graphics: Circuits made to order 59

I dreamt that I was going mad, designing circuits, pad by pad. I screamed, and woke, than thanked the dad, whose fertile mind had fathered CAD.
By Stephen A. Thompson

Cabling fast pulses? Don't trip over the steps. 71

Modern instrumentation can give you pulses with gigahertz bandwidths. And how do you pipe them around your system? With coax, of course. But watch out, because what goes in doesn't necessarily always come out.
By Thad Dreher

IC Ideas 79

- Op amps give mutually-exclusive digital sequencing . . By M. Strange
- Threshold converter preserves waveform symmetry . . By G. S. Oshiro
- Simple circuit speeds digital system checkout . . . . . . By J. R. Jacobs

New, cheaper waveforms at WESCON 88

The cost of a function generator is becoming comparable to that of an oscillator.

General-purpose scope has 250-MHz response 93

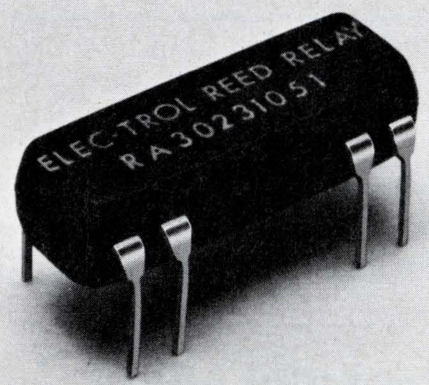
Right now, monolithic ICs in the vertical amplifier limit this instrument to 250 MHz. But improvements in LIC technology would let you use this same scope to 500 MHz.

COVER

In case you haven't noticed, test equipment operating speeds are getting faster every day. But what does high speed mean in an oscilloscope? Well, for one thing, it means vertical amplifiers with response to hundreds of megahertz. For another, it means sweep circuits capable of triggering at such rates. But high speed also means a crt that can display the information for you to see. Our cover shows the deflection region of such a crt. In effect, the tube is a traveling-wave device, with a bright trace on a large viewing area, and a high-sensitivity response to beyond 500 MHz. It is used in a new Hewlett-Packard scope, which is described in the story that starts on page 93.

INTRODUCING

THE DIP REED RELAY



AN IC COMPATIBLE REED RELAY IN A DUAL INLINE PACKAGE

The DIP RELAY can be driven directly from your IC.

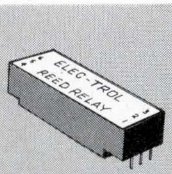
- draws 10 milliamps from 5 volt logic
- switches up to 10 watts, .5 amp. max., 100 VDC max.
- fits directly into a standard 14 pin DIP receptacle
- switches in less than 500 μ seconds
- tested to 500 million operations
- available with 1 form A contact and 5, 6, 12 and 24 VDC coils

This totally encapsulated relay meets military environmental specifications with a temperature range from −55°C to +85°C.

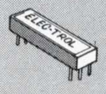
Automated testing and production with 100% inspection from the individual contacts through the completed relay assures quality performance at low cost.

ELEC-TROL FILLS THE GAP...

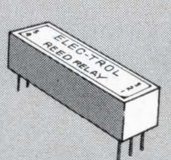
Elec-Trol's Product Line is made up of 96 standard catalog Reed Relays as well as 3000 custom designs.



MILITARY



PICO



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Reshaping concepts in electronic components and systems!

Circle 6 on Inquiry Card

EE

The Electronic Engineer

Vol. 28 No. 8 August 1969

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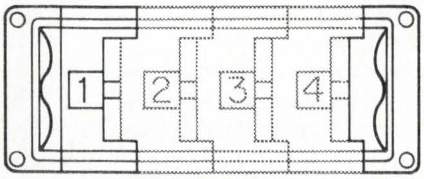
The Chilton Electronics and Instrumentation Group ● The Electronic Engineer ■ Instruments and Control Systems ■ Instrument & Apparatus News ■ Medical Electronics News ■ Electronic Component News

Never underestimate the power of the thumb.

Over ten years ago, Digitran developed the thumbwheel switch. This new device created new importance to the thumb by giving it (and the guy it belongs to), a new power... the power of accurate switching control.

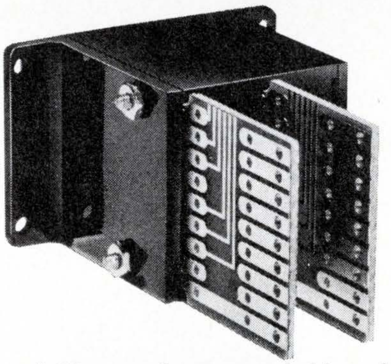
Perhaps a good name might have been **"ACCU-SWITCH,"** for the compact and cleverly designed product had a nice, solid, stop-action between each position. This made it very difficult to switch to the wrong position. The audible and definite click, click, between each position was, and still is, quite an improvement over most other types of switches (even copycat switches).

Maybe they should have named it **"MODU-SWITCH,"** because the second unique feature was the simple way one switch could be added to another to form as many units in a row as the owner of the thumb desired. Each switch fits perfectly together in building-block fashion with standard end sections containing back panel mounting holes.



"COMPAC-SWITCH" might have been an excellent name as well, since Digitran's design allowed the engineer to reduce the size of his panel. We'd like to see someone mount four typical rotary switches in a row and consume only 2.76″ in length X 1.15″ in height, not to mention the space savings behind the panel. Didn't rotary switches go out with high button shoes?

How about **"VERSI-SWITCH,"** because the entire stationary commutator and termination system on Digitran's switches are produced on printed circuit boards. It staggers the circuit and packaging engineer's imagination on what he can do, (or have us do) to the P/C board on the back end of these switches. You can plug them into a P/C connector. You can wire to them. You can interconnect easily from board to board. You can have extended boards with all kinds of additional circuitry on them. (i.e.: IC's, discretes, etc.) You can have "wire wrap" terminals and, oh yes, Digitran switches are available with replaceable lighting to illuminate each position.



Actually, the boss, who dreamed up the name Digitran, liked the names listed below best and although there are many other variations, the two major product lines are as follows:

DIGISWITCH® medium sized—sealed or unsealed 8, 10, 12 or 16 positions

MINISWITCH® miniature—sealed or unsealed 8 or 10 positions

For those of you who are still not filled in on the details of our thumbwheel switches, please write and we will send you our new complete catalog. Convince us that you have a project that can use our switches, and you can pretty easily put your thumb on a free sample.

THE DIGITRAN COMPANY

A Subsidiary of Becton, Dickinson and Co. B-D

855 So. Arroyo Pkwy., Pasadena, Cal. 91105 Phone (213) 449-3110 TWX 910-588-3794

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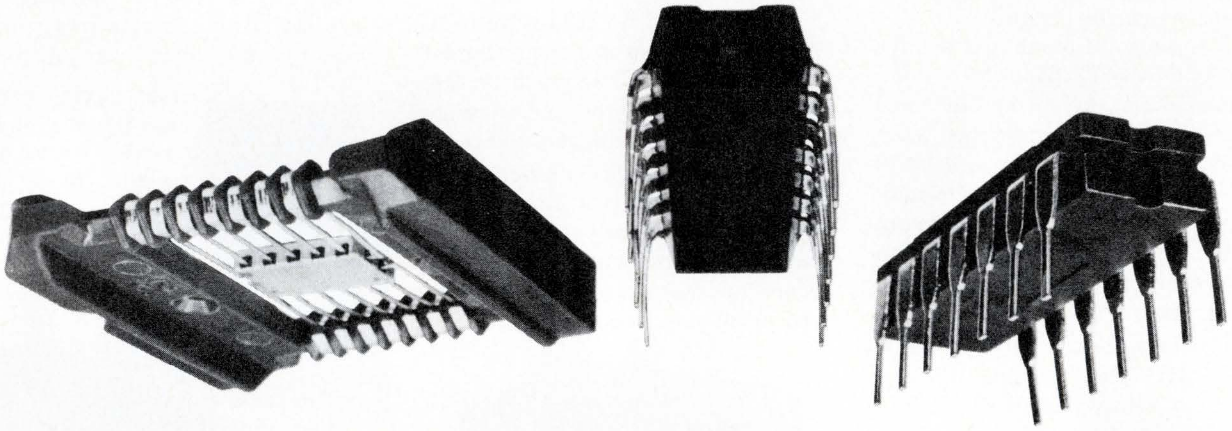
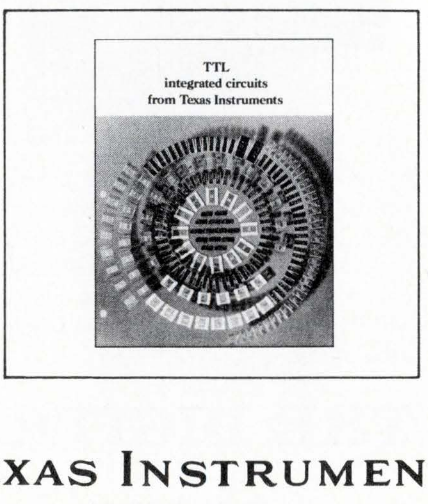
The Choice is TTL.

TI announces the "one-shot" heard 'round the world.



(Listen. It could revolutionize your designs.)

The pulse width of this new monolithic TTL monostable multivibrator is variable from 40 nanoseconds to 40 seconds. Stability is ±0.2%. Tagged SN74121, it is primed to trigger off 50 nanosecond pulses or from slow ramps up to one volt per second. Full fan-out to 10 loads and fully compatible with all Series 54/74 ICs. The new "one-shot" comes in a choice of packages: flatpack and plastic or ceramic dual-in-line. Immediate delivery and reasonably priced. In 100-999 quantities, the plastic dual-in-line is $4.40.



TTL
integrated circuits
from Texas Instruments

Deploy the SN74121 and start your own revolution. For data sheet, application report and a copy of our new 80-page TTL brochure, circle 182 on the Reader Service Card or write Texas Instruments Incorporated, P. O. Box 5012, M. S. 308, Dallas, Texas 75222.

TEXAS INSTRUMENTS
INCORPORATED

EE EDITORIAL

Electronics on the moon

Everybody participated: the astronauts, the people involved in the Apollo project, the public in general. But for electronic engineers the participation was greater—because there was a piece of electronics on the moon. Whether it was the computation of the trajectory, or the picture of it all in your living room, much of what happened could not have taken place were it not for electronics.

The Electronic Engineer magazine extends to NASA, to the astronauts, and to everyone of our readers who was involved in this project, our warmest congratulations. Two American astronauts landed on the moon, and the product of your skills was with them. It was a moment of pride, of reflection, of reassurance. Yet we all know that the technology that took the astronauts to the moon and back can perform similar feats here on earth, if we apply to it the sense of national purpose that backs the space program.

The ghost strikes again

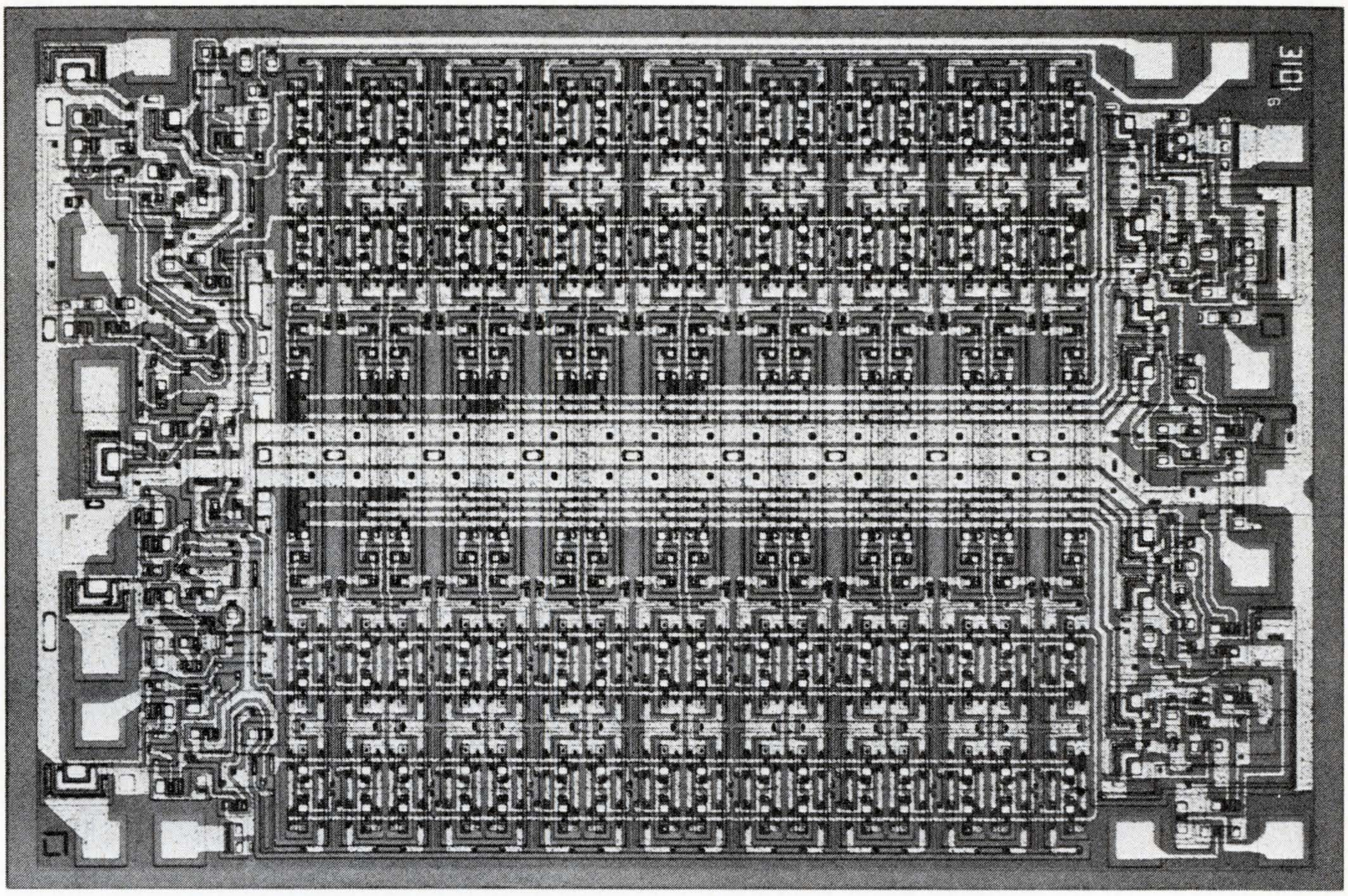
Perhaps you have never met it, but this ghost is real. It has appeared under different names during the past years, names such as MMRBM, Skybolt, Dynasoar. Now it's called MOL. Why the Department of Defense cancelled the Manned Orbital Laboratory is not clear, but it probably doesn't have much to do with the Nation's defense. The pressure of Congress on DOD's budget was so great that a program had to be cut, and MOL was the scapegoat.

Will the 1.3 billion dollars already spent on MOL find their way into the manned space station planned by NASA? We don't know, but in the meantime, over 2000 engineers displaced by MOL must find new jobs.

Yet we did see an encouraging sign in the aftermath of this cancellation. Both major companies involved, MacDonnell Douglas and General Electric, went to great lengths to help their people find new jobs. Both companies helped them by copying resumes, and organizing interviews. General Electric, in particular, kept most employees on its payroll for at least four weeks, and organized a sizeable "outplacement center" for which it footed most of the bill.

But the ills of our profession remain, and the old wounds are still open. Again we see the spectrum of the undersold houses, the interrupted educations, the 50-year-old managers who cannot find other jobs for $25k. Perhaps the only solution is to realize that defense jobs pay more than others, and to enforce a savings plan with each of these jobs.

Alberto Socolovsky
Editor



Introducing the Intel Schottky Process Model 3101 Bipolar Scratch Pad Memory. 64 bits—16 x 4/fully decoded /50 nanoseconds access time/OR-tie capability/simple memory expansion through chip select input/6 milliwatts per bit power dissipation/16 lead D.I.P.

If you are interested in a winner, too, call your nearest Intel distributor.

Intel LSI memory circuits are available from 40 outlets throughout the United States and Canada. Call your local Intel distributor, Cramer Electronics or Hamilton Electro Sales, for instant service. If it is more convenient, you may write or call us collect (415-961-8080).

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Circle 9 on Inquiry Card

ION bombardment used as a tool

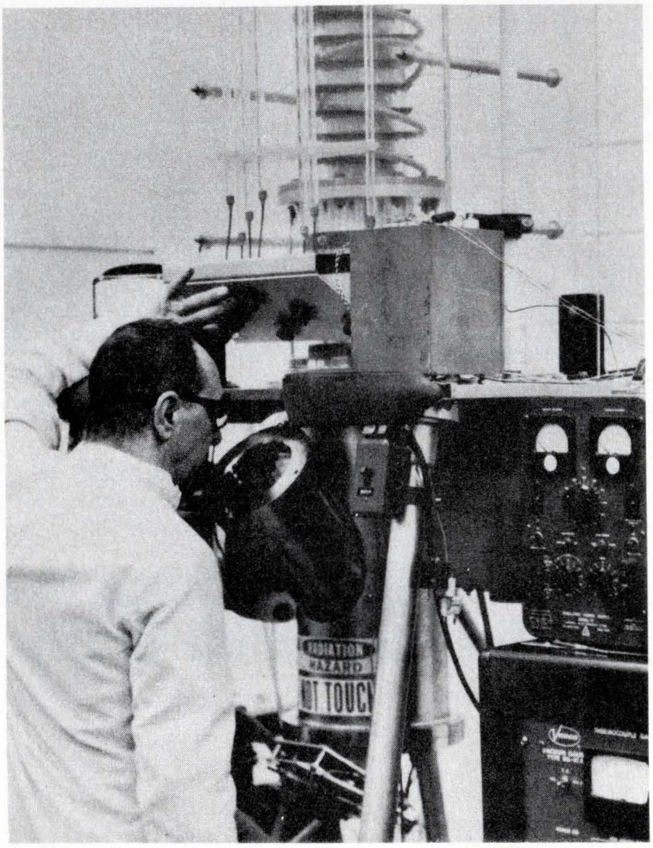
Kollsman Instrument Corp. is using a linear accelerator for precision machining of optical surfaces by argon ion bombardment. The precise removal of material involves applying an eroding beam to the target surface. The technique, called ion beam figuring is an alternative to the production by hand of precision aspheric lenses for optical instruments and telescopes. Other applications extend to turbine blades, bulk-effect semiconductor devices, and thin-film resistors. The surfaces of glass, fused silica, and a ceramic of low thermal expansion coefficient have been eroded. Erosion as shallow as 50 Å (2 ten-millionths of an in.) has been achieved.

The company has been able to use the accelerator to produce a diffraction limited paraboloidal mirror surface whose figure is optically correct to within 1/20 wavelength of visible light (1 μin.), using mechanical scanning methods.

The workpiece to be finished is placed in a vacuum chamber and is manipulated by a mechanical workpiece motion-control system. The ion beam is accelerated by an electric field to strike the workpiece at closely controlled positions. Each position is one of a number, pre-programmed by technicians on a point-to-point basis. Kollsman plans to computerize the process.

The precisely controlled beam energy, accelerator voltage, angle of incidence, and other factors allow the accelerated ion to erode material atom by atom.

Erosion depth is controlled by an optical interferometer which generates optical reference marks and in more advanced systems error signals to control the ion beam. The size of workpieces is limited only by the dimensions of the vacuum chamber of the accelerator. Present facilities figure items with an initial surface of up to six inches in diameter.



Kollsman Instrument Corp., Syosset, N. Y., is using this linear accelerator for precision machining of optical surfaces by ion bombardment. Argon ions are accelerated inside the column at the top of the picture and directed at the surface of the workpiece. In the picture, Kollsman technician Fred Sassone focuses the ion beam while viewing the workpiece through the porthole.

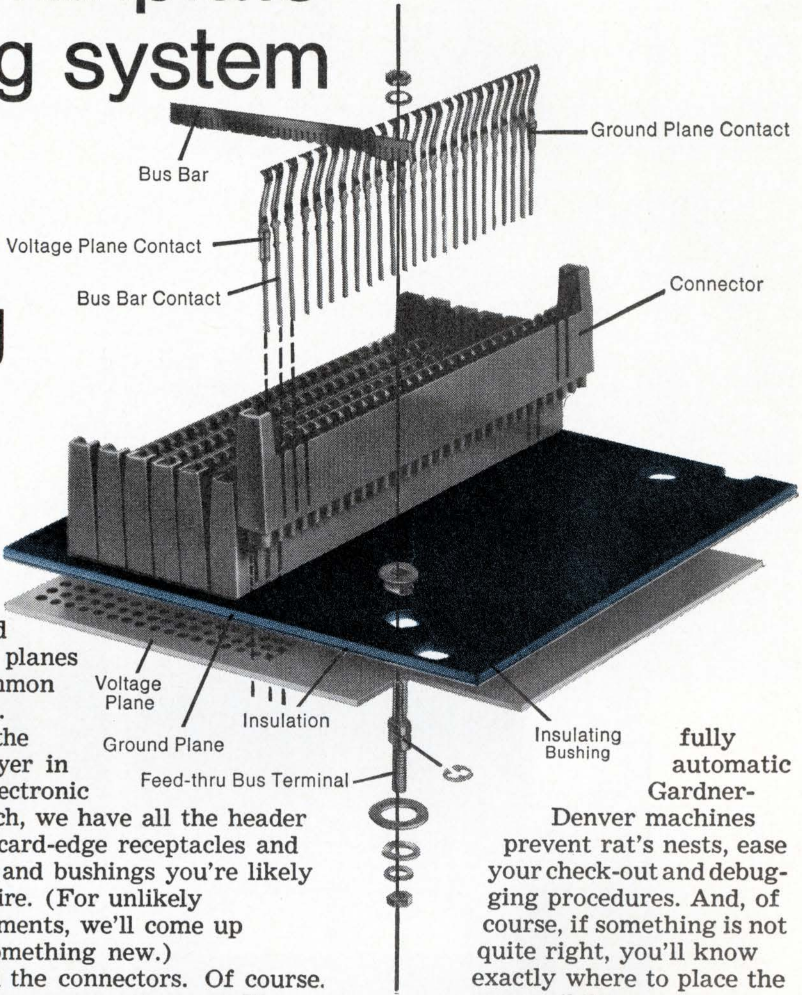
Surface chemistry aids contact reliability

NASA-sponsored metallurgists investigating low-energy electrical contacts used in short duration (less than 1000 cycles) applications at the Columbus Laboratories of Battelle Memorial Institute, conclude that specific types of electroplated contacts are more reliable than most wrought ones because of inherent lubrication.

Battelle's William Abbott, who headed research on the aerospace contacts, says the lubrication is the result of unique surface chemistry. To produce the surface effect, he points out, it is necessary to carefully control this chemistry while the plating is being deposited on

(*continued on page* 13)

How our Variplate™ connecting system keeps your fifty-cent IC's from becoming four-dollar headaches.



IC's don't cost much. Until you use them. You can buy, say 20,000 IC's for the innards of a compact computer, packed in the transistor cans, flat packs, or Dual-in-Line (DIP) packages, for a unit cost of less than fifty cents.

Great.

But then you have to connect them.

Not so great.

Because those 20,000 IC's have anywhere from 200,000 to 280,000 leads waiting to be connected. Fine leads. Closely spaced. And, of course, you want to pack the IC's as densely as possible. So it's really no surprise that your *in-place* cost of an IC can climb to $4.00.

Fortunately, we have a system that can keep your in-place cost down: the Variplate interconnection system.

With the Variplate system, you can pack those IC's—and all the pc boards and other components you have—as densely as the application demands. You can do it on automated equipment—and we'll even do the wiring for you.

All the components you need.

The system begins with the base plate, a self-supporting structural member. It carries the insulated contact modules, accommodates secondary components and hardware, and provides for mounting to support framework.

The plate can be a single metal sheet that provides a ground plane, or it can be a sandwich that provides both voltage and ground planes for common bussing.

For the next layer in your electronic sandwich, we have all the header plates, card-edge receptacles and guides, and bushings you're likely to require. (For unlikely requirements, we'll come up with something new.)

And the connectors. Of course. Our own respected Varimate™, Varicon™, and Varilok™ connectors, or standard fork-and-blade, terminal stud, card-edge, or bus strip contacts. Your choice.

No holes barred.

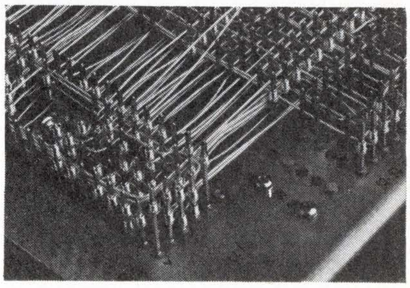
We put all these components together in any size, any shape, and almost any density of package you require. Plates can be any size. Contacts can be spaced on .100″, .125″, .150″, or .200″ centers, in square or offset grids—on non-standard configurations where you need them.

What you get is a solid electrical and mechanical foundation for your electronic network, so precisely made that any automated assembly equipment can take over from there.

However.

You'll save time and money if you let us go one step further and wire your network for you. Our fully automatic Gardner-Denver machines prevent rat's nests, ease your check-out and debugging procedures. And, of course, if something is not quite right, you'll know exactly where to place the responsibility.

Altogether, it's quite a system. And worth all the work we've put into it. Because if we can save you just a nickel on the cost of installing each of your 20,000 IC's you can add a thousand dollars to your company's profits.



We're sure we can save you that nickel, and more. For more information, write, wire, call, or TWX us for our Variplate interconnecting systems catalog. Elco Corporation, Willow Grove, Pa. 19090. 215-659-7000; TWX 510-665-5573.

ELCO Variplate Connectors

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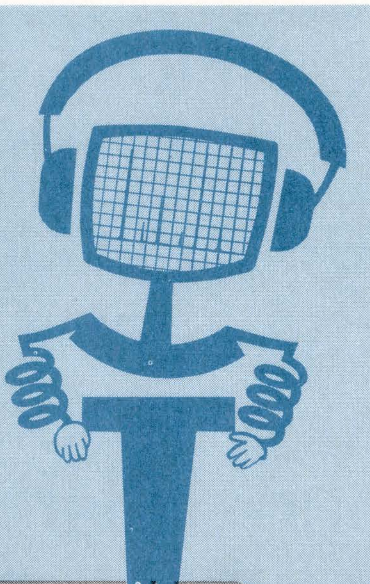
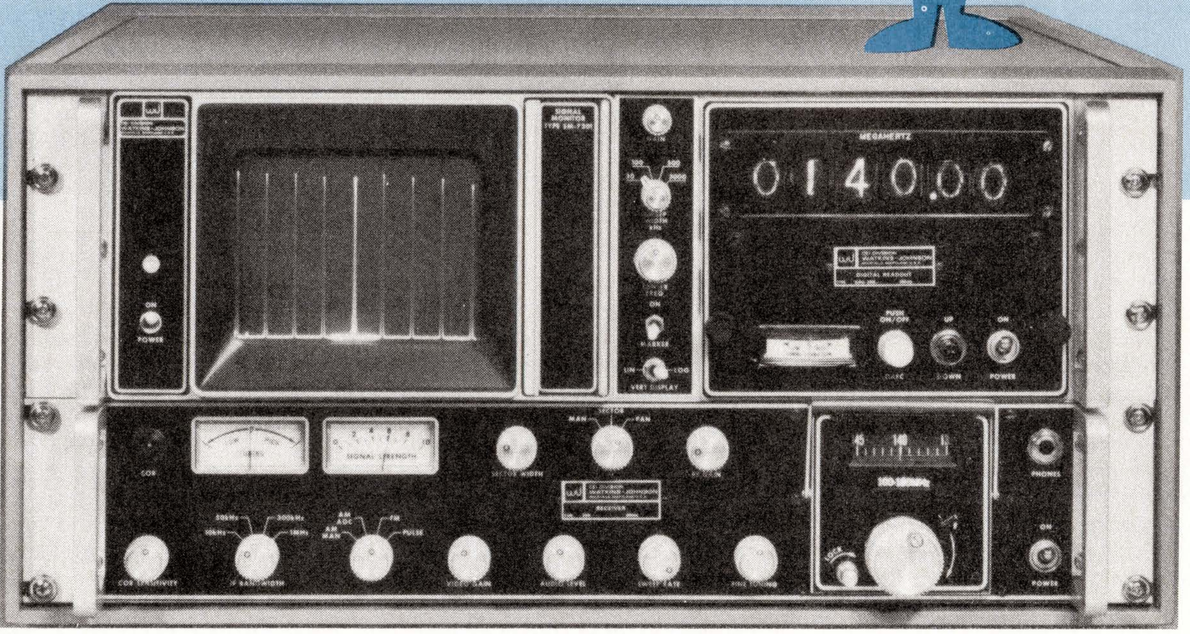
THE INCOMPARABLE PAN MAN RECEIVER



Unique performance features in a low-cost sweeping receiver that is compact and versatile

- **Receives AM, FM, pulse signals, 30 - 300 MHz**
- **High dynamic range**
- **Low noise**
- **High spurious signal rejection**
- **Digital readout of tuned frequency with Digital Automatic Frequency Control**
- **Versatile: for airborne, ship, mobile and fixed site applications**
- **Compact: only 8¾ inches high by 19 inches wide**
- **Costs a fraction of what you'd expect**



W-J reaffirms its leadership in the surveillance receiver field with the introduction of a superb new sweeping receiver system: the RS-160.

The system consists of the Type 205 Sweeping and Manual Receiver, the DRO-308 six-digit Frequency Readout with DAFC (digital automatic frequency control) and the SM-7301 five-inch Signal Display with beam intensification.

The receiver covers the 30-300 MHz range with four plug-in tuners. RF preselection consists of four tuned circuits in two coupled pairs which are voltage tuned using varactors. These circuits provide a high order of IF and image rejection and reduce intermodulation for signals outside the RF passband. The RF amplifier consists of a dual gate MOSFET followed by a junction FET in a cascode configuration for maximum selectivity. This configuration also provides a high reverse isolation to the local oscillator signal which is typically less than one microvolt at the RF input. A double-balanced mixer provides improved intermodulation characteristics, IF rejection and local oscillator leakage.

Each module is designed to operate with others in a system offering maximum versatility, compact, attractive design and low cost.

World's largest selection of receiving equipment for surveillance, direction finding and countermeasures

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Circle 11 on Inquiry Card

Picturephone serves as a computer-driven display

The Bell System's Picturephone—designed to permit face-to-face telephone conversations—is being put to use at the Westinghouse Electric Corp. as a desk-top information center. Under the experimental system, a Westinghouse executive can dial a telephone number and obtain the wanted information in graphic form on the television-like Picturephone screen. The information is retrieved from a computer at the Westinghouse Tele-Computer Center in Braddock Hills in suburban Pittsburgh. The program is part of a six-month Westinghouse trial of Picturephone service in cooperation with Bell. Forty Picturephone sets are installed for the trial period in Westinghouse offices and conference rooms in Pittsburgh and New York.

Using the Picturephone, a user can dial a number to obtain domestic, Washington and International news items, or information on foreign currency exchange rates. Also, he can get late stock market reports or daily reports on special testing programs. The computer also stores Westinghouse Broadcasting audience rating information and reports on the company's international operations.

Obtaining the information is as simple as making a phone call. The user dials the computer's phone number and then dials his own extension number to identify who is calling. The computer then displays on the 5½ x 5 in. Picturephone screen an index of the kinds of information available. The user then dials the number indicated for the data he wants.

Westinghouse management systems personnel adapted the Picturephone to the computer display application, using additional equipment furnished by Bell. Programming was done by the Westinghouse information systems laboratory and the Tele-computer Center.

The information is fed to the computer from several sources. The company's public relations department and wire service provide news items. Foreign currency data is supplied by a bank; and stock information, updated hourly during trading on the New York Stock Exchange, is supplied by a brokerage.

The computer can even be selective in what information it gives to which caller. When a line executive calls for instance, the index lists a number he may dial to obtain particular operating data concerning his own organization. Other callers, however, are not shown the index number. Should they dial the number, the computer politely informs them they have made an "input error."

A phone call to a computer provides late stock market information to an executive of the Westinghouse Electric Corp., as he takes advantage of a system that connects a computer with a Picturephone in his office.

Surface chemistry aids contact reliability (continued)

the contact surface.

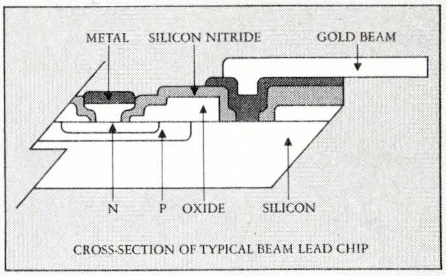
This lubricating film, believed to be an organic polymer co-deposited with unique types of electroplates, provide lower friction, much lower wear rates, and much better contact resistance stability — all which makes for greater reliability.

Although tarnishing of gold electro-deposits is not a problem, oxidation resistance at high temperature (200°C) continues to be a major limiting factor in contact performance. This is due mainly to substrate diffusion of the base metal to the connector surface and subsequent oxidation.

In their search for stable base metals, the scientists evaluated copper and nickel. Neither was found to be satisfactory for 200°C service. However, they do report that rhodium appears to have great potential for use as a barrier material.

Everybody talks about beam lead.

This is the dawning of the age of the leaded chip. In other words, sports fans, August is the month Raytheon uncorks beam lead, and the old semiconductor business will never again be the same.

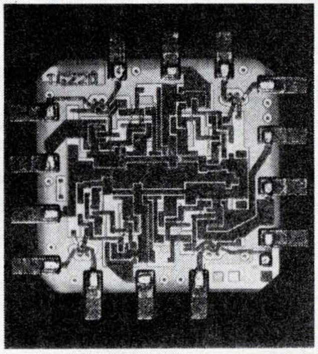


CROSS-SECTION OF TYPICAL BEAM LEAD CHIP

☐ Simply meaning that now you can buy semiconductor chips with leads already formed and integrally attached. This lets you control packaging, save system assembly time and boost reliability.

☐ Take a for instance. With a beam lead chip, bonding's a step, not a career. Every lead's bonded at once, whether you're working with diodes or LSI.

☐ And the chip stays healthier. Your operator can mash down on those little leads and cook them to a turn. The chip sits there, to one side of the action, calm, cool and uncracked.



☐ But there's more. Every beam lead chip sports a Silicon Nitride passivation coat to give it complete hermetic sealing at all junctions. Raytheon's wafer separation process exorcises that evil old chip-cracker, the scribe. Chips are separated by a delicate anisotropic etching process that eases those little babies apart with TLC. No more hidden cracks to surprise you in final testing, or after your system's been fired up for a week. And just to sweeten the pot, in case you *really* hate surprises, we can provide 100% chip testing against all AC and DC parameters at −55 to +125°C.

But we deliver it.

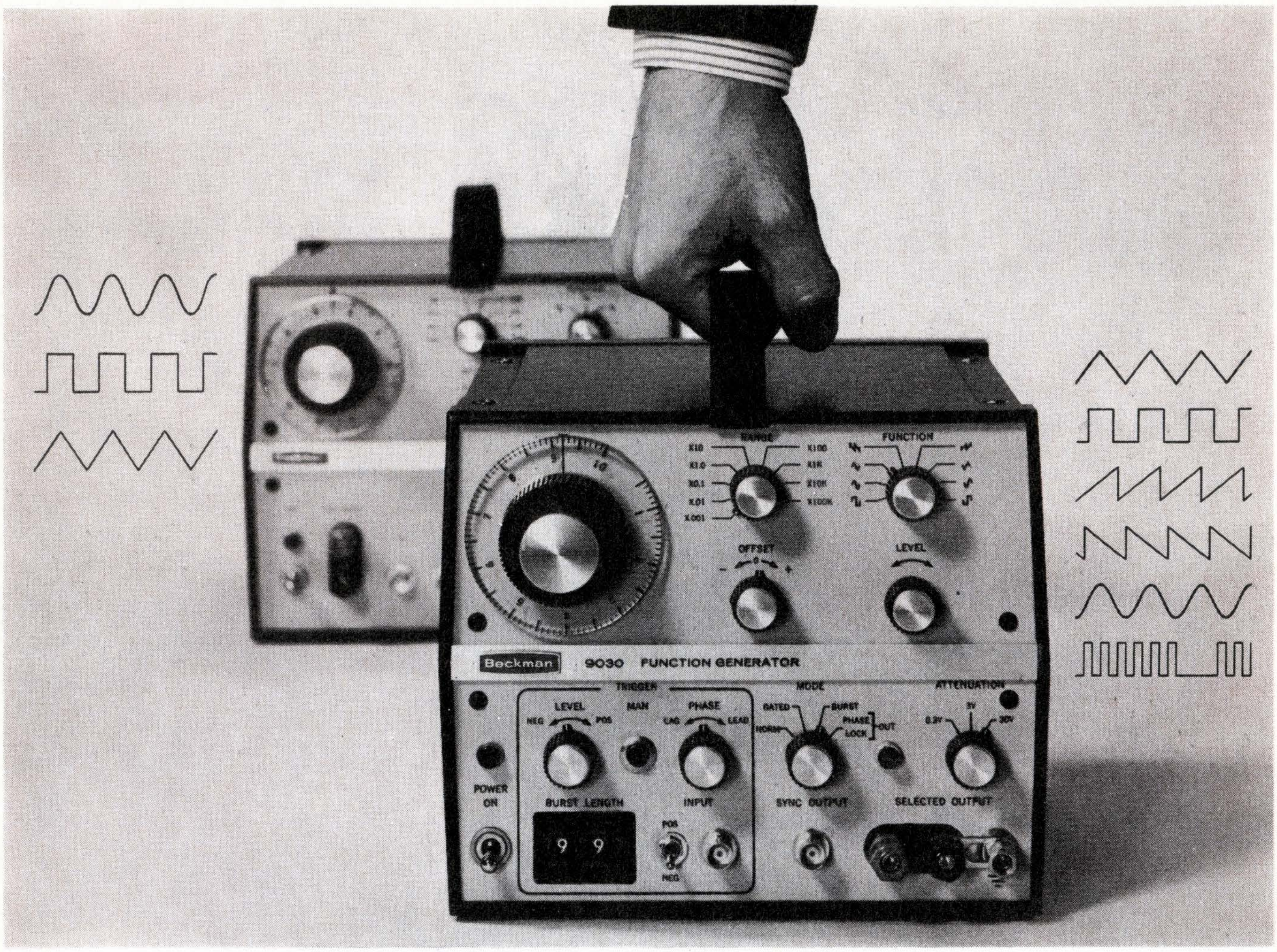
Type No.	Device (−55 to +125°C)	100-999
RM709	Op amp	$6.80
RG250	Expandable quad 2 input OR gate	4.05
RG220	Quad 2 input NAND gate	4.05
RG240	Dual 4 input NAND gate	4.05
RG200	Expandable single 8 input NAND gate	4.05
RG230	Quad 2 input OR expander gate	2.60
RF200	JK flip flop (AND inputs)	6.00
RF100	Dual JK flip flop (separate clock)	7.10
1N914	Fast switching diode	1.25
1N3600	High conductance fast switching diode	1.30
2N2484	Low level amplifier NPN	1.75
2N2605	Low level amplifier PNP	2.15

In segments of 5 chips only.
Commercial grade units at lower prices; delivery to start 4th quarter 1969.

☐ We're kicking off our Beam Lead Derby with an even dozen types, available in quantity from our exclusive beam-lead-franchised distributors, Avnet Electronics and Cramer Electronics. Later on you can buy our whole line in beam lead... TTL, DTL, linears, transistors, diodes.

☐ After that, onward and upward to multi-chip arrays, MSI, LSI and so on. Proving once again the wisdom of doing business with the company that puts its chips where its mouth is. Send for data, including Raytheon-approved list of sources for beam lead bonders. Raytheon Semiconductor, Mountain View, California. (415) 968-9211.

Circle 12 on Inquiry Card



Take a good look...

at the Beckman Models 9010 and 9030 Function Generators.

If you're looking for an exceptional low-cost function generator, take a look at the Beckman 9010; a tough little competitor (sine, square, and triangular waves at 0.005 Hz to 1 MHz, with external VCO control and dc offset for $495.00).

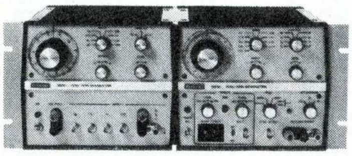
But if you want much more, and your requirements include:

- four basic functions *and* their complements, with an external GATE control mode, continuously variable over a frequency range from 0.0005 Hz to 1 MHz,
- eight unipolar and bipolar outputs, adjustable to 30 volts p-p in three attenuator steps, in addition to dc offset and external VCO control,
- a BURST mode to generate 1 to 99 positive and negative waveforms upon receipt of a trigger input,
- a PHASE LOCK mode to synchronize the instrument in frequency and phase with an external signal from 10 Hz to 1 MHz,

then take a *good* look at the Model 9030 (only $895.00).

Like the 9010, the 9030 is rugged enough for any production or bench environment. It's drip proof, dust proof and shock proof, and stackable, portable and rackable. (8½" H x 7" W x 10" D.)

For your system or component testing, use a 9010 to initiate the burst functions of the 9030 – and rack them together with standard Beckman hardware.



Now that you've seen what the 9010 and 9030 Function Generators can do for you, there's no need to keep looking. Just contact your local Beckman office, sales representative or factory direct. (A special 3½" rack chassis is available for both instruments upon request.)

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ELECTRONIC INSTRUMENTS DIVISION
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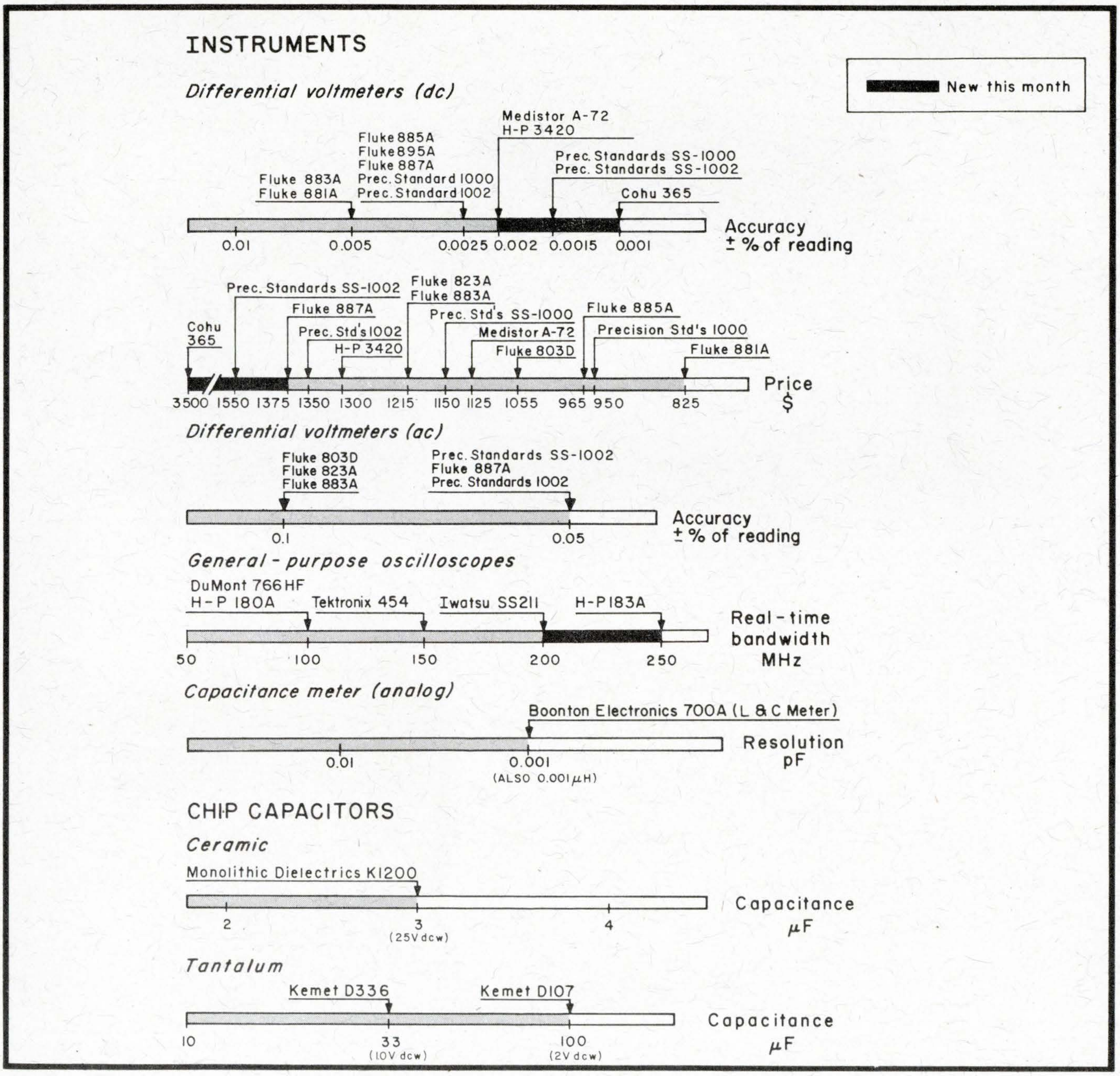
EE FOREFRONT

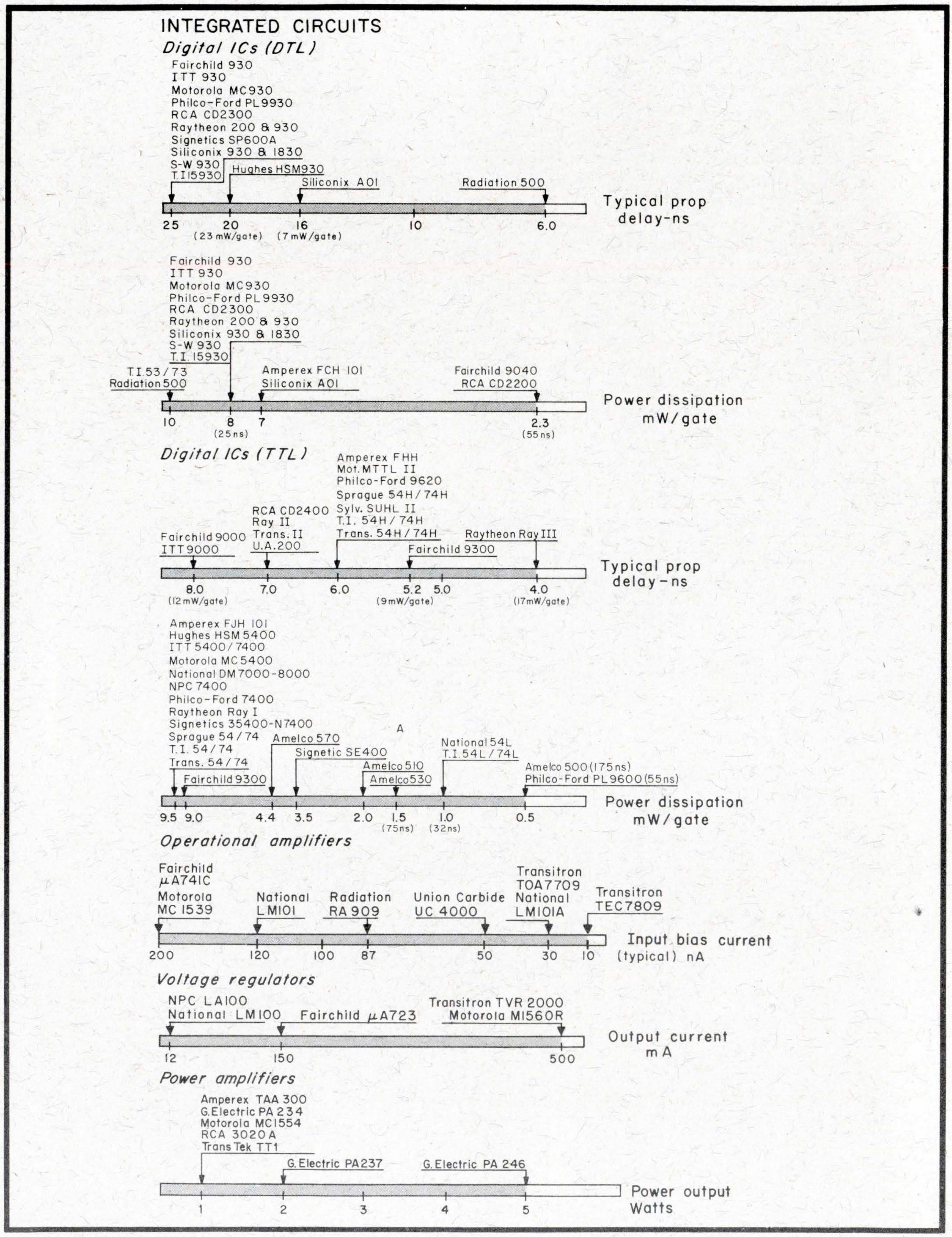
The EE Forefront is a graphical representation of the practical state of the art. You will find here the most advanced components and instruments in their class, classified by the parameter in which they excel.

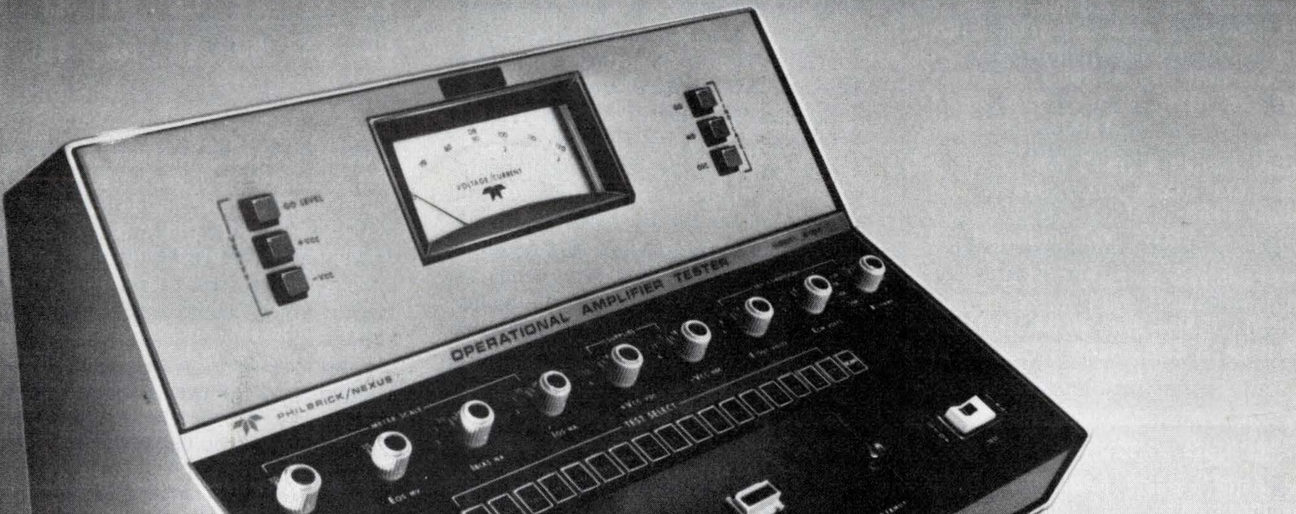
A word of caution

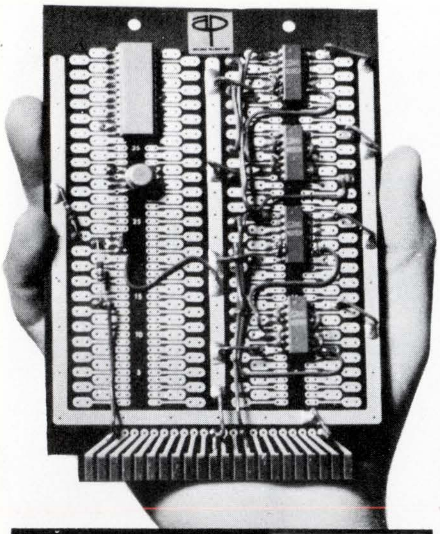
Keep in mind the tradeoffs, since any parameter can be improved at the expense of others. If there is no figure-of-merit available, we either include other significant parameters of the same products, or we provide additional bar graphs for the same products.

Do not use these charts to specify. Get complete specifications first, directly from the manufacturers.




INTEGRATED CIRCUITS
Digital ICs (DTL)
Fairchild 930
ITT 930
Motorola MC930
Philco-Ford PL9930
RCA CD2300
Raytheon 200 & 930
Signetics SP600A
Siliconix 930 & 1830
S-W 930
T.I 15930
Hughes HSM930
Siliconix A01
Radiation 500
25
20
(23 mW/gate)
16
(7 mW/gate)
10
6.0
Typical prop delay-ns
Fairchild 930
ITT 930
Motorola MC930
Philco-Ford PL9930
RCA CD2300
Raytheon 200 & 930
Siliconix 930 & 1830
S-W 930
T.I. 15930
T.I.53/73
Radiation 500
Amperex FCH 101
Siliconix A01
Fairchild 9040
RCA CD2200
10
8
(25ns)
7
2.3
(55ns)
Power dissipation mW/gate
Digital ICs (TTL)
Fairchild 9000
ITT 9000
RCA CD2400
Ray II
Trans. II
U.A.200
Amperex FHH
Mot. MTTL II
Philco-Ford 9620
Sprague 54H/74H
Sylv. SUHL II
T.I. 54H/74H
Trans. 54H/74H
Fairchild 9300
Raytheon Ray III
8.0
(12mW/gate)
7.0
6.0
5.2
(9mW/gate)
5.0
4.0
(17mW/gate)
Typical prop delay-ns
Amperex FJH 101
Hughes HSM5400
ITT 5400/7400
Motorola MC5400
National DM7000-8000
NPC 7400
Philco-Ford 7400
Raytheon Ray I
Signetics 35400-N7400
Sprague 54/74
T.I. 54/74
Trans. 54/74
Fairchild 9300
A
Amelco 570
Signetic SE400
Amelco 510
Amelco 530
National 54L
T.I. 54L/74L
Amelco 500 (175ns)
Philco-Ford PL9600 (55ns)
9.5
9.0
4.4
3.5
2.0
1.5
(75ns)
1.0
(32ns)
0.5
Power dissipation mW/gate
Operational amplifiers
Fairchild
μA741C
Motorola
MC 1539
National
LM101
Radiation
RA 909
Union Carbide
UC 4000
Transitron
TOA7709
National
LM101A
Transitron
TEC7809
200
120
100
87
50
30
10
Input bias current (typical) nA
Voltage regulators
NPC LA100
National LM100
Fairchild μA723
Transitron TVR 2000
Motorola MI560R
12
150
500
Output current mA
Power amplifiers
Amperex TAA 300
G.Electric PA 234
Motorola MC1554
RCA 3020 A
Trans Tek TT1
G.Electric PA237
G.Electric PA 246
1
2
3
4
5
Power output Watts


OPERATIONAL AMPLIFIER TESTER
PHILBRICK/NEXUS
TEST SELECT
POWER
TEST SOCKET
Eout
PSRR
Ecm
Eos
Icc
CMRR
Gain
Ios
Ibias
Stability



EE SPEAK UP

La defi europeienne

Sir:

In your editorial "One electronic world," [**The Electronic Engineer,** May 1969, p. 7], you write of a so-called "salary gap between U.S. and non-U.S. engineers and state further that "an hour of design work costs far more in the U.S. than anywhere else in the world." You request American engineers to "enlist more the aid of the computer to stay competitive." In the rest of your editorial you allude very bluntly to how unfairly non-U.S., especially European engineers underbid their U.S. colleagues.

I would have appreciated if this editorial would have been written by somebody with somewhat better general knowledge. It is a deplorable fact that in this country people have only a very hazy and mostly false notion of anything outside the U.S. borders.

Apart from the regrettable allusion to an imaginary unfair competition between European and American engineers your statement is unfounded. Only in the rare case that an American firm orders a design from a European firm and pays the work from here in U.S. dollars may it be true. This is so because of the discrepancy between the official and the real currency relationships; those relationships were set by the U.S. after WW II and are the cause for the constant monetary crises we are facing in these days. You may or may not know that the U.S. dollar may be devalued together with a revaluation of some European currencies. This will enhance American exports, but will make it more expensive for American companies to buy European firms at half-price.

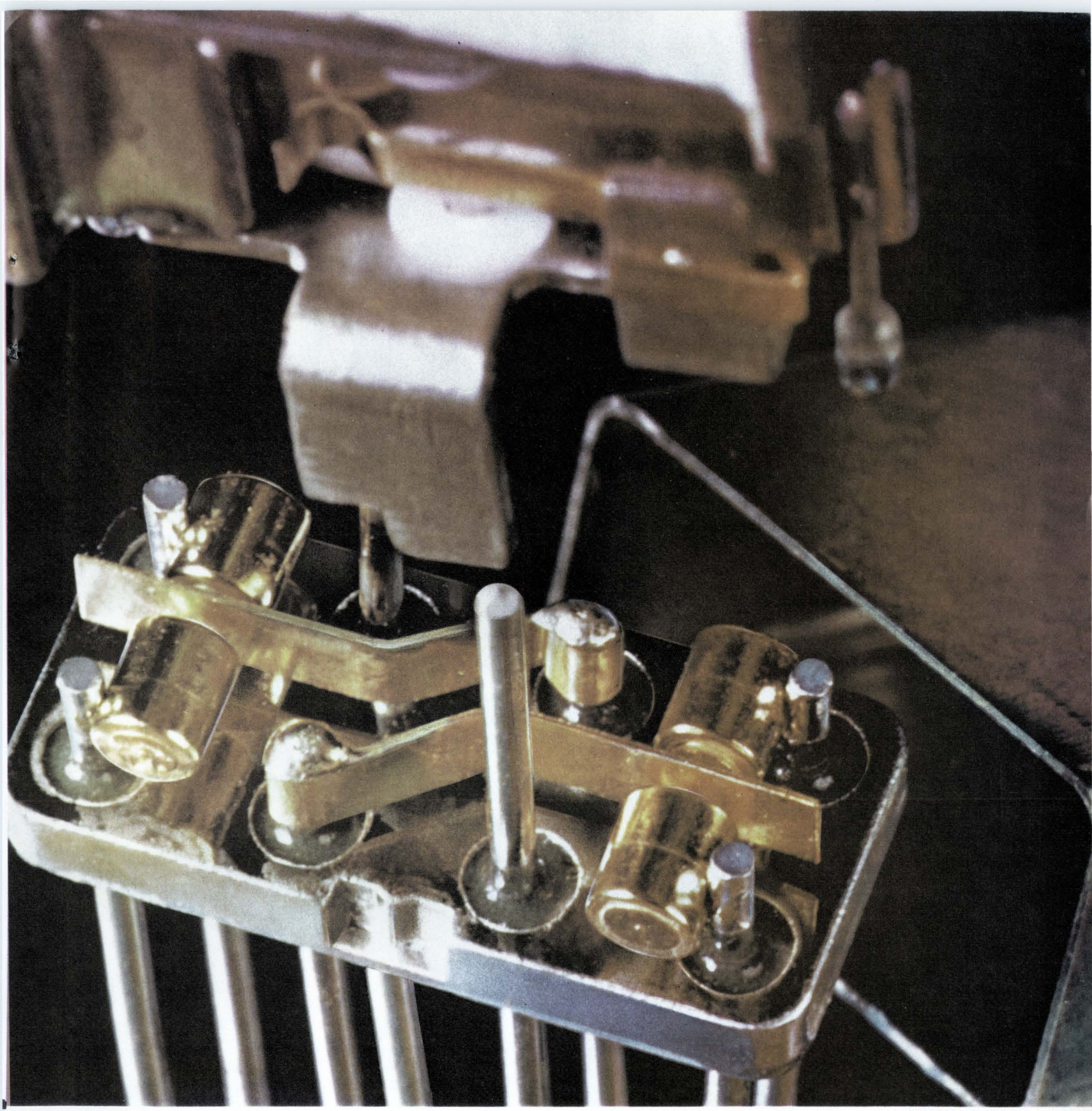
If there is any unfairness which needs pointing out then, is that American companies have been buying and are still buying a major part of the European key industry at half-price.

Why half-price? Taking the strongest European currency, the German mark, as an example: the official exchange ratio is 1:4, the buying power or real ratio is, however, only 1:1.5 to 1:2 at best. There is no difference in the salaries of a German graduate with a master's degree in EE who starts at 1600 marks a month and his American colleague who starts at $800; both can buy the same amount of goods for their respective salaries. A comparison on the basis of those salary figures only is misleading anyway, even if the real currency relationships are taken into account. A fair comparison must include the comparatively enormous social benefits which the European engineer enjoys. The continuous talk about the so-called "technology gap" between the U.S. and Europe tends to let people overlook the enormous "social gap."

If U.S. corporations would have to bear the social expenses European firms have been paying for decades, the picture would look entirely different. Just to enumerate a few examples: even in France, a country often considered here as comparatively poor, 4 weeks paid vacation go without saying; the American engineer with his 10 to maximally 15 days is probably at the bottom of the list in the whole world. Full medical and insurance coverage protects the European engineer: not only are all medical expenses taken care of including all medicines, sanatorium and spa for himself and his family members, but in case of sickness he continues to receive his full salary for at least six weeks. After that the insurance takes over. He is entitled to unemployment payments, pensions, etc. Job security is high; hiring and firing (the very words alone are frowned upon) is greatly restricted as far as the liberties of the employer are concerned. The minimum time for giving notice is six weeks, most engineers have more, up to one year. Layoffs need the consent of an employees' committee; an employee who was fired can go to special courts and if the employer cannot give a very good reason he must rehire the man or otherwise arrange himself with him.

American firms which used to hire a couple of thousand engineers expecting a government contract and lay them off a few weeks later because the contract did not materialize, would think twice about that if they had to pay the salaries for another six weeks to one year and would find themselves forced to change their behavior if only for monetary reasons. Paid lunch and breakfast pauses go without saying, and there are numerous stories about American firms having bought up a European firm which tried immediately to introduce progressive American methods, i.e. abolish the pauses only to find themselves facing a strike. Trying to fire the people thereupon the American managers found out about the laws preventing them. The damage which American managers have done to the good American renown in Europe is enormous. People in Europe just will not put up with treatment like that. When

(continued on page 23)



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Couch 2X relays are true 1/7-size, yet the contacts are as large or larger than many full and half-size crystal can units. Couch 2X relays meet MIL-R-5757D/19 and /30 specs in 1/25th of a cu. in. Design simplicity and oversize contacts assure the ultimate in performance. Each relay is fully tested. Ideal for missile and aerospace switching applications or wherever reliability in small space is of prime importance. Available in many terminal styles and a wide choice of mountings. S. H. Couch Division, ESB Incorporated, 36 River Street, Boston, Mass. 02126.

Write for Data Sheets No. 9 and No. 10 today.

ACTUAL SIZE

	2X (DPDT)	1X (SPDT)
Size	0.2" x 0.4" x 0.5"	same
Weight	0.1 oz. max.	same
Coil Operating Power	100 mw or 150 mw	70 mw or 100 mw
Coil Resistance	60 to 4000 ohms	125 to 4000 ohms
Temperature	—65°C to 125°C	same
Vibration	20G	same
Shock	75G	same

RUGGED ROTARY RELAYS *Dynamically and Statically Balanced*

S. H. COUCH DIVISION
ESB INCORPORATED

ESB Couch

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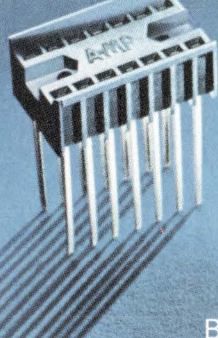
We've lowered the profile and the cost



For years we've made DIP Headers of unquestioned quality. They've stood tall in the industry. A little too tall for some application, perhaps.

But things have changed. A new low profile brings AMP's DIP Headers eye to eye with any in the industry. And a new low cost makes pluggability more practical than ever.

But the most important features have not been changed. Our reusable spring hard posts. Wider range of IC Post and Tab acceptance. Your choice of solder, wrap or TERMI-POINT* Clip method, which permits up to three separate terminations per post.

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For more information write **Industrial Division, AMP Incorporated, Harrisburg, Pa. 17105.**

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INCORPORATED

EE SPEAK UP

(*continued from page* 20)

America once hopefully will have closed the "social gap" the "technological gap" will disappear automatically. In contrast to the U.S. where almost all R&D work is financed by the military or at least the government, therefore entailing no risk, in Europe the burden lies almost entirely on the private corporations which have to bear the commercial risks fully.

Anyway, looking down one's nose at the poor, underpaid European engineers who unfairly underbid and threaten their American colleagues is entirely out of place. Apart from the size of the car, the European fares better than his American colleague. The question then why many come to the U.S. finds its answer in the very genuine interest which those people have in America and her people. It is not true that a European engineer earns more here than at home—contary to the belief of most Americans.

The Tektronix 323 was, by the way, mostly designed in this country by Americans, its price does not convey the impression of being made by underpaid people either. Neither are HP instruments designed and built in Germany any less expensive than instruments made here. The design efforts of American firms in Europe, by the way, have no other meaning but window-dressing; no really important projects are pursued abroad.

I would like to recommend at least a year's stay in Europe, working there as an engineer, in order to establish a minimum basis for a qualified judgment about the poor low-salaried colleagues overseas. I know, however, no American engineer who ever did this.

Artur Seibt
Portland, Oregon

EDITOR'S NOTE: The editorial did not imply any "unfairness" but rather a fact of life. And an hour of design of comparable quality is definitely less expensive outside the United States. Also, American companies in general don't "buy" European companies, since most national laws rule such purchases out. Instead, American companies set up subsidiaries in Europe, and have been more successful at raising money in Europe to finance these subsidiaries than the European companies themselves. (Read "The American Challenge" [La defi americaine] by J. Servan Schreiber, McGraw Hill, 1968.) But Mr. Seibt's points are well founded, particularly on how healthy it will be for American engineers to spend a sabbatical year working abroad.

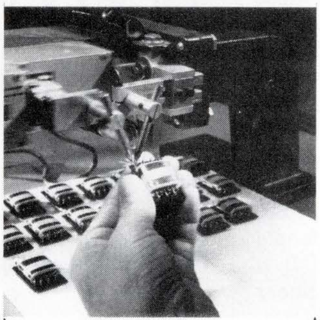
Letters to the editor are published at the discretion of the magazine. Please say so if you do not want to be quoted. Signed letters have preference over anonymous ones.

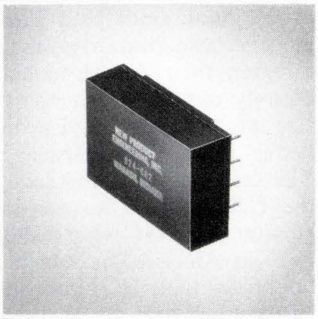
← Circle 16 on Inquiry Card

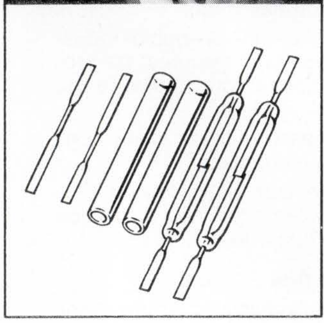
Circle 17 on Inquiry Card

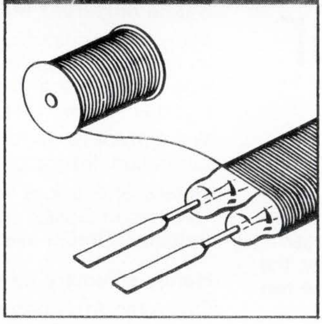
NPE reed relays are reliable... because we build them that way

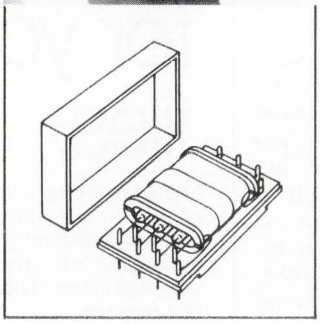
All the way from basic reed switch fabrication / to precision-wound coils / to final packaging / we build in reliability at every step . . .





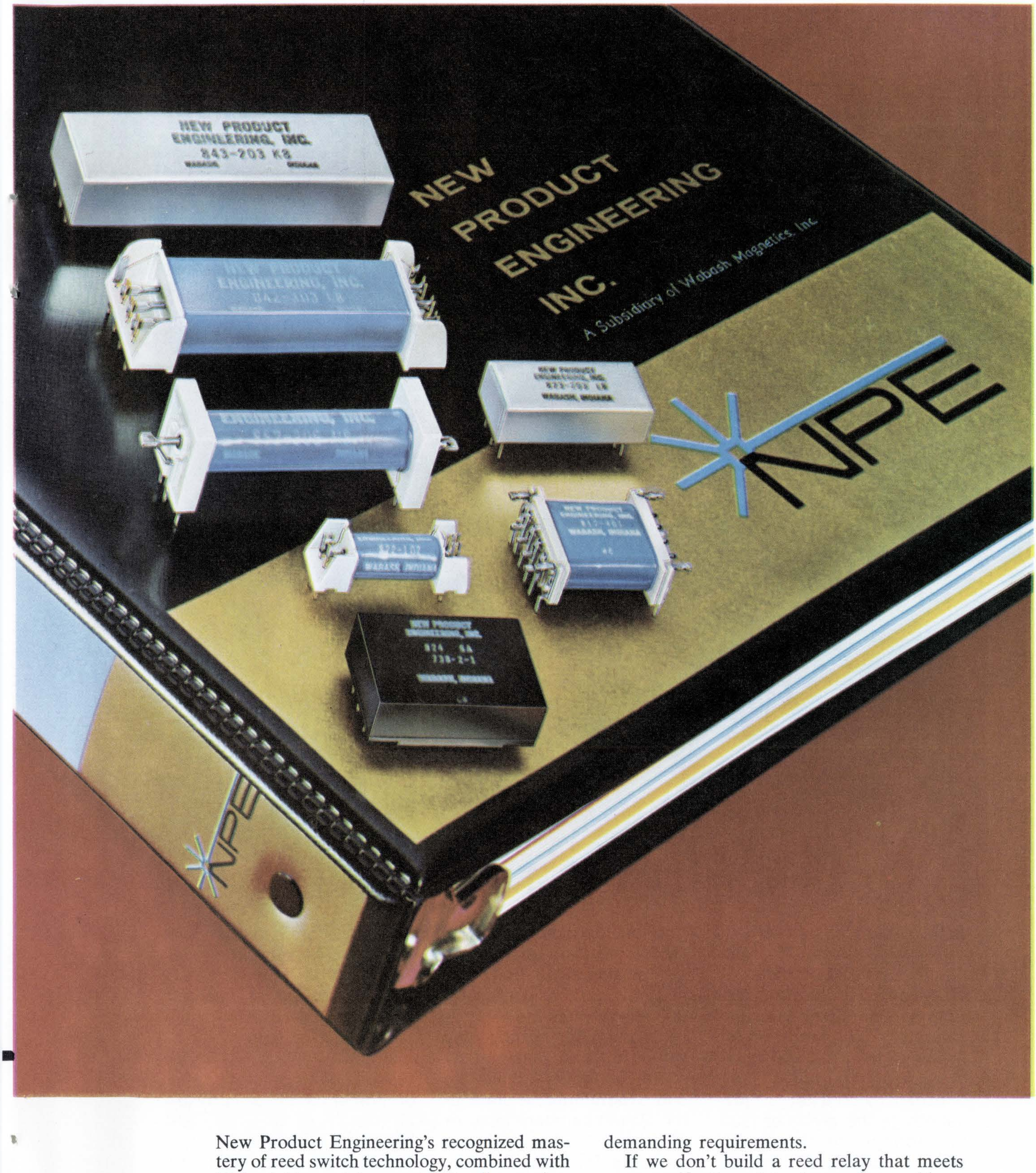






Reliability is exemplified in its highest degree in this miniature 824 Series Reed Relay. Epoxy encased with magnetic shielding standard, NPE's 824 Series is also readily adaptable to electrostatic protection. Other features include: pliable potting of reed switches and coil; welded terminals; standard or magnetic latching. The 824 Series offers superior performance wherever miniature reed relays are used. Other quality NPE relays are described in the chart below and pictured on the facing page.

Series	Contact Combinations	Center-to-Center Pin Spacing	Poles	Construction	Special Features
812 Miniature	Form A, Form B, Form C (A + B)	.150 inch	Up to 6	Open Type	Economy miniature series
822 Miniature	Form A, Form B, Form C (A + B)	.100 inch	Up to 4	Open Type	Smallest package using miniature reed switch
823 Miniature	Form A, Form B, Form C (A + B)	.100 inch	Up to 4	Potted in Plated Metal Can	Environmental protection
824 Miniature	Form A, Form B, Form C (A + B)	.100 inch staggered	Up to 6	Epoxy Cased, Potted in Pliable Compound	High reliability version
842 Standard	Form A, Form B, Form C (A + B) and True Form C	.200 or .218	Up to 8	Open Type	Higher power control
843 Standard	Form A, Form B, Form C (A + B) and True Form C	.200 or .218	Up to 8	Potted in Plated Metal Can	Environmental protection
852 Standard	One Form A only	.250 inch staggered	1 pole only	Open Type	Economy standard relay



New Product Engineering's recognized mastery of reed switch technology, combined with Wabash Magnetic's unmatched coil manufacturing capabilities, assure a superior line of rugged reed relays to meet industry's most demanding requirements.

If we don't build a reed relay that meets your specifications, let us know. Our problem-solving engineers are available to help you design one that will.

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A Subsidiary of Wabash Magnetics, Inc.

812 Manchester Avenue, Wabash, Indiana 46992
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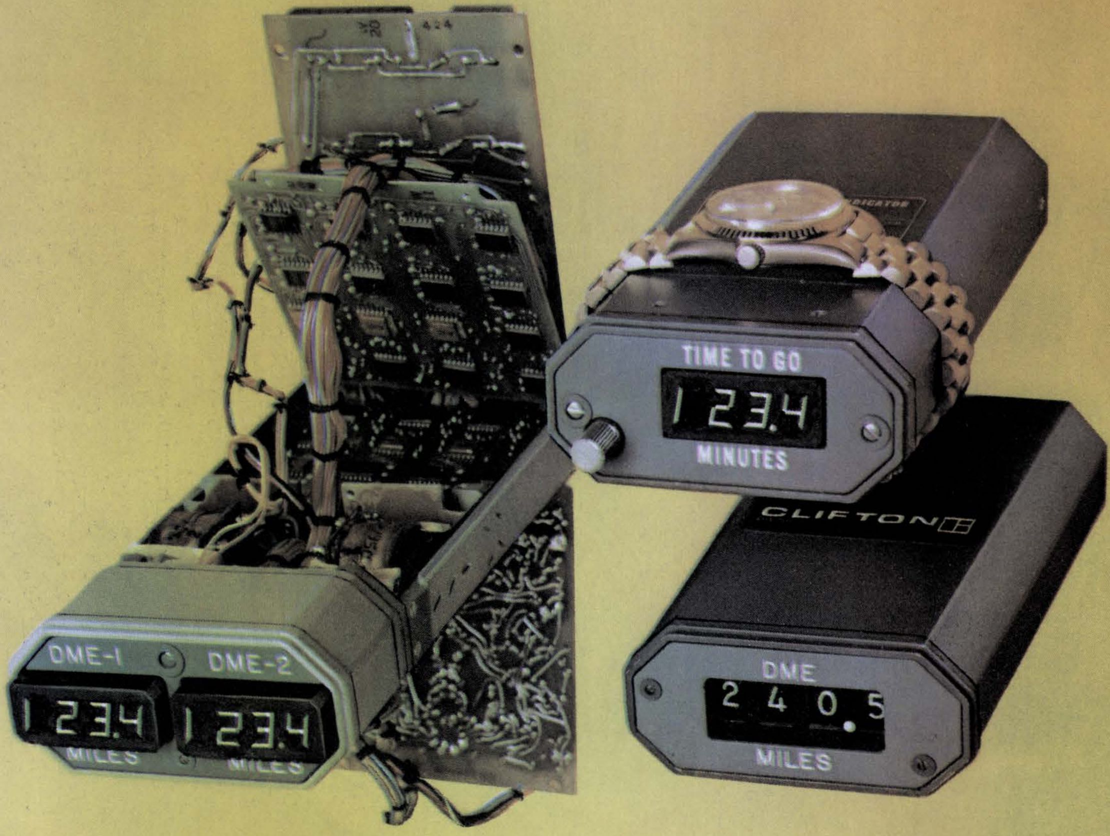
TIME TO GO
1 23.4
MINUTES
CLIFTON
DME-1
DME-2
1 23.4
1 23.4
MILES
MILES
DME
2 4 0 5
MILES

WESCON technical program

San Francisco, August 19-20-21-22

SAN FRANCISCO COW PALACE MEETING ROOM	TUESDAY AUGUST 19		WEDNESDAY AUGUST 20		THURSDAY AUGUST 21		FRIDAY AUGUST 22	
	10:00AM 12:30PM	2:00-4:30PM	10:00AM 12:30PM	2:00-4:30PM	10:00AM 12:30PM	2:00-4:30PM	10:00AM 12:30PM	2:00-4:30PM
A	SESSION 1 IC/Systems; The Changing Interface	SESSION 4 Integrated Circuits in Active Filters	SESSION 7 Time-Sharing: What it can do for the Electronics Industry and Vice Versa	SESSION 10 University Instructional TV Networks: What They Mean to Industry	SESSION 13 High-speed Oscilloscope Recording	SESSION 16 Automatic Production of Semiconductors	SESSION 19 Future Avionics System Architecture	SESSION 22 Instrumentation for High-speed Phenomena
B	SESSION 2 Handling Microcircuits Automatically	SESSION 5 New Company Start-ups: The Engineer Becomes Entrepreneur	SESSION 8 Manufacturing and Computers	SESSION 11 Signal Processing Techniques in Digital Communications	SESSION 14 Overseas Marketing: A Perplexing Opportunity	SESSION 17 High Power Microcircuits: The Real Challenge	SESSION 20 New Solid-state Devices	SESSION 23 Computer-Aided Circuit Design and Testing
C	SESSION 3 Current Solid State Microwave Devices and Circuits	SESSION 6 Computer-Aided Design of High Frequency Circuits	SESSION 9 Linear Integrated Circuits in Communications	SESSION 12 Delay Relay Satellites	SESSION 15 MOS ICs: A Critical Review	SESSION 18 Trends in Large System Data Display	SESSION 21 Computer-Aided Testing, Management and Implementation	

These sessions recommended by The Electronic Engineer editors. ——

AUGUST

10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

Aug. 19-22: Western Electronic Show & Conv. (WESCON), Cow Palace & San Francisco Hilton Hotel, San Francisco, Calif. Addtl. Info.—WESCON, 3600 Wilshire Blvd., Los Angeles, Calif. 90005.

Aug. 24-27: Electronic Materials Tech. Conf., Statler-Hilton Hotel, Boston, Mass. Addtl. Info.—D. P. Seraphim, IBM Components Div., Bldg. 300, Hopewell Junction, N. Y. 12533.

Aug. 26-28: Conf. on Computerized Electronics, Statler Auditorium, Cornell Univ., Ithaca, N.Y. Addtl. Info.—IEEE, 345 E. 47th St., New York, N.Y. 10017.

SEPTEMBER

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Sept. 8-11: Electrical Insulation Conf., Sheraton-Boston Hotel & War Mem. Aud., Boston, Mass. Addtl. Info.—L. R. Samelson, Insulation Mag., Lake Pub. Corp., Box 270, 311 E. Park Ave., Libertyville, Ill. 60048.

Sept. 8-12: European Microwave Conf., London, England. Addtl. Info.—IEE, Savoy Place, London, W. C. 2, England.

Sept. 15-17: Int'l Telemetering Conf., Sheraton Park Hotel, Washington, D. C. Addtl. Info.—R. J. Blanchard, Defense Electronics, Rockville, Md. 20854.

Sept. 16-18: Electronic Mfg. Engineers Conf. & Exhibit, New York Hilton Hotel, New York, N.Y. Addtl. Info.—Circuits Mfg., 167 Corey Rd., Brookline, Mass. 02146.

Sept. 17-19: Symp. on the Biological Effects and Health Implications of Microwave Radiation, Hotel John Marshall, Richmond, Va. Addtl. Info.—Stephen F. Cleary, Symp. Chrmn., Va. Commonwealth Univ., Medical College of Va., Health Sciences Div., MCV Sta. Box 877, Richmond, Va. 23219.

Sept. 23-25: Ninth Annual Symp. on Physics & Nondestructive Testing, Holiday Inn-Lake Shore Drive, Chicago, Ill. Addtl. Info.—W. J. McGonnagle, Coordinator, Symp., Box 554, Elmhurst, Ill. 60126.

Sept. 24-26: Ultrasonics Symp., Chase Park Plaza Hotel, St. Louis, Mo. Addtl. Info.—C. K. Jones, Westinghouse R&D, Churchill Boro, Pittsburgh, Pa. 15235.

OCTOBER

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Oct. 22-23: 2nd Annual Connector Symp., Cherry Hill Inn, Cherry Hill, N.J. Addtl. Info.—Jim Pletcher, AMP Incorporated, Harrisburg, Pa. 17105.

Oct. 26-30: Joint Conf. on Mathematical & Computer Aids to Design, Disneyland Hotel, Anaheim Conv. Ctr., Anaheim, Calif. Addtl. Info.—J. M. Kinn, IEEE, 345 E. 47th St., New York, N.Y. 10017.

Oct. 27-30: ISA Conf. & Exhibit, Astrohall, Houston, Tex. Addtl. Info.—Ray Cooley & Assoc., Inc., 4848 Guiton St., Houston, Tex. 77027.

Oct. 29-31: Int'l Electron Devices Meeting, Sheraton Park Hotel, Washington, D.C. Addtl. Info.—IEEE, Technical Activities Board, 345 E. 47th St., New York, N.Y. 10017.

'69-'70 Conference Highlights

WESCON—Western Electric Show and Conv., August 19-22; San Francisco, Calif.

NEREM — Northeast Electronics Research and Eng'g Meeting, Nov. 5-7; Boston, Mass.

IEEE—Institute of Electrical and Electronics Engineers Int'l Convention & Exhibition, March 23-26; New York, New York.

Call for Papers

Feb. 5, 1970: 4th Annual Technical Symp. on Commercial Applications, Jamaica, N.Y. Submit three copies of 200-word abstracts and a biographical sketch before **October 5, 1969** to Ervin Steinberg, Secy & Patent Attorney, Branson Instruments, Inc., Sub. Smith, Kline & French Laboratories, 76 Progress Dr., Stamford, Conn. 06904.

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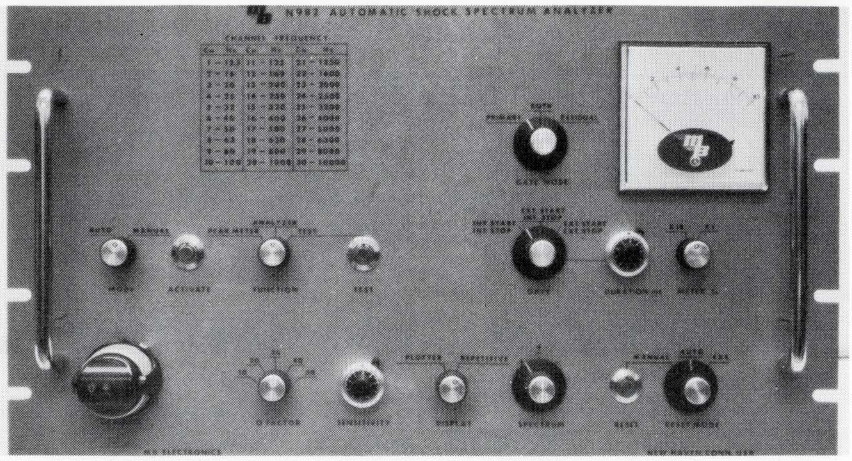


New N982 Shock Spectrum Analyzer offers real time/ on-line performance

The new N982 Shock Spectrum Analyzer provides automatic, real time, one-third octave or one-sixth octave analysis of any shock transient input pulse. The unit provides repetitive scope displays or direct x-y recorder plots of response "g" in either log or linear format.

60dB dynamic range, a 12.5Hz to 10KHz frequency range, and an integral peak reading meter are additional features included in this versatile new instrument.

When used in combination with the N981 Shock Spectrum Synthesizer, the N982 provides the most advanced answer to rapid and accurate shock spectrum analysis and synthesis. Complete information on the N982 is contained in Bulletin No. 261. For your copy, simply circle the reader service number below.

Reader Service No. 101

5-Volt pressure cells strike ideal cost/accuracy ratio

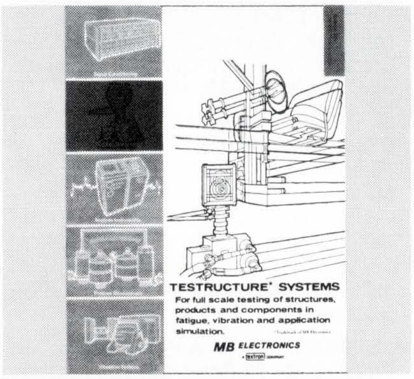
The Series 500 pressure cells have achieved outstanding acceptance in laboratory and permanent field applications. At a cost of approximately $200, the units are sufficiently inexpensive for very broad use. Yet their ½% error band provides more than the level of accuracy required for most applications and their 5-volt output simplifies instrumentation. The 500 (psig) and 510 (psia) Pressure Cells are but two of the extensive line of transducers produced by MB using its unique bonded strain gage, integral diaphragm construction. **Reader Service No. 104**

Permanent magnet vibration systems exhibit wide appeal

The permanent magnet exciter systems manufactured by MB are continually finding new applications because of their range and flexibility. MB offers three such "PM" systems, designated PM25, PM50 and PM100 with respective force ratings from 25 to 100 lbs. The most popular uses for such systems include demonstrations in educational institutions and qualification testing of small components and assemblies. PM shakers can also be used in multi-head arrays for modal and flutter or resonance testing.

Accessories such as the line of Shakermate Slip Tables for horizontal testing are also available for even more versatile operation. A vibration testing capability can be established for as low as $1,500 with the permanent magnet systems.

Reader Service No. 105



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Reader Service No. 102

Seminars scheduled

Data Analysis Seminars are scheduled for Washington, D.C. August 18-21 and Los Angeles November 11-14.

For complete details, use the reader service number below.

Readers Service No. 103

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EE WELCOME

Here we welcome new companies or divisions in the electronics industry. For more details, circle the appropriate numbers on the reader service card.

IC memory: At the forefront. Intel Corp., led by former Fairchild head Dr. Robert Noyce, enjoys many distinctions that preclude its being labeled "just another one of the semiconductor spinoffs in the San Francisco Bay area". From top management, through research, production, and marketing, and down into engineering, Intel's personnel include industry leaders—and pioneers of the IC technology.

It comes as no surprise then that Intel's first commercial product will reflect a bold, innovative step forward. The device is a large-scale integration MOS memory—a 256-bit fully-decoded random-access unit containing over 1800 elements, and encased in a 16-pin dual-in-line ceramic package. Among its features: low threshold voltage thanks to self-alignment of drain and source, and wired OR options that permit paralleling.

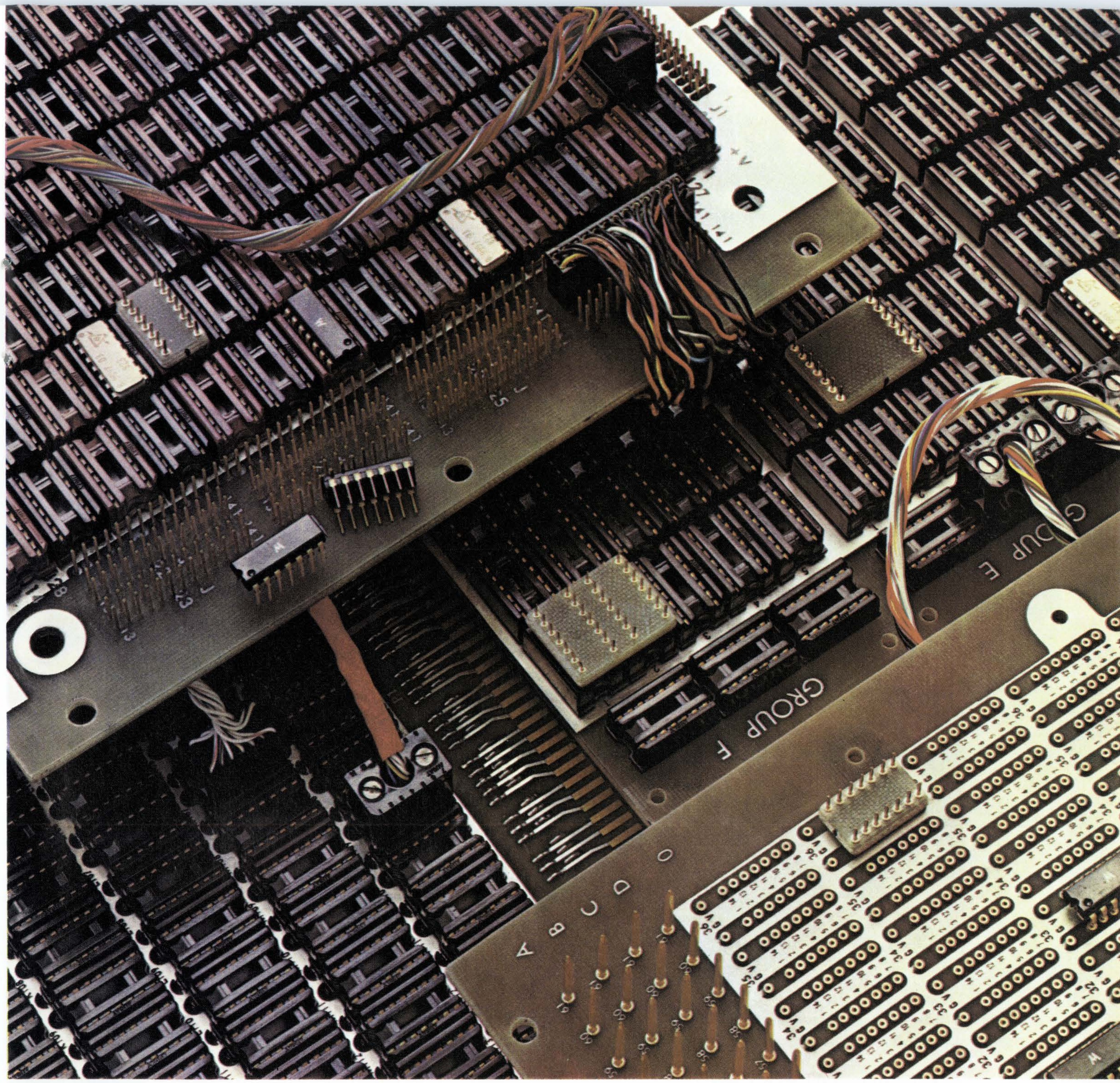
The memory, reportedly six to 12 months ahead of the state of the art, reflects Intel's thrust. "We'll compete with core, drum, plated-wire, and other non-semiconductor memories, as well as advance the IC technology," declares director of marketing Robert F. Graham. Intel, he adds, will make a total memory effort. Plans call for high volume production of both bipolar and MOS products.

Behind the chip is another innovation. Intel will emphasize fabrication as a production forté. "The rest of the industry devotes about nine times as much effort in assembly as it does in fabrication," explains Graham. "That's why costs are too high, yields too low, and technological progress too slow," he submits.

Circle **363** on Inquiry Card

Aptly named components firm. As its name implies, Filters & Capacitors, Inc. is specializing in two product areas—filters and wrap and fill capacitors. It presently has a whole series of miniature ceramic and metallized polycarbonate filters, including L-, Pi-, and T-types, for both dc and ac applications. In addition to using these stable dielectrics, the filters feature high volumetric efficiency.

(continued on page 30)


GROUP E
GROUP F
A B C D O

(continued from page 28)

The firm's second product group consists of mylar and polycarbonate wrap and fill capacitors for computer applications.

Based in San Fernando, Calif., the company has been in existence for one year and already has had about one-half million dollars in sales.

Circle **364** on Inquiry Card

PC boards now; control devices later. Located in Catonsville, Md., just outside of Baltimore, Bargale Industries Inc. has entered the printed circuit board business. The firm fabricates PC boards for both military and commercial applications, and can "plate-thru" holes and handle all precious metal plating. Among its customers are such companies as Bendix, Westinghouse, Lockheed, and the Naval Ordnance Labs.

In addition, Bargale does assembly work and offers an engineering design service in solid state and optical devices. And it is now marketing two products—a flame sensor that uses fiber-optics and a power supply (inverter).

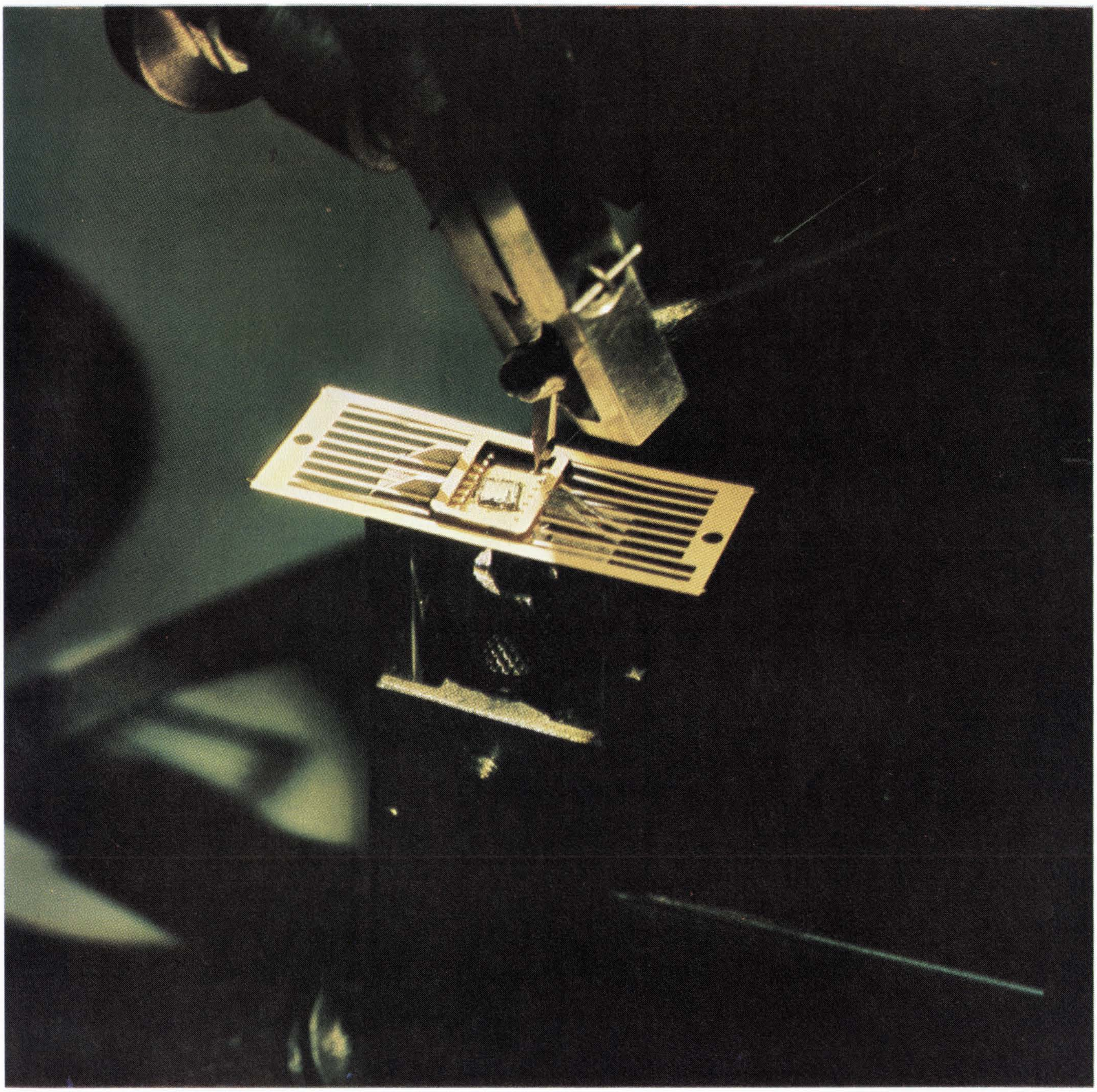
According to Benjamin L. Goldstein, president, the firm's long-range goal, in addition to the full service PC facility, is to eventually have a product line of control devices.

Circle **365** on Inquiry Card

Services for communication projects abroad. Waltham, Mass., is home base for a service-oriented company, GT&E International Systems Corp. An offspring of GT&E International, the infant firm will provide systems engineering and program management services for a range of communication projects, including satellite earth stations, microwave and other communication systems, education networks, and so forth. One of its first tasks will be to work on the Comsat Earth Station in Alaska.

The newly-formed company will not be involved in manufacturing at all. It is strictly a service organization whose aim is to represent a single source in planning, engineering, managing, and operating communication systems. Since the firm is an international subsidiary of GT&E, only under special situations will its services be available in the U.S.

Circle **366** on Inquiry Card



SHIFT REGISTERS, that is — new AMI/MOS Dynamic Shift Registers are rolling off our expanded production line. For instance, the AMI Dual 100 Bit Shift plugs into existing systems pin-for-pin. Other family members are just as shifty, but more lengthy — bit lengths to 1024, plus the "N"-length soon to be unveiled. The entire family is compatible with TTL, DTL, CCSL logic. Send for details. Better yet, hop a jet and visit our new MOS facility — America's largest.

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Circle 22 on Inquiry Card

Introducing Potter & Brumfield's unique

dual thin-line dry reed relays

An entirely new magnetic structure makes possible an exceptionally low seated height of only 0.275 inch for high density board packaging. Circuit boards employing JDT relays may be spaced on 0.5 inch centers.

This design minimizes magnetic flux dispersion, resulting in a very efficient magnetic circuit. This decreases coil power requirements and often permits direct operation of JDT relays in low-power semi-conductor logic circuits. An interfacing amplifier may be eliminated in many applications.

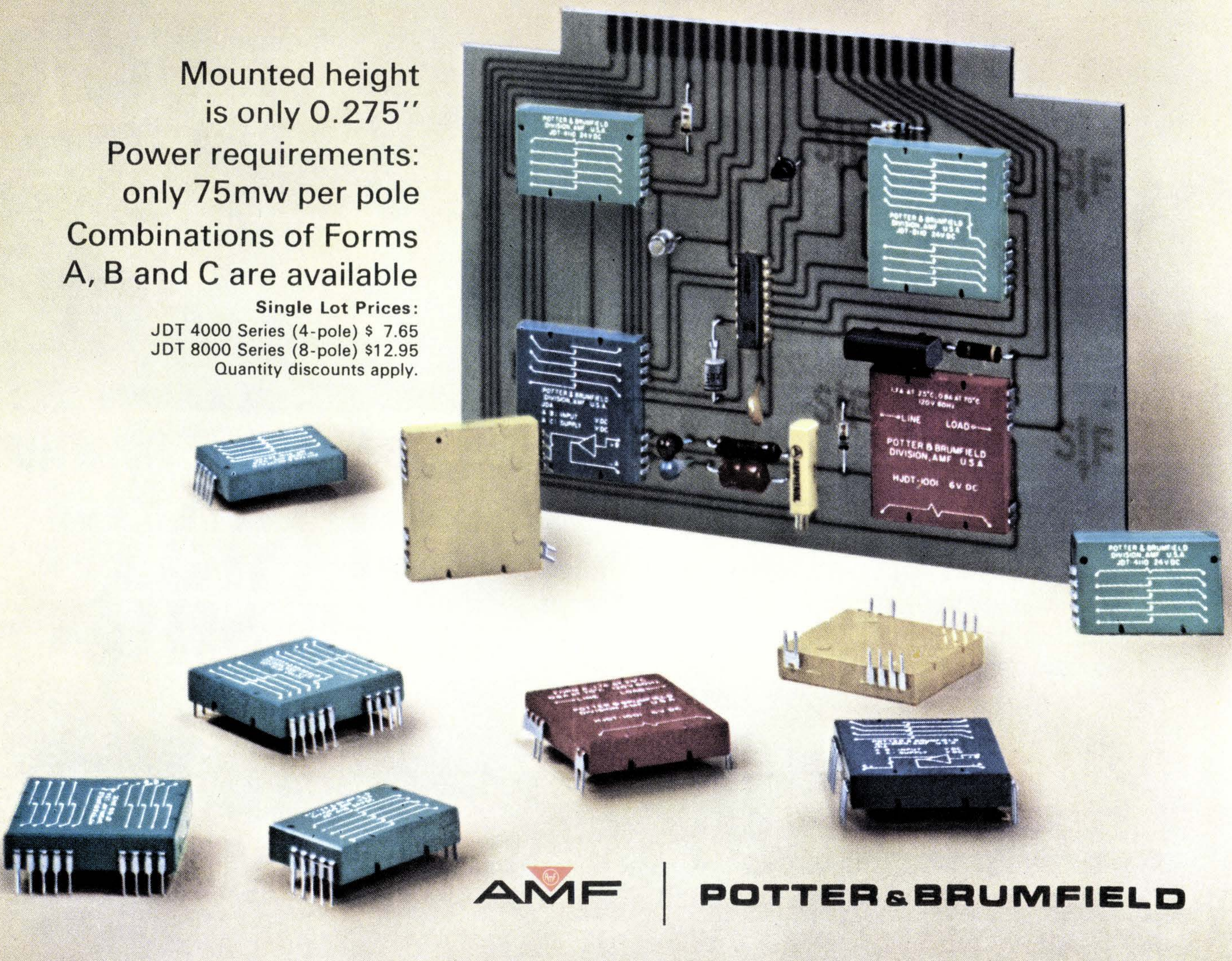
Terminals are similar to those on IC packages, permitting spot testing on either side of a circuit board. The dual in-line terminals on 0.1 inch centers simplify circuit board design. The reed switches are rated at 10 watts maximum resistive (50V or 0.5A DC maximum) switching.

A solid state time delay circuit may be incorporated in this small package. Or a Darlington amplifier can be included to compensate for low current applications. However, the number of available poles for switching is reduced by the addition of either of these circuits.

The JDT is completely encapsulated in epoxy, giving protection against environmental contamination. The Series is presently available in many combinations of Forms of A, B and C.

■ ■ ■

Get full information today by calling your local P&B representative or call direct to Potter & Brumfield Division of American Machine & Foundry Company, Princeton, Indiana. 812-385-5251.



Mounted height is only 0.275″

Power requirements: only 75mw per pole

Combinations of Forms A, B and C are available

Single Lot Prices:

JDT 4000 Series (4-pole) $ 7.65
JDT 8000 Series (8-pole) $12.95
Quantity discounts apply.

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EE PRODUCT SEMINARS

This column lists product seminars that electronic companies offer to users of their products.

Data Analysis: Aug. 18-21, Washington, $200. All phases of spectrum analysis, from fundamentals to advanced analysis concepts and technology. Robert H. Morse, MB Electronics, Box 1825, New Haven, Conn. 06508.

Circle **351** on Inquiry Card

Cable Pressurization: Aug. 18-29, Sept. 8-19, Sept. 29-Oct. 10, Oct. 20-31, Nov. 10-21; Hickory, N. C. Engineering design considerations, field preparation, and installation of a continuous flow pressurization system; air dryer installation and maintenance. Wallace E. Jones, System Equipment Div., Superior Continental Corp., Box 489, Hickory, N. C. 28601.

Circle **352** on Inquiry Card

Soldering Technology: Sept. 3-4, New York, $165. Alpha Metals, Inc., 56 Water St., Jersey City, N. J. 07304.

Circle **353** on Inquiry Card

Veritrak™ Process Control Instrumentation: Sept. 8-19, Phoenix, tuition-free. Product organization, structural design and calibration, computer interface, primary sensors, computing networks, circuit theory and maintenance. Motorola Instrumentation and Control Inc., Box 5409, Phoenix, Ariz. 85010.

Circle **354** on Inquiry Card

Real-Time Sound & Vibration Measurements: Sept. 9-10 or 23-24 and Oct. 7-8 or 28-29, West Concord, Mass., no charge. The real-time analyzer, its theory, operation, and applications; ancillary support equipment, analysis systems, and use of the instrumentation computer. General Radio Co., West Concord, Mass. 01781.

Circle **355** on Inquiry Card

Relay Think-In: Sept. 10, New York, $15. Guidelines for reliable relay application and selection; safety in relay application; 21 known factors contributing to functional deviations of contacts during shelf life, service life, evaluation or prototype tests; application problems in ground support systems; relay reliability; and so forth. Director of Think-In, c/o Ohmite Manufacturing Co., 3601 Howard St., Skokie, Ill. 60076.

Circle **356** on Inquiry Card

21-621 Modular Mass Spectrometers: Sept. 15-19, Monrovia, Calif., $225. Analyzers, pumping systems, sample introduction systems, circuitry, cabinetry, and recording equipment; instrument calibration, mass spectra interpretation, analysis of mixtures. Coordinator of Training and Technical Publications, Bell & Howell, 1500 S. Shamrock Ave., Monrovia, Calif. 91106.

Circle **357** on Inquiry Card

Audio Reproduction: Sept. 16-18, Cleveland, $50. Electronic instruments and techniques used to measure performance of communications systems and devices in the laboratory and on the production line. B & K Instruments, Inc., 5111 W. 164th St., Cleveland, Ohio 44142.

Circle **358** on Inquiry Card

Integrated Circuit Design and Layout: Sept. 22-Oct. 10; Chadderton, Oldham, Lancs., England; 300 pounds (about $125). Semiconductor physics and mathematics, IC techniques, circuit design and layout, economic aspects. W. Alan Jones, Seminar Mgr., Ferranti Ltd., Gem Mill, Chadderton, Oldham, Lancs., England.

Circle **359** on Inquiry Card

Instrumentation for Industrial Measurement and Control: Oct. 6-17, North Wales, Pa., no charge. Emphasis is on the process industries. Leeds & Northrup Co., Sumneytown Pike, North Wales, Pa. 19454.

Circle **360** on Inquiry Card

Resistance Welding & Reflow Soldering: Oct. 7, Monrovia, Calif., $5. AC and dc resistance welding fundamentals, metallurgical considerations, welding techniques, weld schedule development, soldering, packaging techniques. E. F. Koshinz, Unitek/Weldmatic Div., 1820 S. Myrtle Ave., Monrovia, Calif. 91016.

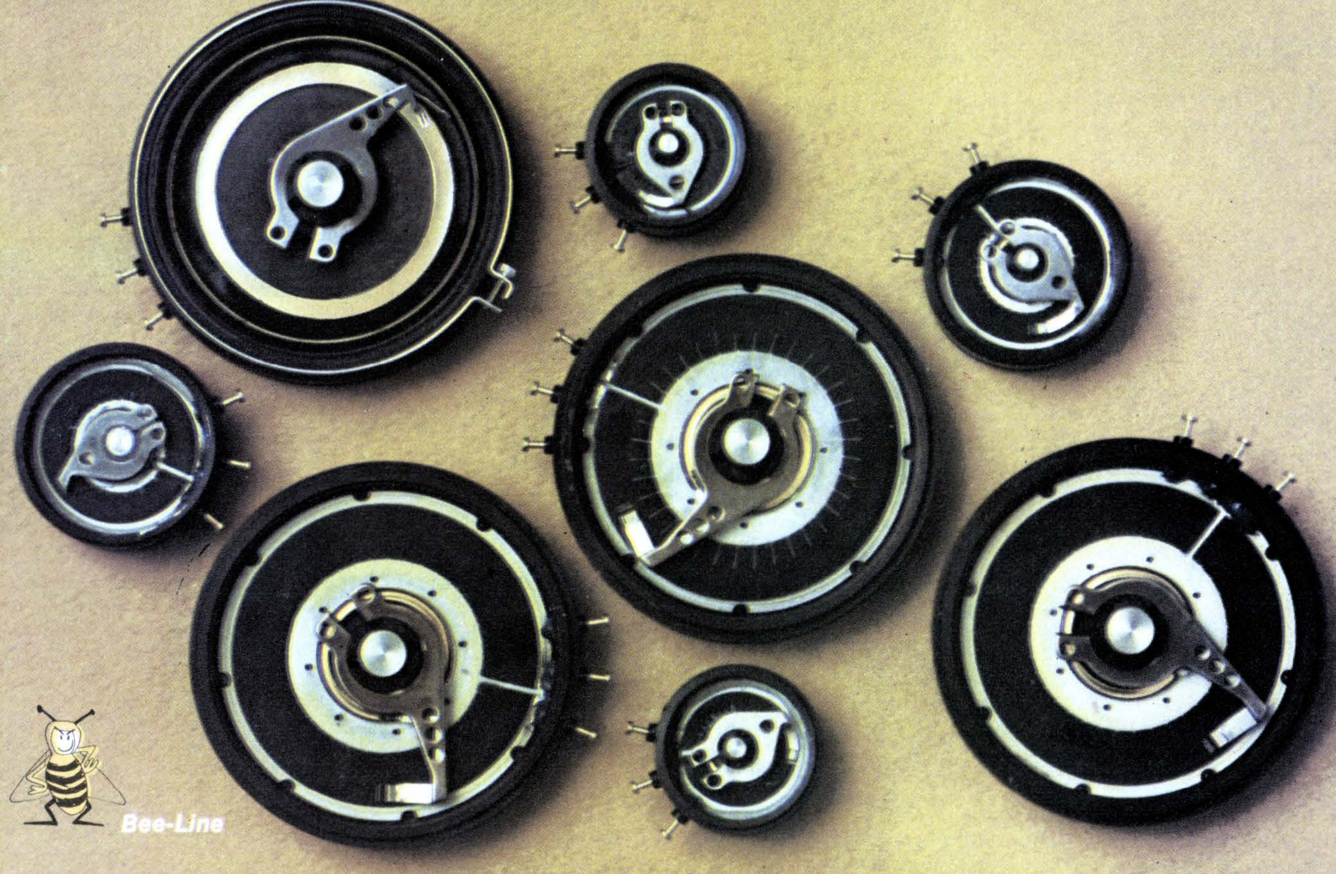
Circle **361** on Inquiry Card

Automatic Impedance Measurement: Oct. 21-23, West Concord, Mass., no charge. Techniques, instrumentation, and systems for the automated measurement of Z, R, L, and C. General Radio Co., West Concord, Mass. 01781.

Circle **362** on Inquiry Card

←Circle 23 on Inquiry Card

BLACKBOXING...?



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Circle 25 on Inquiry Card

The undergraduate . . .

or How come we can't talk to one another?

A farce on engineers and communication, complete in one act.

By Roger D'Aprix, Contributing Editor
Rochester, N. Y.

The scene opens in the office of well-known psychiatrist Sigmund Fried, who specializes in the treatment of deranged or disturbed engineers. The curtain parts to reveal a comfortable waiting room occupied by an obviously disoriented professional man. He is supplying one-word answers to the questions of a receptionist, who bears a strong resemblance to the June Playmate of the month.

RECEPTIONIST: Now let's see, your name again was—

PATIENT: De Forest. Rudyard De Forest.

RECEPTIONIST: Oh, yes, Mr. De Forest, and why do you wish to see Dr. Fried?

DE FOREST: I've got this problem. I can't communicate.

RECEPTIONIST: I see. Now when did you first notice your problem?

DE FOREST: Not until I went to work last July after graduation from M.I.T.

RECEPTIONIST: And before that you were all right, to the best of your knowledge?

DE FOREST: Yes I was. Well, you know, except for the usual problems of the generation gap and stuff like that.

RECEPTIONIST: I see. And your age is 22 and you've been employed by Quik-Buck Industries now for three months?

DE FOREST: Right.

RECEPTIONIST: You understand, of course, that your group medical plan covers only half the cost of your treatment here?

PATIENT: (*With some agitation.*) That's okay. I don't care what this costs. I need help badly.

RECEPTIONIST: Dr. Fried should be with you in a minute.

The office door opens and Dr. Fried emerges with a stylish and well-preserved woman in her forties. Part of their conversation can be overheard as he leads her to the door of the waiting room.

DR. FRIED: Now, Mrs. Robinsen, my advice to you is to go home and forget your young man. You could never hope to communicate with one so much younger than yourself. (*With a leer.*) What you really need is a spiritual companion—someone more about my age. See you next Thursday.

His eyes follow her down the hall as she moves toward the elevator. His reverie is abruptly broken off by the desperate clasp of De Forest's hands on his lapel.

DE FOREST: (*Practically dropping to his knees.*) Oh, Dr. Fried, you said that word, the word that has driven me here to your office in a shambles.

DR. FRIED: What word? What are you talking about?

DE FOREST: **Communicate.** That's the word.

DR. FRIED: (*With resignation.*) Oh, another one of those engineers. Say, you guys are getting as common as the obsolete engineers. Okay, come on in. Follow me. What's your name?

Dr. Fried leads an obviously shaken Rudyard De Forest to the couch.

DE FOREST: My name's Rudyard, but most people call me Rudy.

DR. FRIED: All right, Rudy, what seems to be the trouble?

DE FOREST: I don't know where to start. My main prob-

lem is that I'm a non-verbal engineer. I can't communicate. I'm also alienated as hell.

DR. FRIED: I see. Not an uncommon feeling these days, but how do you know you can't communicate?

DE FOREST: Well, that's obvious. Everybody at Quik-Buck says so. It's just awful.

DR. FRIED: Can you give me some specifics. I don't have enough information to know what you mean.

DE FOREST: The first indication I had was when I wrote my first technical report for Quik-Buck. I showed it to my boss, and he sent it back with a note saying, "Something's drastically wrong here. We're simply not communicating." I tried to rewrite it, and the president scrawled across the bottom that "communication has apparently broken down here."

DR. FRIED: (*Suppressing a smile.*) I see. What **other** evidence do you have?

DE FOREST: Well, last month in a meeting of the system design department, while I was making a long technical presentation, the manager kept looking at his watch and finally said, "Rudy, get to the point. You're telling me more than I want to know." I was so rattled I practically forgot the rest of my talk.

DR. FRIED: Un-huh. Anything else?

DE FOREST: Oh yes. Just last week I wrote a long memo to the manufacturing manager—outlining some design changes, and he wrote back saying, "Obviously, what we've got here is a communications problem."

DR FRIED: I see. What you're trying to tell me is that you are seriously disturbed about communications and communications problems. Right?

DE FOREST: (*Suddenly more aggressive.*) Oh, you've hit the nail right on the head. I'm so uptight about communication I can't stand it. What can you do to help me? I've got to learn to communicate or Quik-Buck will drive me crazy. Should I quit and join the Peace Corps?

DR. FRIED: Well, first thing you've got to do is find out what communication is really all about. And then you can figure out what to do about your problem.

You've also got to learn that every problem in industry today is generally described as a communications problem . . . even if it isn't.

Look, I've got an idea. Let's take a ride downtown to the university. I think I can make my points better if I can give you some practical examples. Right now a university offers about the best example of bad communications that I can think of.

The scene shifts to the doctor's car. Doctor and patient ride the five or six blocks to the university in silence. De Forest stares out the window, distracted by his anxiety. As they near the campus, Dr. Fried speaks.

DR. FRIED: Let's see . . . the engineering school should be around here somewhere. What's that crowd over there?

DE FOREST: Looks like some kind of fight or a demonstration. I see some cops and some kids carrying signs. Let's drive over a little closer. (*They park the car and walk toward the demonstrators.*)

DR. FRIED: (*Reading some of the signs aloud.*) "Engineering is a black art: we want black instructors," "Engineers of the world unite," "Make love, not money," "Eliminate defense research," "Ban the bomb."

Ah, here's our chance to observe bad communication in action. That's the dean with the bullhorn trying to get them to class.

Quick, tell me your conception of the communication process, De Forest.

DE FOREST: Well, that's kind of a tough one, but you know it's the old idea of a transmitter and a receiver with the transmitter sending a message and the receiver picking it up, interpreting it, and sending its own message back to close the loop. The process is continuous.

DR. FRIED: Good. Now listen and watch. Is that happening here?

DE FOREST: Well, let me see if I can hear what the dean is saying. He just told them to return to classes and he would grant them a general amnesty.

They're booing the dean.

DR. FRIED: Okay, how does their reaction fit the model. Is that what they're supposed to do?

DE FOREST: Sh . . . The dean just said something to the cops. They've got their night sticks out. Let's get out of here before they mistake that goatee of yours and bat you over the head.

Hey, the kids are shoving them right into the administration building. They're barricading the doors. Let's get back to the car.

DR. FRIED: Come on. Run like hell! The cops are getting reinforcements.

Back in the car, Fried and De Forest continue their discussion.

DE FOREST: (*Trying to catch his breath.*) Well what was the point of getting involved in that mess?

DR. FRIED: That "mess" as you describe it illustrates some important communications lessons. Let's reconstruct the situation and try to figure out what happened and why communication finally broke down.

Was the transmitter sending? Did the receivers receive the message?

DE FOREST: Well, yes and no. A message was sent, and it was received, but the end result certainly was not what the dean wanted.

DR. FRIED: Fine. Now if we can just figure out what happened, we will have learned something important.

DE FOREST: Look, Dr. Fried, I don't mean to be rude,

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Circle 27 on Inquiry Card

but I came to you with a very real problem and you're driving me around town to look at campus rebellions. Frankly, I don't really see how all of this is relevant.

DR. FRIED: Trust me, Rudy. All of this is highly relevant. As we drive back to the office, try to mull over what went wrong in this communication effort.

The scene shifts to Dr. Fried's office. De Forest is talking impatiently.

DE FOREST: Okay, I've thought it all through. The trouble back there at the university is that the sender and the receivers had no empathy for one another. The dean obviously was interested only in dealing with the immediate disturbance. The students knew this and had no respect for the dean. More than that, they evidently didn't trust him as far as they could throw him.

DR. FRIED: Ah, now you are getting somewhere, to principle number one to be exact. Do you see what it is?

DE FOREST: Yes. I better go to a doctor who can take care of my communications block.

DR. FRIED: No, no, no. The point is that **effective communication depends to a significant degree on past experience and on mutual trust and respect.** Without that mutual respect and good faith, communication can and will break down.

DE FOREST: But wait a minute—they **were** communicating. They **did** talk to one another. They just didn't agree. There was no breakdown really.

DR. FRIED: Wasn't there? Did the dean want to be over-powered and barricaded?

DE FOREST: Don't be silly. He wanted to cool that bunch down and get them back to their cages.

DR. FRIED: Which leads us to principle number 2. **The communicator's purpose must be taken into account in judging if communication is successful,** or even in saying **how** successful it is.

DE FOREST: I see. The dean's purpose was to stop the demonstration. He offered them amnesty. They rejected his offer and locked him up in his office. Ergo, he's a bum communicator like me. Right?

DR. FRIED: What could he have done to get results more to his liking?

DE FOREST: Well, presuming he could ever get through to that bunch, he might have offered them a compromise more to their liking. Maybe he should have just given in and said to hell with it.

DR. FRIED: That's debatable, but he did make one obvious mistake. He didn't read his audience properly. Which brings us to point three: **You must know your audience, and you must formulate a message which the audience will somehow find acceptable or at least as acceptable as your respective positions can allow.**

DE FOREST: Look, I might as well just face up to the fact that we engineers can't communicate. Everybody says so. I've read the articles that say we're nonverbal and that we deal in things that can be seen and felt. Everybody knows we can't write or speak.

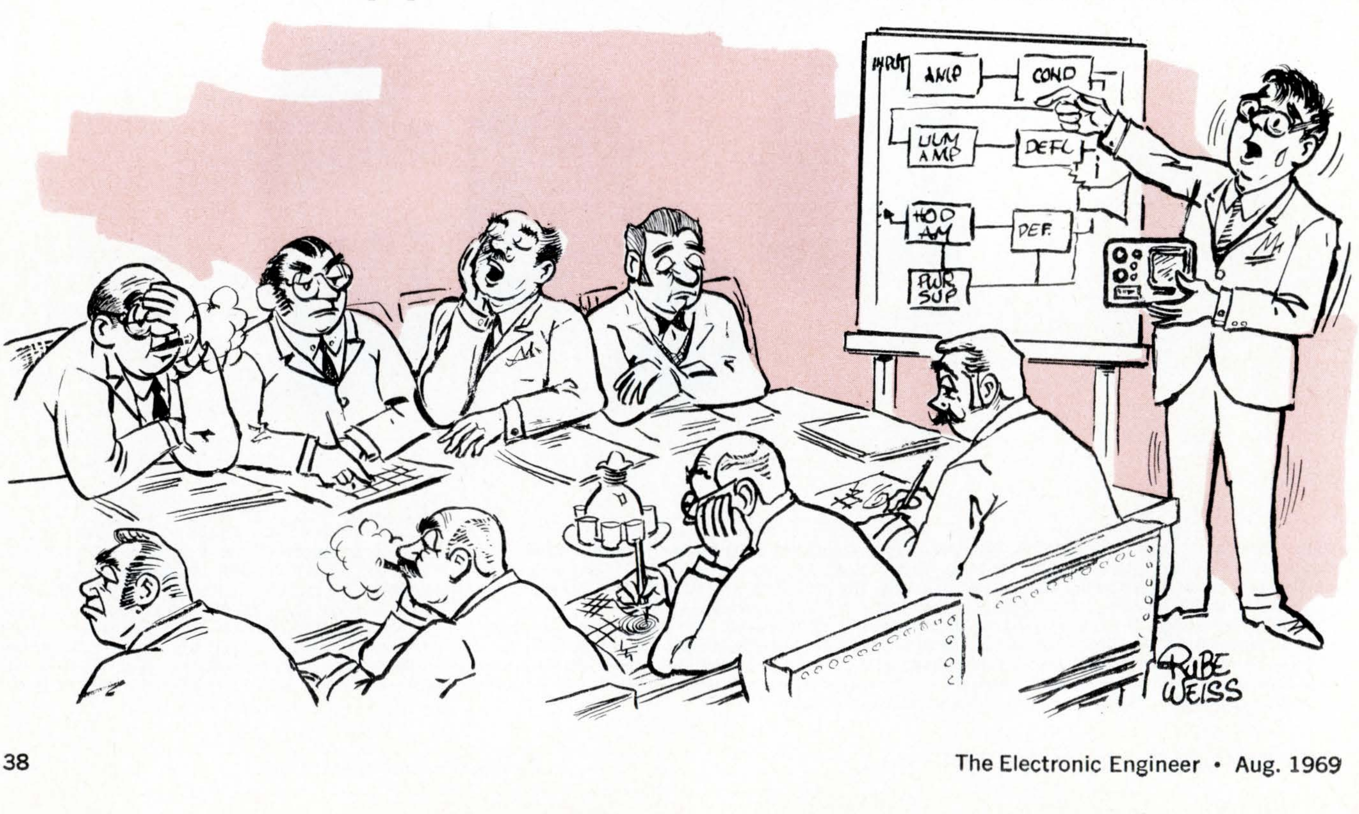
DR. FRIED: My boy, you're dead wrong. Engineers are neither better nor worse than any other group of professionals on this score. In fact, the only unique communications problem that an engineer has is that his message frequently has a technical flavor. Which means that he has to find an audience that understands his specialized language, or he has to learn to translate so laymen can understand. But every professional, whether he's a doctor, a lawyer, or whatever, has this problem. Did you every try to discuss an operation with a surgeon? Or a contract with a lawyer?

DE FOREST: (*Impatiently.*) There's no connection between Quik-Buck and all of this.

DR. FRIED: That's where you're wrong again. The principles are exactly the same.

Let's begin with empathy. How are you regarded by the people with whom you're trying to communicate at Quik-Buck?

DE FOREST: Damned if I know. What difference does



that make? All they need is my technical advice. I'm an engineer, not a public relations man.

DR. FRIED: You're wrong, Rudy, my friend. When you are trying to influence decisions and make recommendations, you have to sell. You have to sell not only the worth of your ideas, but you must also sell yourself. And you must use every sales trick in the book.

DE FOREST: Oh no, not me! That's where I draw the line. I'm going to give them my expert technical opinions and they can take 'em or leave 'em. If the idea's good, they'll use it. If not, the hell with them.

DR. FRIED: You know, you're right. You do have a communications problem.

Look, Rudy, a new idea is a tender thing. It must be carefully nurtured, and it must be sold skillfully by a man who identifies with it, who feels some commitment to it.

To do that you must empathize with the people you're trying to sell it to. You must recognize their sensitivities, and you must anticipate their objections. You must show them that you are to be trusted and that what you are proposing will be beneficial.

All of that takes salesmanship. It also takes a sensitive antenna that can pick up all the signals an audience continually beams to you.

Otherwise you'll wind up like that dean with your audience rejecting both you and your message. And as soon as they reject you that's the end of your idea.

DE FOREST: Look, I just don't know if I can be a phony like that.

DR. FRIED: Now hold it right there. That's a crucial point. You can't be a phony if you want to communicate, but you can't always expect people you're trying to communicate with to know who and what you are. You must demonstrate all that by your words and actions.

The phony is the guy who tries to pass himself off as something he isn't, who hoodwinks an audience.

The next thing is purpose. You've got to know exactly what and why you're trying to communicate. It's like the president of Quik-Buck told you. Nobody wants to be given more information than he feels he needs.

The good communicator is the guy who determines well in advance exactly where he wants to go and how he will get there. Learn to do this **before** you start writing or talking.

In other words, develop a plan or a strategy and follow it. At the same time be flexible and change that strategy as the need demands.

DE FOREST: Look, all I want to learn how to do is communicate. I don't want to be a politician and I'm not a psychologist or a philosopher.

DR. FRIED: Well, then listen to what I'm saying because this is closely related to both empathy and purpose. **Learn to read your audience.** It isn't enough just to identify with them. You've also got to be able to evaluate their reactions—a nervous tap of a pencil, somebody fidgeting in his chair, a troubled expression on somebody else's face, a knowing smile or a sympathetic nod. All of these things are a silent dialogue that tell you whether or not the message is getting through.

Generally you also know something in advance about your audience. You may even know their prejudices, their weaknesses, or their goals. Factor these things into your strategy. Look for common ground. Anticipate objections.

And, finally, when you've made your point, shut up. Samson killed a lion with the jawbone of an ass. Lots of good communication has been killed with the same weapon.

DE FOREST: That's what I like—funny psychiatrists.

DR. FRIED: Well there you have the basics of communication, Rudy my friend. But there is one final point that I like to stress to people in industry. And that's the matter of your audience.

DE FOREST: What are you getting at?

DR. FRIED: Just this. It's important to remember that the audience you are trying to reach is often a very diverse group of people. For example, look at the problem any manager has when he wants to communicate with his people. The British author, William Golding, has stated the problem beautifully. He claims that there are three grades of thinkers in the general population.

Grade 3 is far and away the most common type—about 85% of the population. This is the guy who never really thinks. All he does is **feel** his way through life. Emotion is always his guide—so much so that he becomes incapable of hard thinking. His wide range of prejudices and preconceptions protects him from the painful job of examining or analyzing any idea.

DE FOREST: Boy, that sounds exactly like the top people at Quik-Buck.

DR. FRIED: The grade 2 thinker, according to Golding, is the guy who spends all his time looking for what's wrong with society or the system or the Establishment or whatever.

His favorite pastime is shooting down somebody else's pet scheme.

DE FOREST: Oh boy, we've got a pile of those guys in our management too.

DR. FRIED: The third type Golding speaks about is the grade 1 thinker. He's the open-minded, objective type, whose only real concern is searching out truth. Needless to say, he's far and away the least common type. I think I've known about a dozen grade 1 thinkers in my lifetime.

DE FOREST: Man, we don't have **any** of those cats in our management.

DR. FRIED: You know, it's interesting that you apply all of this to your **management.** How about the troops? How many grade 1 thinkers do you have among your colleagues? How about grade 2's and grade 3's?

DE FOREST: What's that got to do with anything? People like me don't run the company. We do what we're told until we can get some authority.

DR. FRIED: Maybe so, but you're the audience for your manager's communications. And if you're a grade 3 type who simply reacts according to your prejudices, your manager's licked before he starts.

Or if you're a grade 2 type, and all you can do is look for flaws in all your manager's schemes, damned little can be accomplished.

On the other hand, if you can manage the grade 1 frame of mind a good share of the time, you'll be amazed at how much can be done and just how effective communication can be, both from him to you, and from you to him.

DE FOREST: That sort of makes sense, but you still haven't told me what I can do about **my** communications problem.

DR. FRIED: I've been telling you nothing but. Look, the one last point I want to make before this session is over is that you probably don't have a serious problem in the first place.

DE FOREST: Dr. Fried, how can you say something like that after all the examples I gave you?

DR. FRIED: Easy. You'd be amazed at the things that are called communications breakdowns that aren't. A toilet is out of order in the men's room, and someone will swear up and down that it's a communications breakdown when it isn't fixed instantly.

What it really is is an oversight or maybe a question of priorities or one of a million other things that we lump under the heading of "a communications breakdown." In those terms every human failure or misunderstanding becomes a communications failure, by definition. That's so imprecise that it's a meaningless cliché.

DE FOREST: You know I'm beginning to feel better already. Maybe I'm not a bad communicator after all.

DR. FRIED: (*With a sigh.*) No, Rudy. I'm afraid that you probably aren't such a hot communicator, but if you remember some of these things you **can** be better in the future. But it's going to take a lot of concentration and effort.

The conversation is interrupted by a loud knocking at the office door, which swings open abruptly. Mrs. Robinsen is standing in the doorway.

MRS. ROBINSEN: Oh, Doctor, I'm sorry. I thought you would be alone.

DR. FRIED: That's quite all right. Mrs. Robinsen, meet Mr. De Forest. He seems to feel he has a communications problem too.

MRS. ROBINSEN: That's interesting. I suppose you're an engineer like most of Dr. Fried's other patients.

DE FOREST: Yes, I am. I work for Quik-Buck.

MRS. ROBINSEN: Quik-Buck? What a small world. My husband is president of Quik-Buck. Do you know him? I've been trying to get him to Dr. Fried for years. He has this **terrible** communications problem. We had a complete communications breakdown years ago. Why don't you buy me a drink someplace and I'll tell you about it?

DE FOREST: (*Obviously flustered.*) Uh, why yes. I'd . . . I'd like to. I know Mr. Robinsen very well.

DR. FRIED: (*Aside to the audience.*) I have a feeling he's going to get to know Mrs. Robinsen a lot better than he does Mr. Robinsen.

DE FOREST: Well, I think we'll run along then.

DR. FRIED: Did you want to see me about anything, Mrs. Robinsen?

MRS. ROBINSEN: Oh, just the usual communications thing, but don't worry about it. Somehow it doesn't seem important now.

(*Curtain*)

EE COURSES

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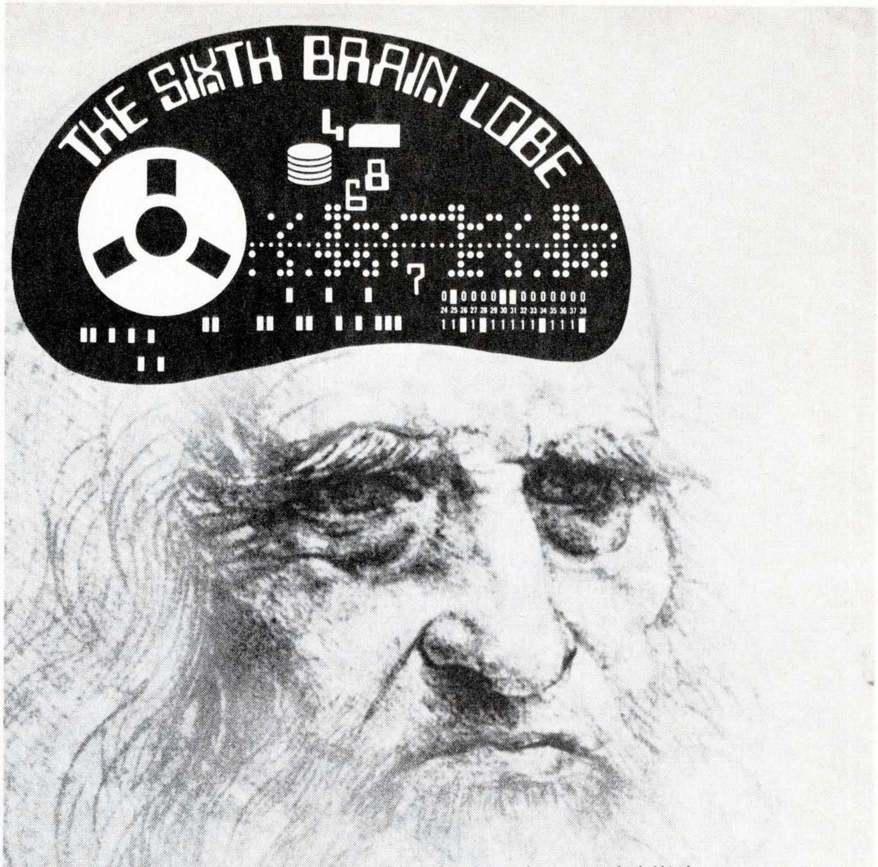

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Circle 30 on Inquiry Card

Understanding solid-state or static relays

Surprisingly, they are not in competition with other relays, but rather they created their own unique applications.

By Michael Joyce, Supervisor, Development Engineering,
Solid State Controls, Ohmite Mfg. Co., Skokie, Ill.

Much has been written about electromechanical (e-m) relays. Solid-state relays (or static relays)* in comparison, are relatively new; and with most new products, many misconceptions and misunderstandings exist about their capabilities.

These misunderstandings have been compounded because some electro-mechanical relay manufacturers have not been willing to recognize the need and place for solid state types. At the same time, the semiconductor manufacturers have been pushing the solid-state approach. But the semiconductor manufacturers, unfortunately, are not totally familiar with basic relay application concepts and practices that have been developed over the years. Hence, many solid-state relays, or what have been claimed as relays, have been misapplied. The user is still in the dark as to what can make the difference between a reliable control circuit and one that is not.

To help "defog" the subject of solid-state relays, let's examine some simple descriptive schematics of relays and switching devices available today. (see Fig. 1).

Types of relays

For purposes of definition we are assuming a true relay possesses at least 500 gigaohms of isolation. The

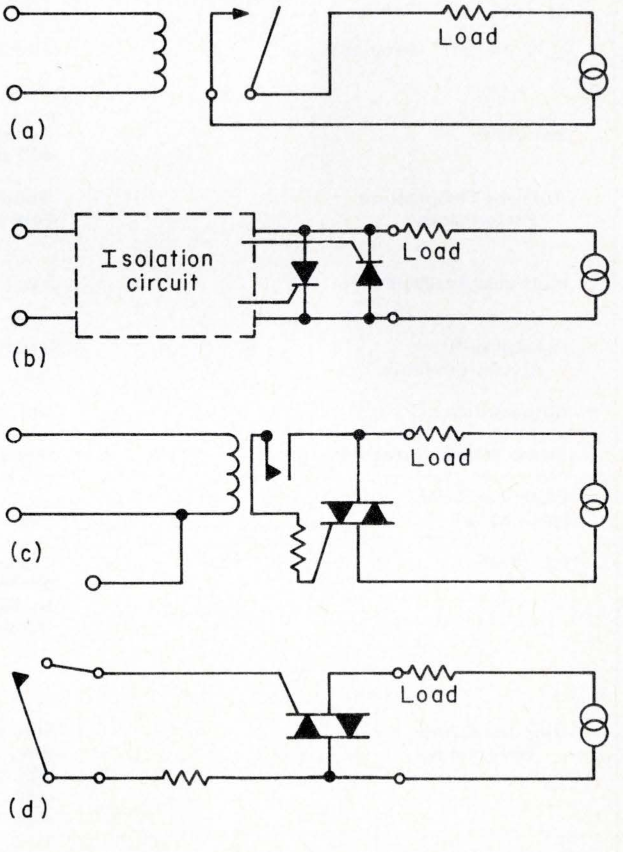

Fig. 1: These are four typical basic types of relays (switches). Fig. (a) is an electromechanical type, (b) a solid state relay, (c) a hybrid relay, and (d) a triac type switch. The latter, although sometimes claimed to be a relay, is not considered by relay manufacturers to be a true relay.

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* The solid-state or static relay is an all semiconductor device that performs the function of an electromechanical relay and possesses the same degree of isolation, the important delineation defining the difference between a true static or solid-state relay and a solid-state switch.

Table A: Relay Comparisons

		Electro-Mechanical	Solid State (static)	Hybrid	Solid State Switches
Isolation (500 gigaohms minimum)		Yes	Yes	Some yes, some no	No
Contact capability	Inductive	Yes	Yes	Yes	Some yes, some no
	Capacitive	Yes	Yes	Yes	Some yes, some no
	Resistive	Yes	Yes	Yes	Yes
Operating frequency of contacts		1-10 Hz	1Hz to 10 kHz	1-10 Hz	Depends on speed of external contacts
Minimum current, contacts		Dry circuit types avail.	10 mA	20 mA common	20 mA common
Contact Resistance	Closed	10 to 100 milliohms after use	100 milliohms thruout use	100 milliohms thruout use	100 milliohms thruout use
	Open	500 gigaohms	20 megohms	as high as 20 megohms	as high as 20 megohms
Synchronous Operation		No	Some yes, some no	Some yes, some no	Some yes, some no
Coil Voltages		6,12,24,48, 115,230 Vac	3 to 140 Vac	Generally	Does not apply
		6,12,24,110, 220 Vdc	3 to 200 Vdc	Same as Electro-Mechanical	
SPEED	Turn "on" (Pull-in)	1-20 ms.	5 μsec.	5 to 20 ms.	5 μsec.
	Turn "off" (Drop out)	2 to 20 ms.	100 μsec. to 8.3 ms.	100 μsec. to 8.3 ms.	Depends on speed of external contacts
Sensitivity		As low as 400 mW	As low as 6 mW	As low as 400 mW	Does not apply
Ambient Temperature Performance		Good Hi Temp Poor Lo Temp.	Good @ limited Hi temp. Good Lo temp.	Good @ limited Hi temp. Good Lo temp.	Good @ limited Hi Temp. Good Lo Temp.
Multipole Availability		Yes	Yes	Yes	Highly application dependant
Reliability/life-Cycles Operation		3 million max.	Unlimited	100 million	Depends on external contacts
Contact Bounce		Yes	No	No	No
Size & Weight (Relative)		Bulky, Heavy	Small & light	Small & light	Small & light
Electrical Shock/spark hazard		Yes	No	No	No
RFI/EMI		Can be suppressed with auxillary componets	None, if synchronous use	None, if synchronous use	Better than electro-mechanical but poorer than solid state or Hybrid
Vibration/Shock Environment		Susceptable to shock. Can exhibit unwarranted contact closure	Resistant to shock, no unwarranted contact closure will occur		
Radiation Environment		Less sensitive than semi-conductors	Sensitive	Sensitive	Sensitive

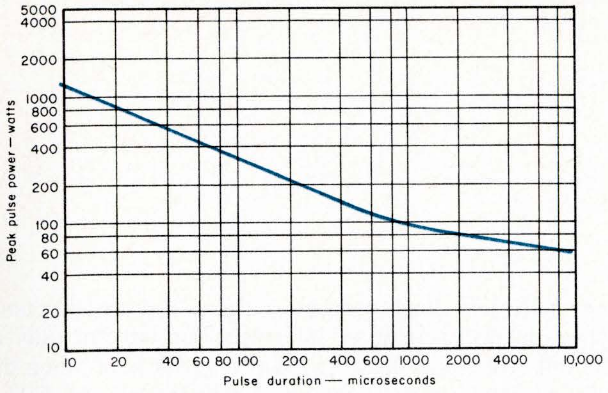

Fig. 2: Solid-state relays are not as susceptible to transient voltages as sometimes thought.

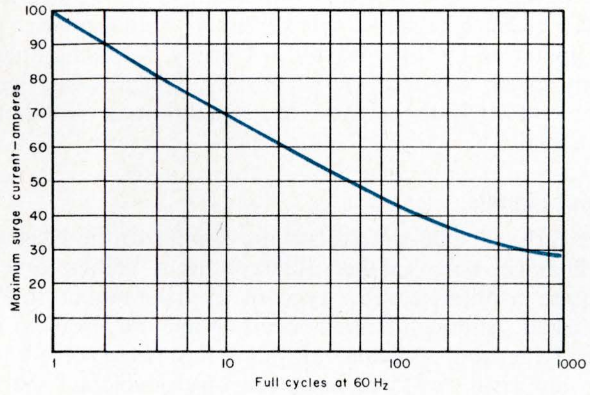

Fig. 3: Surge handling capabilities of solid-state relays can be made good as indicated here.

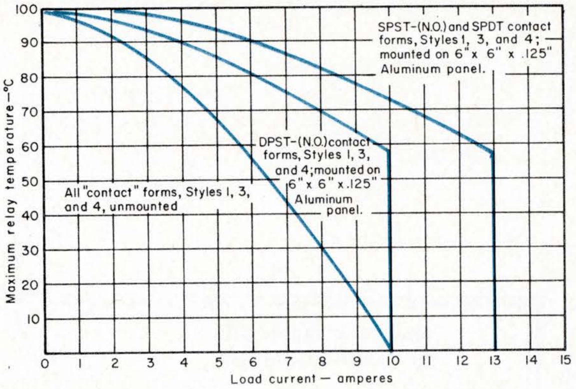

Fig. 4: Load current/temperature derating curves depend upon mounting of relay. These curves are for Ohmite solid-state relays.

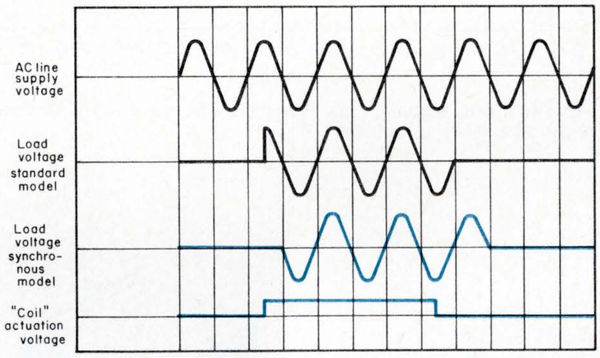

Fig. 5: The synchronous switching type relay is best to prevent wave distortion and spurious signals.

electromechanical type offers physical isolation between input and output of about 500 gigaohms. Certain solid-state relays also offer this same coil-to-contact, or input-to-output, isolation.

The hybrid relay, while it possesses the isolaton levels of the electromechanical and true solid-state relays, relies upon an electromechanical device (typically a reed switch) to achieve its isolation.

The triac circuit (Fig. 1d) though sometimes confused with solid-state relays, actually is a switching device and offers no isolation between the input and output. Moreover, the solid-state switching device must be actuated by some type of external switch closure, and will not accept a source voltage/current as do electromechanical, hybrid, and true solid-state relays.

The relay specifier should be completely familiar with the characteristics of electromechanical, hybrid, and solid-state relays. Besides the isolation characteristics, other parameters should be compared and examined. Table A covers the most important characteristics.

As the table shows, there are vast differences between solid-state switching devices and relays. A solid-state relay is a packaged circuit that performs all the functions normally attributed to electromechanical types. The user must be aware of these differences to properly apply them in circuitry.

The material below examines such characteristics of the true solid-state relay as transient protection, surge current handling, load current/temperature derating, and standard or synchronous switching. It is important to understand these characteristics because they are unique to solid-state relays; there are no counterparts in their e-m equivalents. Some of these characteristics permit the application of solid-state relays where electromechanical relays heretofore could not have been successfully applied.

About solid-state relays

Transient protection: Though they are sometimes thought of as being susceptible to transient voltages, solid-state relays are protected from *damage* resulting from transient voltages. (see Fig. 2).

Electromechanical relays, on the other hand, need auxiliary transient arc suppressors and like devices to protect the contacts from excessive arcing. Solid-state relays integral circuitry prevents false actuation by transients. Because of their slow actuation time, however, electromechanical types are not susceptible to false actuation by transients.

Surge current handling: Surge current handling capacity is another factor that is usually built into a quality solid-state relay. It is too costly to achieve similar surge current capabilities with electromechanical relays, especially in high duty cycle applications. Figure 3 shows the characteristics of a solid-state relay capable of withstanding ten times rated current within the limits shown. Surge current overloads within these limits should not be repeated more than once per min.; thus, overload cycling limitation is important.

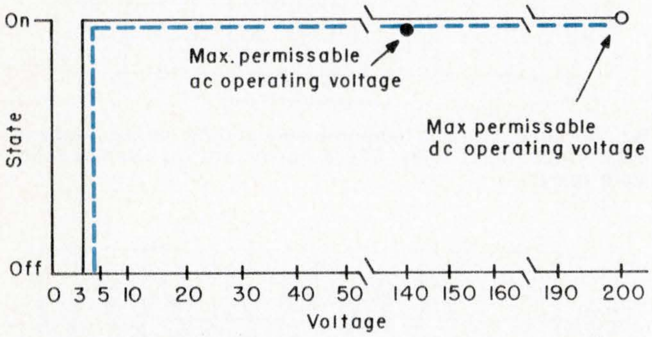

Fig. 6: An input signal of as low as three volts can actuate a solid-state relay to full on.

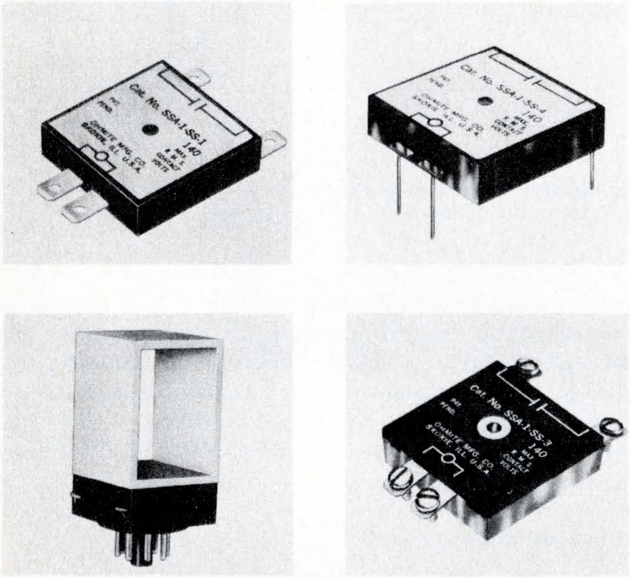

Fig. 7: Various types of solid-state relays available from one manufacturer.

Load current/temperature derating: These characteristics of solid-state relays largely depend upon the physical structure of the device and the mounting method used. Figure 4 shows typical derating curves. Load current and temperature will affect the total relay package size and mounting method to be used. These parameters are not normally associated with electromechanical relays. But don't forget to watch the coil and contact temperature rise in e-m relays.

Synchronous switching: Almost all solid-state relays are essentially ac power switching devices that may be actuated by a pulse or continuous low dc voltage input. Some units are designed to actuate at any point during the half-cycle load current. Others are synchronous types that will actuate or interrupt load current only at the full-cycle, zero crossing point regardless of when the coil actuating voltage is applied or removed. As Fig. 5 shows, non-synchronous switching gives rise to wave distortion and generates spurious signals. Therefore, the synchronous type is best if the application demands that the switching function be free of Radio Frequency Interference. This is a very important factor in meeting EMI (electromagnetic interference) requirements in computer and military systems. Clearly, from the operating speeds required, the electromechanical relay does not lend itself to perform the synchronous switching function.

Input signals

Nearly all solid-state relays are similar to the electromechanical types in that different input voltage levels require a different relay type or model number to be specified. Although this has been an age-old problem in specifying and applying relays, it has been solved by the universal "coil" concept recently developed for a solid-state relay. This concept allows you to operate a solid-state relay within the range from 3 to 140 Vac or 3 to 200 Vdc so you can use the exact relay anywhere within the voltage input limits shown in Fig. 6.

Summary

Although solid-state relays were designed originally to replace electromechanical relays, they actually have found new areas of application. For conventional applications requiring multiple poles, normal environments, and so forth, the old standby electromechanical type is probably your best choice. For applications involving interfacing with integrated circuit logic signals, a solid-state device that will accept a low level signal without op-amps or other devices is probably best. Another good application for solid-state relays is as a level detector if the relay has a predictable and well defined threshold with low hysteresis. It all depends on the application.

The National Association of Relay Manufacturers and the A-2R Relay Committee of the Society of Automotive Engineers are doing a comprehensive job of providing a continuous flow of relay application information to relay specifiers. Also, the efforts of individual relay manufacturers through more detailed relay literature and industry idea-exchange meetings, such as Ohmite's Think-In relay seminars, are assisting in this communication area.

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Components, Relays

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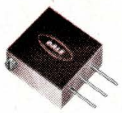
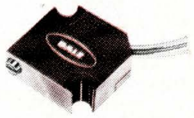


5850—Insulated leads
5880—PC pins, top adjust
5887—PC pins, side adjust
5891—PC pins, base mount
Size: .375" x .375" x .145"

1/2" MODELS



5050—Insulated leads
5091—PC pins, base mount
5080—PC pins, top adjust
Size: .50" x .50" x .19" (5050)
.50" x .50" x .22" (5091, 5080)

Resistance Range: 10 ohms to 50K ohms
Resistance Tolerance: ±5% standard
Resolution: 1.01% to .09% (3/8") .54% to .10% (1/2")
Power Rating: 1 watt at 70° C
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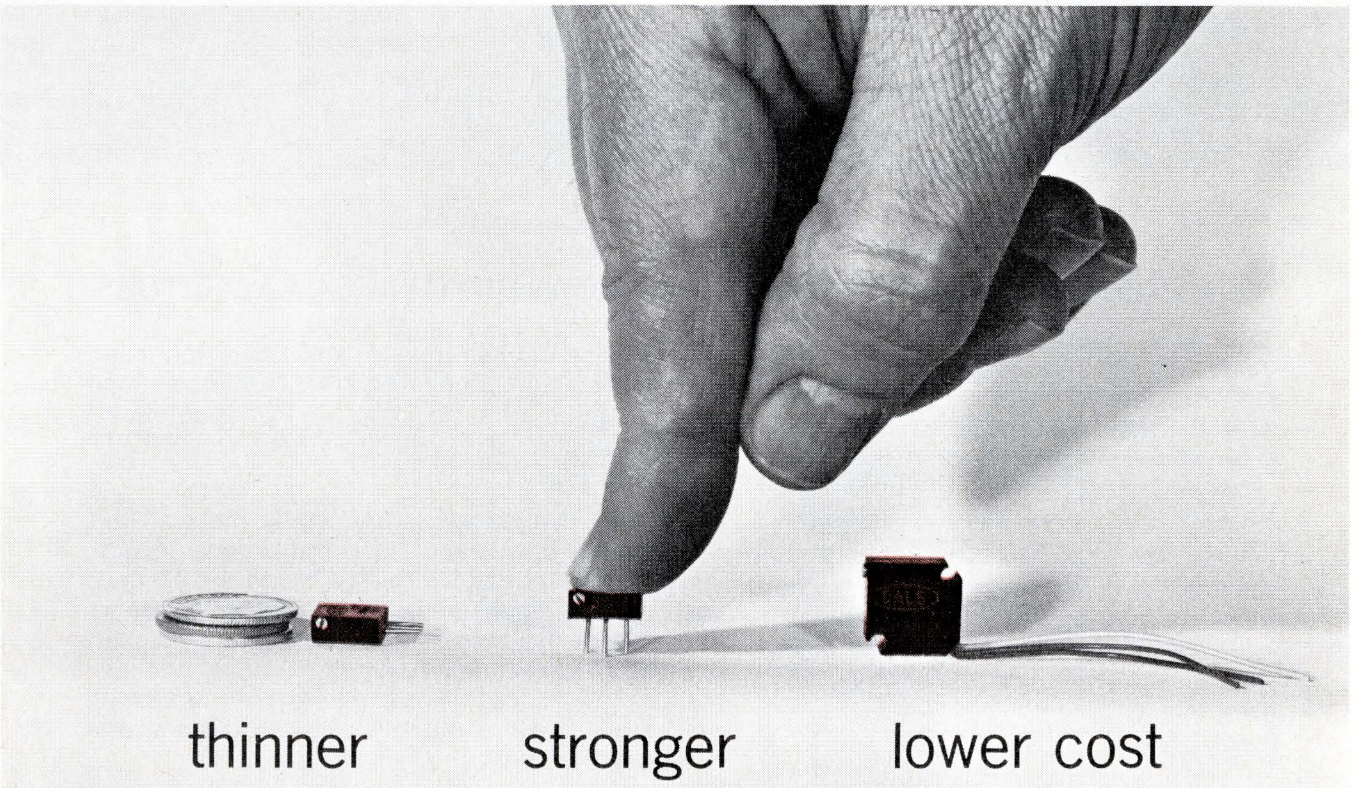
Temperature Coefficient: ±50 PPM/° C Max.
Moisture Resistance: 10 Meg. minimum insulation resistance
Mechanical Adjustment: 25 turns (3/8") 25 turns (1/2")



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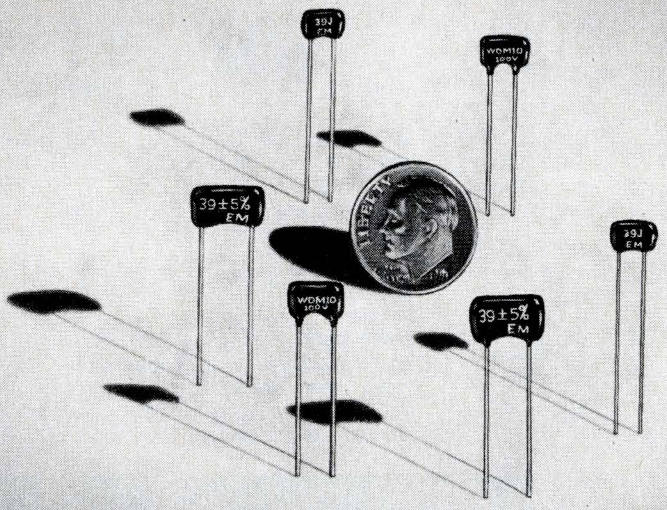

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		D, E	27pF thru 400pF
		F	85pF thru 400pF
DM5	100VDC	C	1pF thru 200pF
		D, E	27pF thru 200pF
		F	85pF thru 200pF
DM10		C	1pF thru 400pF
		D, E	27pF thru 400pF
		F	85pF thru 400pF
DM15		C	1pF thru 1500pF
		D, E	27pF thru 1500pF
		F	85pF thru 1500pF
DM5	300VDC	C	1pF thru 120pF
		D, E	27pF thru 120pF
		F	85pF thru 120pF
DM10		C	1pF thru 300pF
		D, E	27pF thru 300pF
		F	85pF thru 300pF
DM15		C	1pF thru 1200pF
		D, E	27pF thru 1200pF
		F	85pF thru 1200pF
DM10	500VDC	C	1pF thru 250pF
		D, E	27pF thru 250pF
		F	85pF thru 250pF
DM15		C	1pF thru 750pF
		D, E	27pF thru 750pF
		F	85pF thru 750pF

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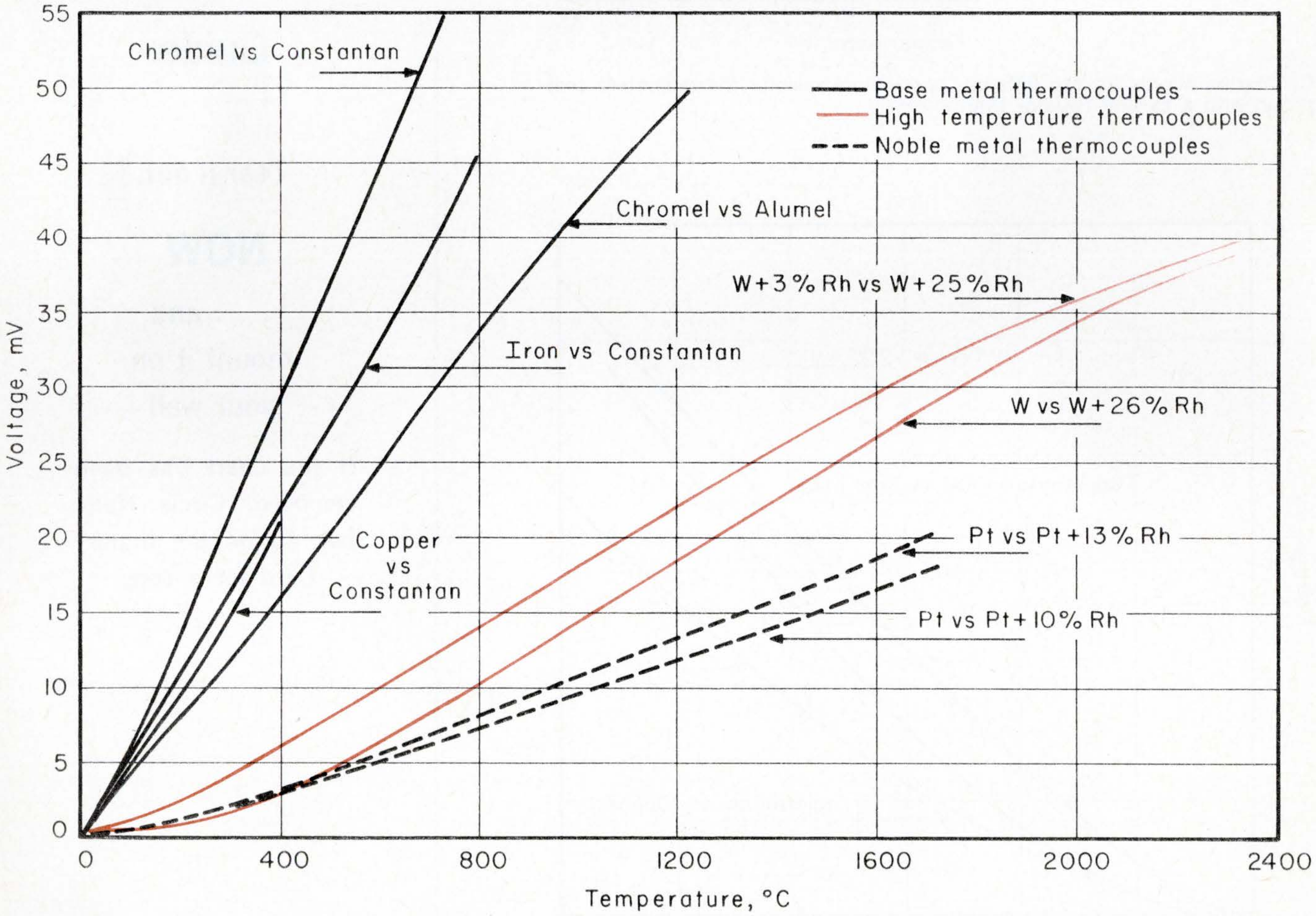
Calibration curves for temperature sensors

These graphs show thermocouples for high and low temperatures and resistor thermometers for cryogenic temperatures. Although only a few typical sensor calibrations are represented, you can find a complete list of temperature measuring devices along with information on calibration in the Temperature Measurement Guide, a pull-out chart following the next page.



Calibration curves for base metal, noble metal, and high temperature thermocouples.*

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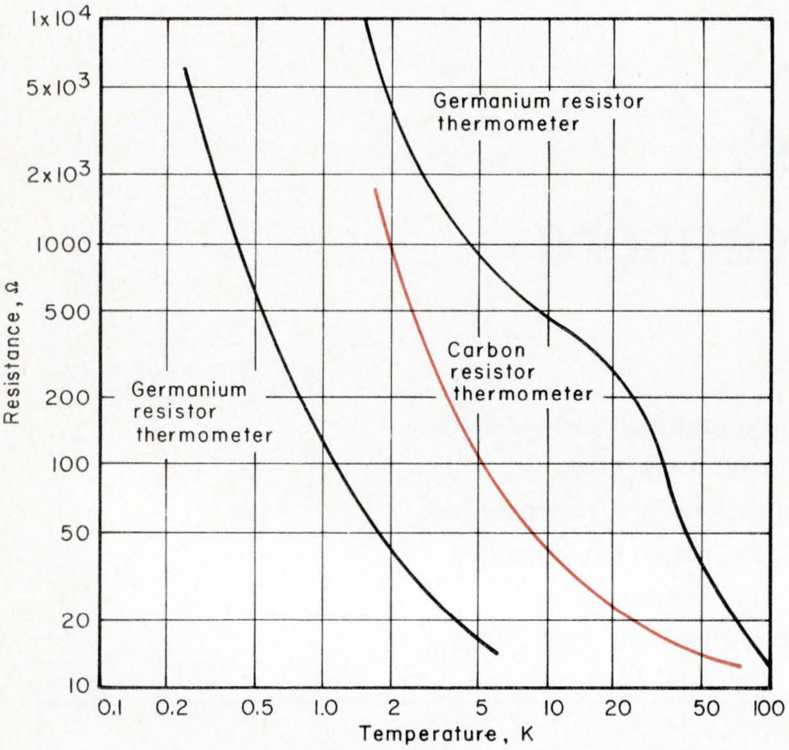
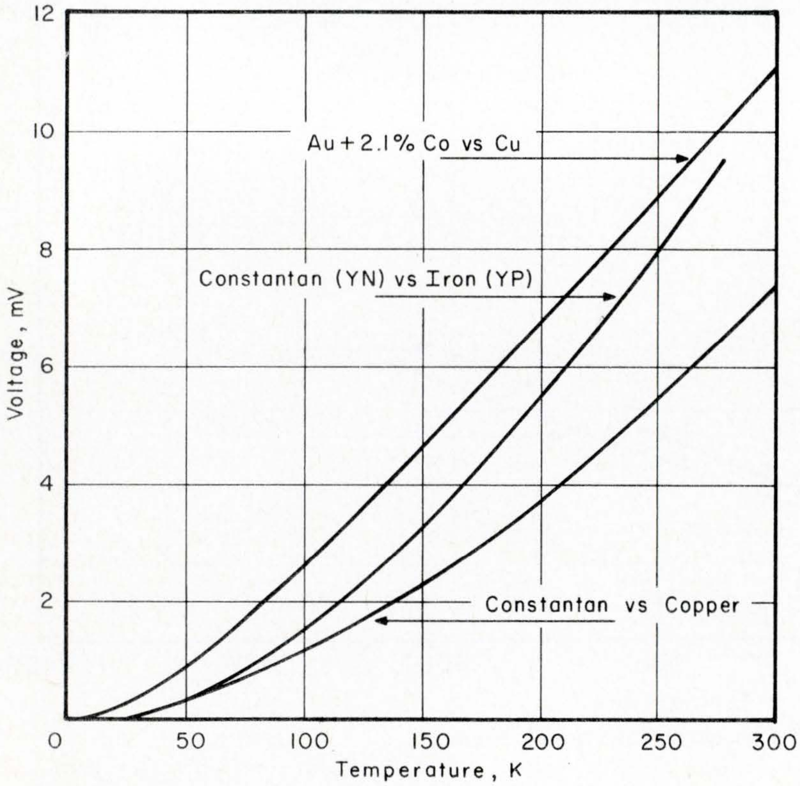
*Based on information supplied by Prof. G. Ruffino, Colonetti Institute of Metrology, Torino, Italy. Constantan, Chromel, and Alumel are tradenames for metal alloys.



Calibration curves for two different germanium resistor thermometers compared with a carbon resistor thermometer.



Calibration of three thermocouples for subzero temperatures.

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CAD Graphics: Circuits made to order

I dreamt that I was going mad,
Designing circuits, pad by pad.
I screamed, and woke, then thanked the dad,
Whose fertile mind had fathered CAD.

By Stephen A. Thompson, Western Editor

Computer Aided Design Graphics is a rose that goes by many other names, such as Interactive Graphics or Design Automation. To put it into perspective, consider that there are three areas of Computer Aided Design (CAD): circuit design, graphic design, and test program design. CAD Graphics is defined here as that portion of CAD that starts with a logic diagram, or its equivalent, and ends with the generation of a mask set. Other areas, such as circuit board design, hybrid circuit design, and microwave design obviously employ CAD techniques, but the emphasis here will be on CAD applied to integrated circuits.

Aided—the forgotten middleman

The crux of CAD, the term **aided,** is often forgotten. The mind naturally extends the concept of a computer aiding a designer to its logical extreme, complete computer design. This would collapse CAD to CD. There is a little of this going on in special cases, but today industry has its hands quite full trying to make the aided systems work.

The ingredients of the problem that force CAD into being are classic: A few basic building blocks are being combined in increasingly complex designs; the number of people with the potential to manually handle the complexity is limited; the same details show up again and again; the press is for ever more, ever larger, ever more complex circuits; schedules and errors must be reduced, yet human judgment must also be retained.

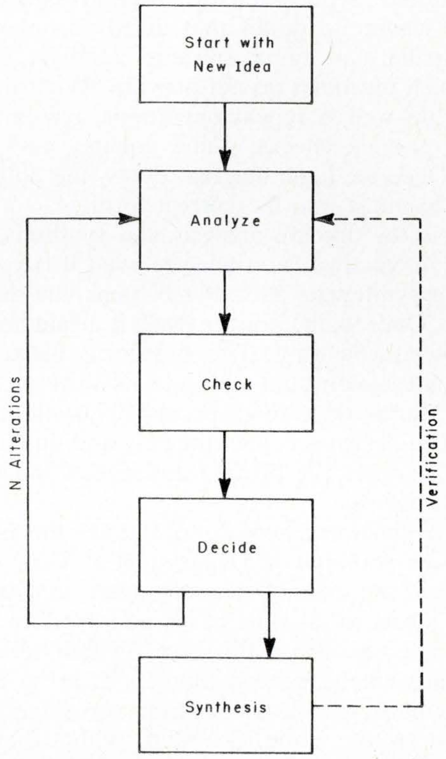


Fig. 1. **How a designer turns his creation into final form.** He starts with his new circuit concept, analyzes it to see how to build it, and checks to see that he has what he wants. He may decide several times to alter his building plan before deciding to build. Once built, the device itself is analyzed to verify that it is what was wanted originally. Much of this process can be mechanized once it is understood. The designer supervises the process, adding innovations as needed.

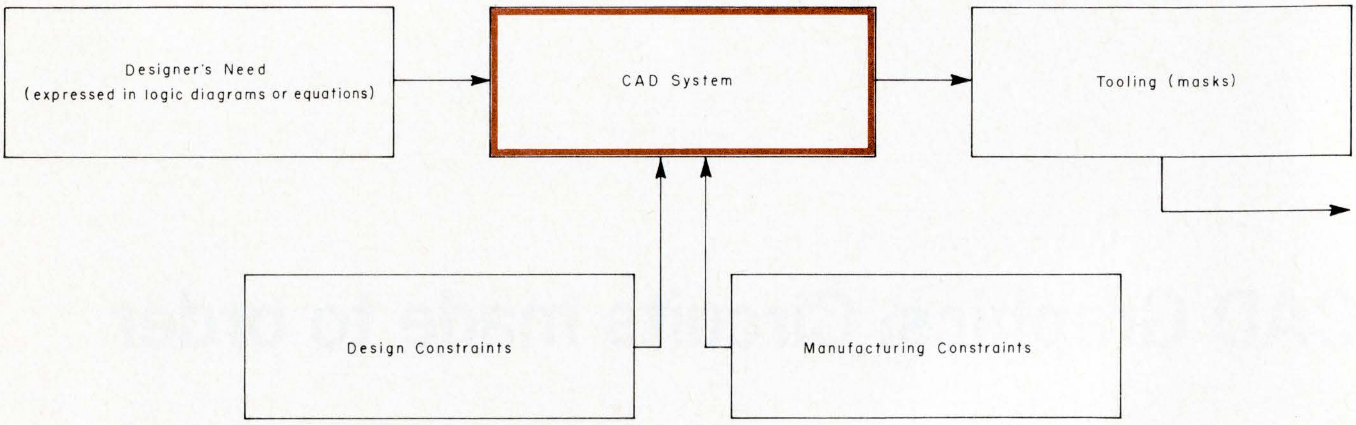


Fig. 2. **The role of CAD.** The designer's job is to take his needs and produce the required tooling—masks in this case—within certain design and manufacturing constraints. Once he has his needs formulated into logic diagrams or equations, the CAD system can be made to operate within these constraints to do the mask fabrication portion of his job.

The solution is also classic: Machines are devised to do the dog work and keep track of the details, thus enabling the small talented nucleus of designers to race ahead and create.

At National Semiconductor, Section Head Vahe Sarkissian leaves no doubt that **aided** gets the stress. His view is that new circuits require creativity, or innovation, which machines do not provide. What the computer can do well is repeat operations, remember details, and provide checks. Vahe equates design with creation: Once the logic diagram exists, the only creating left is to put it into the correct form.

The tools for this are analysis and synthesis, which are highly interactive. You analyze what it is you want to build, or synthesize, and after N steps you decide to go ahead. Once built, you analyze it again to verify that it is what you want. This process is illustrated in Fig. 1. Analysis constantly adds to its store of evaluation tools things that were successfully synthesized in the past. The designer is the authority and final arbitrator who supervises the process and makes innovations and key decisions.

Figure 2 illustrates how John Hanne, the manager of the Design Automation Department at Texas Instruments, views the role of the computer in CAD. The designer's job is to take his needs and produce the required tooling—masks in this case—within certain design and manufacturing constraints. Once he has his needs formulated into logic equations or diagrams, the CAD system can be made to operate within these constraints to do the mask fabrication portion of his job.

Eenie-meenie-miny-mo

Where human creativity is retained, multiple solutions often occur, and CAD is no exception. There are several approaches to CAD systems. Classified as the array, standard cell, and discretionary wiring methods, they are illustrated in Fig. 3.

Arrays—the bargain basement

Paul Sullivan, product manager for integrated circuits at Raytheon Semiconductor, describes the **array,** or universal approach. Wafters are processed, to a point. Each one contains arrays of components that are located on the chips, but are not connected to each other. They can be parts of gates, or parts of almost anything. At this stage, each array represents many potential chips, and different sets of wafers can contain different arrays. Within this approach there are degrees of sophistication. Arrays can be made up of gates, flip-flops, and so forth, instead of just their component parts.

A customer's circuit requirements are matched against the chip potential of the available arrays and the best match is made. Then the minimal metallization is devised to connect the components into the desired circuit. A computer can check all possibilities and pick the best.

For small volumes, an array is cheapest and quickest method. Wafers can also be stockpiled in partly processed form, and often only one mask needs to be generated. It implies, however, an extra capability, or redundancy, because every customer will not use the complete capability of a given array. Silicon will be wasted because of this, and because component form and arrangement will not be optimized.

The main examples of commercial arrays are the Master Slice® by T. I., and Fairchild's Micromatrix®.

"Standard cells"—the most for the money

Standard cells—such as Motorola's Polycell and Fairchild's Micromosaic®—are based on a computerized

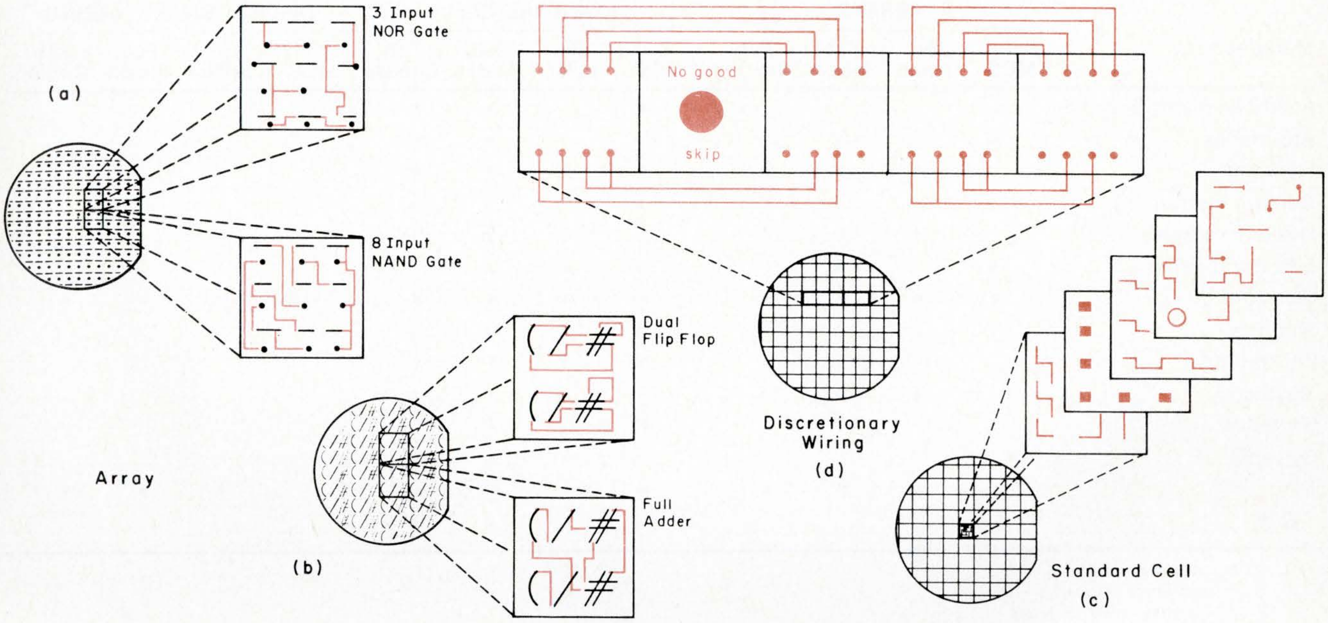


Fig. 3. **The three approaches to CAD.** In (a) the wafer contains a predeposited array of gate components. How they are connected determines what type of gate is produced. An array of completed gates is used in (b). A variety of more complex circuits can be formed, depending on the connection pattern used. These are the array approaches. The standard cell approach is shown in (c). The wafer starts as a blank and a set of several masks is used to produce a circuit that can vary in size and complexity. In both the array and standard cell approaches the identical pattern is repeated over the entire wafer. Discretionary wiring is used in (d) to connect predeposited, pretested, complete circuits into more complex circuits. Those circuits testing "bad" are skipped in the interconnection program and the three-cell circuit on the left is identical to the two-cell circuit on the right. This represents the highest order of complexity and can get much more complicated than is shown here.

inventory of basic circuits (the standard cells). All circuits, or chips, will merely be some arrangement of these cells. The logic design tells you how many of each kind you need. The computer handles the details of remembering how each cell is constructed, arranges them efficiently, and generates the artwork for a mask set. The masks are stepped to produce identical chips in a pattern all over the wafer. Software is obviously the key here.

There are degrees of sophistication with this method too. Standard cells usually allow reasonable tolerances for placement and processing. If each chip were custom designed to the full capability of the system, the cost would rise substantially, but as much as a 20% reduction in silicon area might be realized.

The advantages of the standard cell are that it is almost as good as a custom design in efficiency of arrangement, circuit density, and use of silicon real estate. This is important, because yield is a function of area and many manufacturers are not balking at chip sizes of 150 mil squares. Paul Sullivan estimates at top of column 2 the relative cost of a circuit designed by the array, standard cell, and custom cell methods.

Estimated relative costs for 100% yield

	First Circuit	10,000 Circuits	Total
Array	$10,000	$300,000	$310,000
Standard cell	30,000	300,000	330,000
Custom cell	80-100,000	300,000	380,000

This assumes $30/circuit. In small quantities arrays are cheaper. They may make the best development tool. In large quantities the total cost of all methods begins to converge. The $30/chip is probably not valid for large custom runs because there are some savings. If it could come in at about $23/chip, it would be as cheap as arrays. It is always the best circuit for the job.

Discretionary wiring—simply the most

So far, we have been within the framework of the 100%-yield approach. Unfortunately, this does not mean that all the chips made will work; rather it implies that when the chips are fabricated, 100% of the parts on some chips will work. The rest will be discarded.

Discretionary wiring departs from this philosophy. Arrays of cells are laid down all over the wafer and each one is probed. The computer that tests them also keeps track of where the good and bad ones are, and determines an interconnection pattern that skips the bad ones.

Who makes what in CAD

Manufacturer	ARRAYS				STANDARD CELL				DISCRETIONARY WIRING			
	MOS	Bi-polar	Fab. Masks	Fab. Circuits	MOS	Bi-polar	Fab. Masks	Fab. Circuits	MOS	Bi-polar	Fab. Masks	Fab. Circuits
American Micro-Systems					•		•	•				
Autonetics	•		•	•	•		•	•				
Fairchild		•	•	•	•	F	•	•				
General Instrument					•		•	•				
Hewlett-Packard		I	I	I		I	I	I				
Litton Industries	•		•		•		•		•		•	
Motorola	•	•	•	•	•	•	•	•	•	•	•	•
National					I	I	I	I				
Philco-Ford					•	I	•	•				
Raytheon		•	•	•		•	•	•				
Signetics					F		F	F				
Sylvania						•	•	•				
T I	•	•	•	•	•	•	•	•		•	•	•
T R W					•		•	•				

NOTES: • = commercially available
I = for internal use only
F = accepting orders for future
Read-only memories are not included in this chart, because their design by computer is relatively simple.

Texas Instruments is the leader in this field and Charles Phipps, manager of the Technical Customer Center, added some insight into the process. There is a defined cell size that discretionary wiring can accommodate. The wiring program does not care what is in the cell; for instance, it can be bipolar or MOS. With cells 150 mils square, you can get five to ten circuits per cell. This translates to between 500 and 1000 logic circuits on a slice. The finished slice would be cut into sections containing about 200 circuits per package.

At T. I. there is currently one circuit per cell and the cell sizes are 40 mils square or 40 x 80 mils. This yields from 150 to 200 circuits per slice. Cell size is mainly determined by the fact that routing gets more severe as cell size gets smaller. This means that MOS is harder to work with than bipolar, because one circuit fits into a cell that is about 5 x 10 mils. More complex, or larger MOS cells will lend themselves to discretionary wiring better. Chuck Phipps estimates the relative cost of several fabrication methods, including discretionary wiring in the table below.

Estimates for relative fabrication costs

	Cost/gate	No. of Packages	PC Board Inter-connections
Plastic ICs	$.15	300+	4,200
MOS MSI	0.20 (sometime this year)	12	480
LSI (Disc. Wiring)	1.00 (next year)	5	400

The critics of discretionary wiring are many and they point out the problems associated with it. A new mask is needed for each chip so that the cost of prototypes and production units will be similar. Like the array approach, it implies a certain redundancy and waste of silicon. The area taken up by the probe pads alone largely contributes to this.

Generating the connection pattern is not the end of the problem. Still to be done are two metallization steps, alloying in of the metal, cutting of silicon, die attach, die bonding, sealing, and testing. At each step there is a yield factor. Some feel that it was conceived at a time when nobody could foresee the processing improvements that would give reasonable yields on chips much larger than 40 mils square.

Nonetheless, even the sternest critics smile when they reflect on the complexity of the circuits that can be achieved. Some circuits are so complex that they simply cannot be handled any other way.

The big three—Fairchild, Motorola, and Texas Instruments—are the leaders in CAD of ICs. Their turnaround times from logic diagrams to initial deliveries typically range from two to three months. Motorola has—since 1966—been best known for its standard cell (Polycell) but, as the table on this page shows, it also provides the most complete line of services in CAD, including arrays and discretionary wiring. Texas Instruments also has working capabilities in all three approaches. Fairchild has been producing CAD arrays since 1966 and mosaics for about two years.

A guided tour

We will now follow the development of a circuit as it progresses through the generalized flow chart shown in Fig. 4. Its structure, though general, is more representative of the standard cell approach simply because this is the area that most manufacturers think will have the largest application.

Round one—the customer-vendor interface

A customer has to get into the system somewhere. At many houses he can enter almost anywhere, with truth tables, logic diagrams, Boolean equations, masks, or just a verbal description of what he wants. (Usually, he has a logic diagram.) Wherever he enters the flow chart, there is a customer-vendor interface.

The importance of this interface cannot be overstressed. The entire project can be made or broken right there, so a good rapport is needed early. Placing so much trust in the vendor is sometimes a hard idea for a customer to get used to, but to date, there have been no reported instances of a vendor's compromising a customer's proprietary ideas or circuits.

Part of our definition of CAD Graphics was that it started with a logic diagram; however much can transpire before this is achieved. If nothing else, the vendor will give the customer the ground rules to follow that will make the product amenable to his processing techniques, CAD format, and CAD capability. Such factors as pin numbering, rotation, current capability, and other circuit tolerances can be specified.

In an extreme case, the semiconductor house may contract to do a customer's design right from scratch. This means that some of its engineering staff must live with the customer for a week or two, finding out what he really wants and setting the ground rules for implementing his circuit.

One way or another, a logic diagram evolves. If the system being designed is large, all circuitry will not fit onto one chip. This means that the system must be partitioned, usually to minimize the customer's wiring and assembly problems. There are many orders for multichip systems from systems people.

Logic consistency test

Once a logic diagram exists, it is subjected to a logic consistency test. Two things are determined: (1) Does the circuit do what the diagram says it does? and (2) Is that what the customer really hand in mind? This test helps the vendor to make what the customer wants, and this is not necessarily what he *says* he wants.

Since logic errors are found in the great majority of cases, the chips will be useless if made according to the original diagram. Seventy-five percent of customer requests fail the logic consistency test at Texas Instruments. The score does not improve with time. Once the customer finds that T.I. can back him up, he lets T.I. provide that service, even though it increases his cost. Some see this step as the potential bottleneck because simulation and correction take time.

Often the test enables a more efficient design to be generated. Besides checking out logic, it checks against the manufacturing constraints that were laid out in the ground rules earlier. The customer gets mathematical and technological verification of his design.

Rob Walker of Fairchild explains that "digital simulation of all LSI is a must for two reasons. First, it verifies that the manufacturer understands the design objectives of the customer. Second, it provides verified input data to test-generation and mask-design programs." Fairchild has published a manual (with software instructions) for its Fairsim® simulation program, which allows the user to interface directly with the CAD system, bypassing the logic diagram.

Once the design is verified, it is ready to enter the rest of the graphics mill. Here the customer-vendor interface again becomes critical. The manufacturer is going to make a circuit that cannot be exhaustively tested within any reasonable time or cost limits. Both customer and vendor must agree on the criteria for acceptance testing before the vendor can proceed.

Partitioning

Now the manufacturer partitions the logic diagram into units that correspond to a set of standard cells that he has stored in a computer library. The particular technology to be implemented, say MOS, will contain about 30 to 60 such cells. Every effort is made to assign each function a standard cell counterpart, because this step largely determines the final cost of the chip. If there is some unique aspect to the circuit, or some function not in the library, the designer will have to design a custom cell for it. With some vendors, the addition of one non-standard cell can double the cost.

The designer has used his CAD system to design his standard cells and he spreads the design costs among all of his customers. A customer with a non-standard requirement will have to bear the entire design cost of

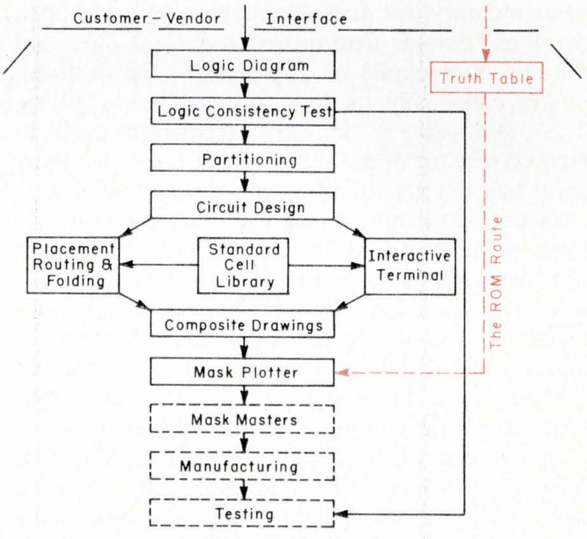


Fig. 4. **Generalized flow diagram for CAD Graphics.** Graphics starts with a logic diagram and finishes when a mask set is plotted. The operations in dashed boxes are not part of Graphics as defined here, but the acceptance test program is defined at the logic consistency test phase. The position of the customer-vendor interface depends on where customer enters the flow, but it usually occurs where shown. ROM's are a special case where a truth table, which is roughly a logic diagram equivalent, is a sufficient input to enable proceeding directly to mask plotting. This represents a collapse of CAD into CD (computer design, unaided).

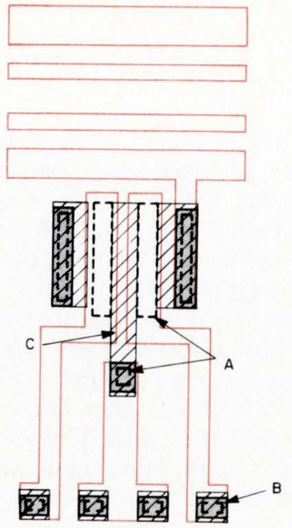


Fig. 5. **A Calcomp four-color plot of a standard cell** from the library at American Micro-Systems. Red represents metallization and the four bars at the top are power buss and phase lines. Areas A (dashed) represent gates and contact holes. B (grey) is the oversize for contact holes, and C (cross hatched) is the P region diffusion. The X in the lower left hand corner indexes the cell so that it can be placed in any of its four possible positions: right hand, left hand, or upside down of either.

Computer design is here in ROM's

There is one area where CAD has already become CD. Read Only Memories (ROM's) adapt themselves to custom mask making very nicely. It is not certain how many logic functions can be taken over by ROM's efficiently, but the area is expanding rapidly as more and more of the potential is understood. (See *ROM at the Top,* **The Electronic Engineer,** May 1969.)

The beauty of ROM is its simplicity. Since its basic memory cell doesn't change, a series of open or closed circuits determines the layout once and for all. A stockpile of 256-, 1024-, or 4096-bit arrays can easily be built up containing all l's. The customizing is done by preparing a mask to etch certain metal paths and make them 0's. Fairchild has the capability to do 8000-bit arrays.

General Instrument, for example, goes directly from a chart (filled by the customer) through punched cards into comptuer tape. This tape controls a David Mann step-and-repeat camera that makes a (second) metallization mask that determines word length and content for the array of memory cells. The same tape loads the data pattern into their computer-controlled LSI tester.

The impact of this is that all of the steps in Fig. 4 between the logic diagram and mask generation can be eliminated. These services are now being provided by many. J. Robert Logan of Litton points out that in computer memory design, it is possible to go from an even earlier step, the assembly language, directly to the mask. The merits and demerits of ROM's is a discussion in itself; however, where they can be justified, processing by CD is a reality.

that cell. Worse yet, every time the manufacturer's processing changes, he must update his entire library of cells. Unless the manufacturer stores the non-standard cells and can easily update them (as, for example, in Fairchild's and Motorola's systems), when the customer comes back a year later for the same circuit, he will have to pay for a non-standard design again.

Circuit design at last

The designer proceeds to call up the required cells from the library. (A cell from the American Micro-Systems library is shown in Fig. 5.) There are two popular methods. The first is a highly interactive computer terminal (such as in Motorola's system), where the designer uses a light pen to call up cells onto a CRT display. He can then position them on the screen and design the entire circuit on the CRT. Compared to a manual approach, it is incredibly fast.

In the second method, the designer obtains a stack of punched cards that describes the cells he wants. He feeds the cards into a computer that juggles the cells so that interconnection length is minimized. The constraint is that they all lie in a straight line. The computer then "folds" this rather useless arrangement in a more convenient shape, like a square or rectangle, while keeping track of all interconnection patterns. Either way, he gets a cell placement and an interconnection scheme.

Information is stored in the computer that will allow a plotter to generate single layer drawings, multi-layer composite drawings, or masks. The first two are invariably asked for by the designer so that he can check them for obvious errors. The key breakdown point is usually in cell to cell interconnections. Nobody quite trusts the systems enough yet to proceed directly to the mask generation stage. Besides, there are other optimizations the designer can make at this point. Very often, a man can now enter the system and rearrange a couple of cells or pads to achieve a much better layout.

Let there be masks

When the designer is satisfied that things are A-OK, he calls for a magnetic tape or cards that will drive a Calcomp or Gerber plotter to cut "Rubyliths," or that use of a photo head to make masks. The masks are photo-reduced and stepped to produce a master. Copies of the master are used to fabricate the wafers. After the chips are packaged, they are tested in the predetermined fashion and those that pass are shipped.

This is a somewhat idealized example and it should be remembered that any one of these steps can be done manually or with computer aids. Different manufacturers are in different stages of evolution. In general, one loses degrees of freedom, or choices, as he proceeds down the chart. Therefore, the automation usually develops from the mask making and proceeds up the chart, because it is easier to design for fewer contingencies. Most people agree that CAD systems must evolve around existing pay-as-you-go product lines.

Testing—mission impossible

Les Hazlett of Motorola illustrates the hopelessness of exhaustive testing with the following example: "For a *combinational* circuit of *n* imputs, the total number of input patterns necessary to exhaustively test a fully interconnected array is 2^n. For example, if $n=37$, the number of input patterns is approximately 140 billion. A high-speed IC tester, which can perform a functional test in approximately 8 μs, would require 13 days non-stop to test such array exhaustively. For *sequential* circuits or memories, the time required would be even longer. If m is the number of internal states for such circuit, the required number of test patterns is 2^{m+n}."

"In addition, there is the problem of determining the correct output for each input pattern." According to Hazlett, the solution to both problems is computer-aided test plan design, which employs ingenious algorithms to minimize the number of test patterns. These algorithms take into account the likelihood of logic states, the signal paths, and the modes of failure.

Costs and their justification

Thurber Moffett, manager of Interactive Graphic Systems at TRW, assesses how CAD is being justified. In general, a strict economic case for CAD has not been made, because the technology is not that far along. The criteria for the moment are based on (1) specific applications that programs and hardware are tailored to fit, (2) a general belief that the manufacturer will have to have the capability in the future.

Part of the reason that costs are not yet known is because many people want to get into CAD much more than they want to know relative costs. They can either justify it as best they can and get a large stand-alone machine, or go to an existing machine and schedule time on it and do multiprogramming. This looks tempting, but you may get tied to a machine with a different primary mission (e.g., it could be a financial machine most of the week). You cannot go in and fiddle with the existing operating system or you may affect other users, and to run development and production programs on the same machine is difficult. The best justification is that a job cannot be done any other way.

Interactive terminals

Mr. Moffett cautions that one should not take for granted that interactive graphics systems will make or save money. There is genuine soul-searching among many people about this point. There are alternatives to the interactive graphic terminals that may be cheaper in many cases, although this will be proven only with experience.

Interactive graphics may turn out to be only an interim solution for doing things. It is for the man who doesn't know everything in the way of answers—who needs a freedom to roam as he designs because the consequences of what he is about to do are not known to him at the start. But it should lead to better batch systems as understanding of the process increases.

With all of the talk about interactive terminals, it was a shock to find that they are virtually unsupported by software programs. According to Mr. Moffett, 60-70% of each new application costs are similar, and such things as how to draw a line or a circle should be made a standard part of these systems. Then you can develop new applications instead of spending the time redoing the same problem again and again. This is now not the case. Anyone who purchases an interactive terminal should be prepared to reinvent the wheel. Motorola, which uses the interactive graphic terminal, is excited about its flexibility, but it is not sure that this is the most economic way to go.

TRW follows a different approach. It has a storage-scope graphic terminal combined with a RAND tablet. The cost is about $21,000 for the unit versus about $7500 a month for the rental of an IBM 2250 light pen regenerative terminal. Changes can be made on the tablet and incorporated into the display later. Several key features are that information is automatically digitized on the tablet, engineering drawings can be traced directly into the system, and transmitted over telephone lines. The theory is that since masks are statics, why pay for the constant redraw, reedit, and redisplay programs. Edit the text, then display it.

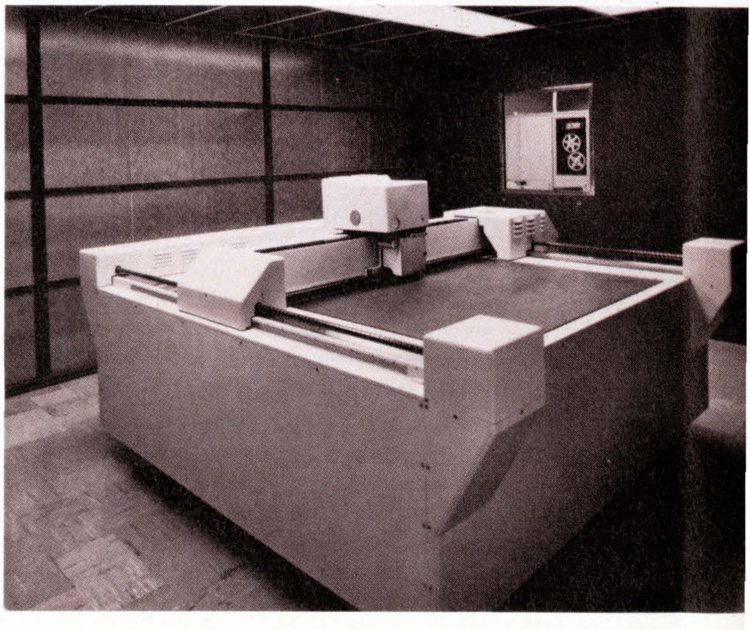
The end of the line

One place where equipment is crucial is at the final step, mask making. Signetics has a large Calcomp with a 60 in. bed for cutting masks because it foresees 200 mil chip sizes, especially in the MOS ROM's. Adequate resolution is available with a 30 in. bed, but some pieces to be stripped would be about 1/20 in. wide, and they get hard to peel.

The cost of a Gerber plotter installation is about $200,000. Though it is rated by all as a solid piece of equipment for mask making, it can take a year to get one into active production. Many facilities operate them on multiple shifts. Mask making units could well become system bottlenecks, with a $200,000 incremental cost for increasing production capacity.

Another method is to use a David Mann pattern generator, which produces artwork (at 10 times full size) that the step-and-repeat camera uses directly. Cost: about a quarter million dollars.

The Gerber plotter mask-making installation at TRW. Mask-making times are reduced and accuracies improved far beyond manual methods. Working tolerances enable masks for semiconductors to be made much closer to final size than with manual methods, eliminating photoreduction steps. Printed circuit board masks can be made 1:1.



What costs are being saved?

Though accurate cost comparisons are not available between manual and computer aided systems, there are many reliable estimates that give a feel for the benefits CAD is providing. The customer, of course, does not really care how a thing is made, but only that it is better, cheaper, and delivered sooner.

AMI predicts that CAD will soon be the only way to handle the flow of MOS business, because this is doubling each year and there just are not enough people to do it all. Right now the cost of doing a job manually or with CAD is about a toss-up. If all standard cells are used, CAD is slightly cheaper. If some unique cells are needed, CAD costs slightly more. But CAD costs are expected to drop significantly in the next year.

At Litton, a multilayer board can take four to six man-weeks to lay out and check, and photos and photoreduction take another week. The computer, on the other hand, takes 15-30 minutes to lay out the board and throws a tape for the Gerber plotter into the bargain. About six hours are needed for 1:1 artwork on the Gerber so a one month's job gets compressed into one day. It is also cheaper. The computer time costs about $80 for a large board, whereas the photoreducing alone in the manual case is expensive.

The greatest payoffs are in reduced schedule turnaround and in error and error rate reduction. Designers let designs go much earlier because the degree of confidence needed for them to release designs is established much earlier. National estimates that the saving in development of a new circuit is about half of the five to six months it would take to do manually.

With CAD, errors are cut so substantially that a design may even make it the first time through the system; twice through is the maximum. Manually it averages about three cycles. Each cycle saved is a saving of $1500 to $2000, with better yield to a given spec.

Norm Schweitzer of TRW's Computer Graphics Department offers a reason why a CAD designed circuit may perform better, even though the manufacturing process for manually- or CAD-designed circuits is identical. An inadequate design is easy to come by with either method, but doing it manually takes three months, so the designer tends to try to patch it up and make it work somehow. A CAD design takes two days, so even if it is expensive to recycle, you still have another chance to do a much better job.

The designer-programmer interface

No matter what any of the hardware costs, the software will probably cost at least as much. Programs, programs, and more programs are what make CAD go, and right now it is a do-it-yourself proposition.

We have mentioned the customer-vendor interface. The designer-programmer interface can also be difficult, because these two technical types seem to view the world in completely different terms. Programmers and engineers have problems getting processes and circuits into software.

At Hewlett-Packard, Percy Smith has viewed this problem at first hand. He says a typical programmer-engineer interface arises when an engineer has been working on an R&D job and has written programs that he has used at time-sharing terminals. As the amount of his data gets large, time sharing gets too slow. When he wants to go into volume production, he goes looking for a programmer to help get his speed up.

The programmer's first job is to try to find out from the engineer just what it is he is trying to achieve. The programmer may try to combine several programs into one and make them compatible, but if it is too large, he just starts from scratch.

Percy sees several contributing factors to the interface problem. Engineers don't like to program, and they don't know how to get certain features into their programs. They don't write programs for programmers. They fail to document their programs with comments, or to segment them into digestible lumps, and wind up with just one long program. It is not easy to understand, or to get in an extra variable, or to modify the program in any way.

Engineers also have a distorted appreciation of difficulty. Their "simple jobs" often take weeks, while the ones they think will be tremendously complex may take only a couple of hours.

Most would agree, though, that whatever the input, the desired output is a simple, easy-to-use, debugged program. If it is not all of these things, the engineer will spend his time programming instead of engineering.

CAD and MOS—natural allies

Many manufacturers are applying CAD to MOS technology. The early popularity of MOS may be attributed to the fact that it is an easier problem to solve on a computer. According to Charles Phipps of T.I., there is only one diffusion, so the designer's problem is reduced to two dimensions. The same structure is used for all circuit elements and MOS devices tend to be symmetrical. T.I. has been designing MOS exclusively with CAD for two years.

While arguments of MOS vs bipolar rage on, most agree that CAD should not enter the decision about choice of technology. That choice is made way back in the technical analysis of the system, long before a logic diagram is thought of. But although CAD should be responsive to your needs, and not dictate the choice, when you go looking for a vendor MOS capability will be easier to find.

Many thanks . . .

. . . for the many hours of fruitful discussion they devoted to contributing to this report, to the gentlemen mentioned in the text and to Howard Bogart, Dick Curso, and Andrew Prophet of American Micro-Systems; Bill Cleary, Bob Larsen, and Alex Willtman of Autonetics; Richard Eiler of Electronic Arrays; Bob Williams of Fairchild Semiconductor; Lester Penner of General Instrument; Les Besser of Hewlett-Packard; Chuck Liotta of Interdyne; Dennis Stewart and Charles Wallace of Litton Industries; Tom Hart of Motorola Semiconductor; Floyd Kvamme and Bill Routh of National Semiconductor; Leo Craft of Signetics; and Rober Emmerling, Robert Schreiner, and Neil Burcham of TRW Systems.

INFORMATION RETRIEVAL

Circuit design, Computers and peripherals, Integrated circuits, Semiconductors.

An opinion on CAD

Although we can only conjecture at the long-term effects of developments in CAD Graphics and semiconductors in general, some things can be predicted with minimal risk. As CAD becomes a way of life, the pressure for CD to take over part of its function will grow. Norm Schweitzer of TRW voiced a point of view that will gain support with time: If programmers and designers knew what they wanted, there would seldom be a need for the interaction implied in CAD.

The significant thing is that man is in the loop to compensate for his deficiency in specifying the problem initially. He is a necessary evil now. We should not be proud that he is there, but should make it our goal to eliminate him from the system. If nothing else, he slows down the computer every time he enters the system. Interactive systems should be interim steps to better batch processes. This does not mean that there is not a place for them, but that place should constantly shift to new areas.

In summary, CAD makes people think about what they are doing, it formalizes their thinking and defines problems. The result is permanent solutions, and the opportunity to go on to other problems.

There is an interesting contrast in perspective between the aerospace firms and the semiconductor makers with regard to CAD. Semiconductor people tend to trace the history of CAD from about two or three years ago, which is when it began to emerge as a tool for solving their particular design problems. People in aerospace tend to view CAD as just part of the natural evolution of computer technology toward increased automation. For them, it started many years ago and will continue long after today's semiconductor problems have been solved.

What price circuitry?

As circuit complexity goes up and costs go down, designers will find that manufacturing costs will become relatively independent of circuit complexity. Inclusion of that extra protection circuit, or that element that would make a circuit perform just right, will cost next to nothing. The contribution of circuit manufacturing costs to the price difference between the top and the bottom of a product line will tend to disappear.

Increased standardization

Most CAD people take the position that CAD makes custom designs easy, so that the tendency is away from standardization and toward getting the best circuit for the particular job. The fact that the building blocks are getting larger means that fewer people can use any given one. They cite that the nature of competition works against standardization, since vendors want to capitalize on their different abilities. They also point out that system designers will not accept standardization because it implies a further encroachment by the semiconductor manufacturer into systems.

This argument may be one of time scale. It may be that in the short run there will be a shift toward custom circuits as CAD systems come into general use; however, the long run should also see another trend. Again, the aerospace viewers see the long-term possibility of increased standardization more often than do those in semiconductor houses.

Those who reject larger standard circuits use the same old argument that said that engineers would never accept semiconductor houses designing their flip-flops. Each designer had his own design that was the best in all the world. That barrier was utterly demolished and now nobody would waste his time designing a flip-flop. The same thing will happen in all areas of circuitry, and there will be a definite rise in the complexity of things that are classed as standard.

National Semiconductor, for example, does not see its mission as creating large numbers of custom circuits, but as using the CAD to make better standard ones. Good examples of complex items that are now standard are IC op amps and voltage regulators. ROM's also blur the distinction between what is custom and what is standard. Each design can be considered custom, but the similarities far outnumber the differences.

Outsiders doing CAD

There is a question of who will be doing CAD in the near future. Semiconductor manufacturers are almost unanimous that CAD Graphics services cannot be performed by outsiders. They contend that outsiders would always be too far behind in process technology to compete in CAD. This may be true, but to suppose that outsiders will not take a stab at CAD is wishful thinking.

Litton Industries is an example of just how far a non-semiconductor house can go. In talking to its CAD people, you cannot tell whether you are in a semiconductor house or not. Litton treats all of the CAD Graphics problems gnerally in the same way and can generate masks. It modifies its mask cutting programs with programs for each vendor's capability and gives the mask set to whomever it chooses. Knowledge of vendors' capabilities, not methods, is all that is required, and that must be made available to customers if vendors are to do business at all.

Lest anyone think Litton is involved in trivial examples, consider the scope of its work. It has made masks for chips that are 320 mils on a side and these chips have been manufactured elsewhere and are working. It has designed masks for individual 1¼ in. dia wafers that contain 24 cells of 400 transistors each, or 9600 transistors. Those also work.

It is a hop-step-and-jump to hypothesize a company that could act in the interest of groups of systems houses or semiconductor houses, no one of which is big enough to afford to develop the capability. There is even a rumor that CAD services type of corporation, which will be able to go from logic diagrams to masks, will come soon into being. The management consists of four top people in CAD. One CAD manager in a reputable semiconductor house admits that he is tentatively committed to let them do his CAD Graphics.

The effect on EE's

Another implication of all of this is quite clear. In the next few years the EE's job as he knows it today will change. The designing of circuits, subsystems, and even systems will be taken over more and more by machines, regardless of whether they are located in the systems house or the semiconductor house.

When you reflect on the number of circuits in use today that have been produced by the few engineers in semiconductor houses, and contemplate how large this number will grow to in the future, it is obvious that the number of engineers involved in circuit design must necessarily drop.

This is either good or bad, depending on your outlook. The engineer will be freed of a certain amount of pencil pushing in order to do more thinking. An engineer who wishes to grow constantly in his ability to perform ever larger tasks should relish the thought that as his building blocks get more powerful, so does his total capability. He will be able to create huge systems because he can use large sub-systems as his components.

This implies a desire, and an ability, to change with the times, as well as a recognition that change is the order of the day. If an engineer does not have these qualities or outlooks, and if he is uneasy doing today's jobs, he will be terrified tomorrow.

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Cabling fast pulses? Don't trip on the steps

Modern instrumentation can give you pulses with gigahertz bandwidths. And how do you pipe them around your system? With coax, of course. But watch out, because what goes in doesn't necessarily always come out.

By Thad Dreher, E-H Research Laboratories, Oakland, Calif.

The scope photo of Fig. 1 shows how a coaxial cable distorts a step transmitted through it. You can see from the rounded corner that the drive pulse loses high-frequency components in the line. There are two possible sources of such a loss: conduction loss in the dielectric, and resistive loss in the copper. Both are functions of frequency. But dielectric attenuation varies *directly*[3] as frequency,

$$\alpha_d = [2.78\, \epsilon_R^{1/2} F_p] f \text{, dB/100 ft.,}$$

and copper loss (skin effect) varies as the *square root*[3] of frequency,

$$\alpha_{cu} = \left[\frac{0.434}{Z_o}\left(\frac{1}{d}+\frac{1}{D}\right)\right] f^{1/2}\text{, dB/100 ft.,}$$

where D = diameter of inner surface of outer conductor, inches
d = diameter of outer surface of inner conductor, inches
f = frequency, megahertz
ϵ_R = relative dielectric constant
F_p = power factor of dielectric at frequency f.

This relationship follows directly from the fact that skin effect causes the effective cross-section of a cylindrical conductor to decrease as $f^{-1/2}$, so that the resistance of a cylindrical copper conductor[3] of diameter D inches is

$$R = (0.996 \times 10^{-6}) \frac{f^{1/2}}{D}\text{, } \Omega\text{/ft.}$$

To get some idea of the relative magnitudes of the two losses, let's calculate the attenuation of RG-213 at 1 GHz. This frequency is near the upper limit of the band of practical interest, because of the risetimes of available pulsers. The Amphenol catalog gives these constants for RG-213:

$D = 0.285$ in.
$d = 0.085$ in.
$Z_o = 50.0\ \Omega$
$\epsilon_R = 2.26$
$F_p = 5 \times 10^{-4}$
$\alpha = 8$ dB/100 ft.

Substituting these values into the previous equations, we find, $\alpha_d = 2.1$ dB/100 ft., and $\alpha_{cu} = 4.2$ dB/100 ft.

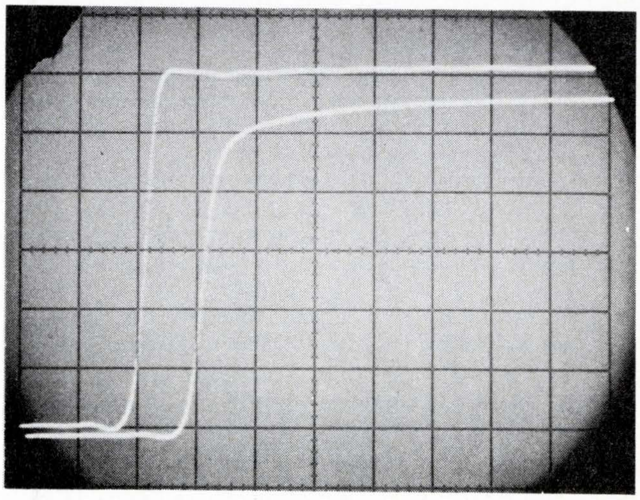


Fig. 1. Small-diameter coaxial cable distorts fast-pulses. This scope photo's time scale is 2 ns/cm. See how the 1-ns step at the left loses its sharply-defined upper corner and is slowed to about 4.5 ns (the right-hand trace) after an 18-ft. run through RG-174 (0.1-in. dia. coax).

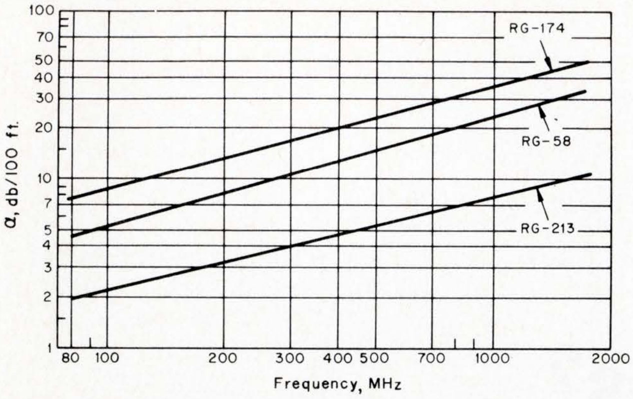


Fig. 2. Log-log plots of attenuation vs frequency for three miniature cables have parallel lines with a slope of about ½. This shows that the total loss varies directly as the square root of the frequency. Such a variation means that in the frequency range shown here (below 1 GHz), most of the loss is due to the skin-effect phenomenon.

Dielectric loss is about one-third of the total attenuation at 1 GHz. And since $\alpha = \alpha_d + \alpha_{cu} = 6.3$ dB/100 ft., but it is specified as 8 dB, there is a 1.7-dB discrepancy between calculation and measurement. Presumably, part of this is the manufacturer's guardband, and part is due to the braided and stranded nature of the actual conductors (calculations are based on smooth and homogenous metal).

Since α is proportional to frequency, at 500 MHz $\alpha_d = 1.05$ dB/100 ft., and $\alpha_{cu} = 2.97$ dB/100 ft. You can see that the dielectric losses are now down to one-fourth of the total Copper losses tend to dominate below 1 GHz, and you can expect the total attenuation to vary as

$$\alpha = Kf^{1/2}$$

Now, the same catalog gives you this information about α:

	100	200	400	1000 MHz
RG-174	8.8	13.0	20.0	30 dB/100 ft.
RG-58	5.3	8.2	12.6	24 dB/100 ft.
RG-213	2.1	3.3	4.5	8 dB/100 ft.

"Not long ago," the author says, "I saw competent engineers try to pipe a 1-ns pulse to a test fixture through nearly 18 ft. of RG-174 coaxial cable. The small-diameter coax, with miniature snap-on connectors, made a neat installation. Unfortunately, though, the drive pulse finally delivered to the device under test was a wretched thing; its vital upper corner was chewed down to the point where the delivered risetime was more than 4 ns. Of course, these men knew that coax distorts fast steps. But what they didn't know was *how much* to expect from *so many* feet of a particular cable."

And thus you have the reason for this article: to give you quantitative information on these effects, and to show you how this information is derived. You will be reading specifically about the three sizes of 50-Ω solid-poly coax most commonly used in industrial instrumentation: RG-58, 174, and 213. But because the method of data derivation is clearly shown, you'll be able to work out tables and plots for any other cable.

There are two basic references on the subject, from which this information is both extracted and extrapolated. The prime paper, by Wigington and Nahman[1], reveals the basic fact of cable distortion: for frequencies to 1 GHz and beyond, distortion is due largely to skin effect. They assumed that skin effect is the sole cause of the distortion, and calculated its effects on a step transmitted through several different cables. They then compared the analysis with experimental fact. The paper's orientation is, therefore, not to provide information, but to verify a hypothesis.

The second source is a paper from the University of California's Berkeley Radiation Lab, by Kerns, Kirsten, and Winningstad.[2] This one is more for the man with an actual problem on his hands: there is much handbook-style data on many different kinds of cable. But the paper isn't generally available, because it has been published only in RadLab in-house manuals.

A serious shortcoming of these papers, written in the mid-fifties, is that the authors made the illustrations with state-of-the-art equipment of the time. For example, Kerns and his associates used a mercury pulser (a reed switch with mercury-wetted contacts that discharges a charged transmission line) and a direct-deflection realtime scope with obvious deficiencies in sensitivity and bandpass, Wigington and Nahman used a similar arrangement, with a 60-V step from a mercury pulser. As displayed on their direct-deflection scope, this pulse showed a 250-ps risetime, but with serious distortions that called for a five-segment piecewise-linear approximation as an analytical model.

Since those papers were written, the state of the fast-pulse art has come a long way. Instrumentation such as 4-GHz sampling scopes and megahertz reprate pulsers has greatly extended the study and understanding of fast-pulse distortion in coaxial cables. And from such studies, have come the following conclusions:

- **Distortion** of nanosecond pulses in coaxial lines is due mainly to skin effect. And since the more skin, the less skin effect, the diameter of the center conductor is the prime factor in determining the performance of a line.
- **Step response** of skin-effect-limited lines is
$$e(t) = E_o\left[1 - erf\sqrt{\frac{\beta}{t}}\right]$$
(approximately), where β is a line constant, and **erf** is a tabulated **er**ror **f**unction. (See Fig. 3.)
- **Risetime** of a section of cable varies as the square of its length. (See Fig. 4.)
- **The non-Gaussian nature** of the step-response of coax makes it impossible to use the rms addition rule in systems containing coax, unless the risetime of the cable is insignificant compared to the risetimes of the other system elements.
- **Even short lengths** of miniature coax have a noticeable effect on fast edges. And at lengths of 20 feet, with a 250-ps step input, there is an order of magnitude difference between RG-174 and RG-213: 4-ns against 0.4-ns response time, respectively.

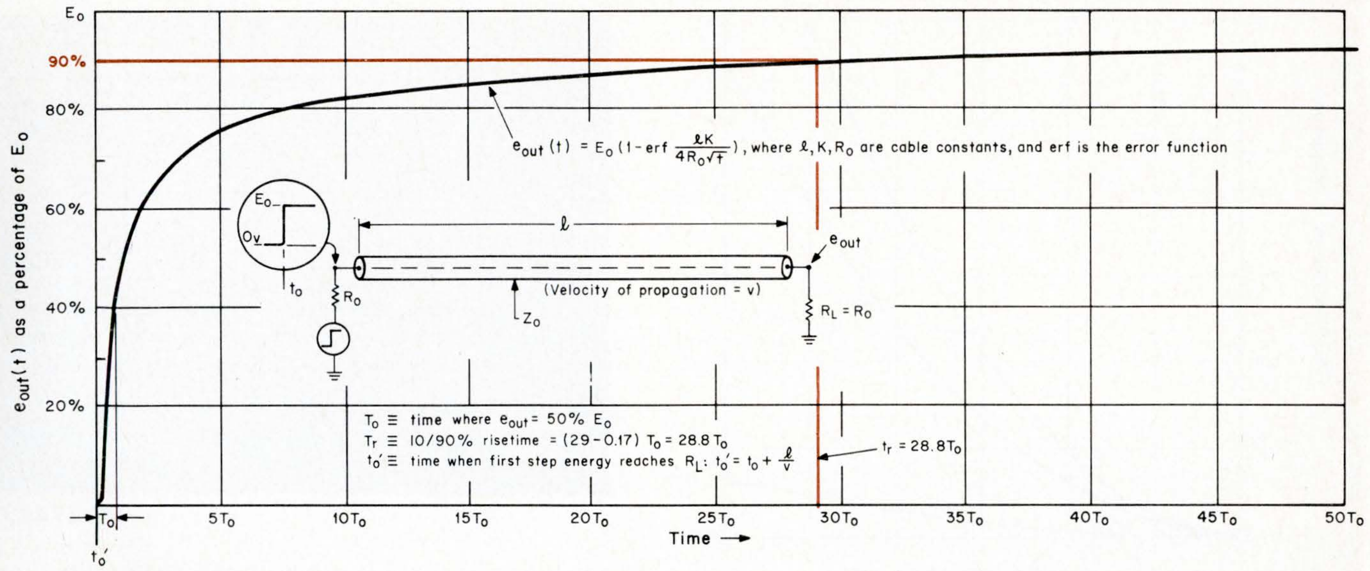


Fig. 3. This calculated step-response of coax assumes that distortion is due mainly to skin effect. It shows why risetime degrades: e_{out} takes 29 times as long to reach its 90% value, as it takes to reach its 50% value.

A log-log plot of this data (Fig. 2) shows the expected parallel lines, with a slope of about ½. At 1 GHz we should expect a slight upward curvature, because α_d starts to add appreciably to the straight line of α_{cu}; but this is not apparent in the empirical data until about 2 or 3 GHz. (See Ref. 3, p. 615.)

Skin-effect limits step response

The approximation $(t_r)(f_r) = 0.35$, where t_r is the 10/90% risetime and f_r is the upper passband-limit, tells you that nanosecond pulses have appreciable frequency components up to about 350 MHz. Further, 350-ps risetimes need a 1-GHz passband.

If you assume that skin effect dominates the region below 1 GHz ($\alpha = Kf^{1/2}$), then the transform impedance of a round wire[1] is

$$Z(s) = Ks^{1/2}, \text{ where } K \equiv \frac{1}{2\pi r}\left(\frac{\mu}{\delta}\right)^{1/2},$$

r is the conductor's radius, μ the permeability, and δ the conductivity of the wire.

Now, transmission-line equations give a transfer function[1]

$$\frac{E_{out}}{E_{in}} = \epsilon^{-\gamma l}$$

$$\text{where } \gamma \equiv \left[(R + sL)(G + sC)\right]^{1/2},$$

l = length, and R, L, G, C are line constants per unit length. For a negligible dielectric loss ($G = 0$), and substituting $Z(s) = Ks^{1/2}$ for R,

$$\gamma = \left[s^2 LC + s^{3/2} CK\right]^{1/2}$$

If you expand this by the binomial theorem,

$$\gamma = s(LC)^{1/2} + s^{1/2}\frac{K}{2}\left(\frac{C}{L}\right)^{1/2} + [\textit{higher order terms}] .$$

The first term accounts for the time delay, the second for the first-order distortion.

Using only the first two terms and taking

$$R_o = \left(\frac{L}{C}\right)^{1/2},\ T_d = (LC)^{1/2}$$

gives

$$\frac{E_{out}}{E_{in}} = exp\left[-l\left(sT_d + s^{1/2}\frac{K}{2R_o}\right)\right]$$

$$= \left(\epsilon^{-slT_d}\right)\left(\epsilon^{-\frac{s^{1/2}Kl}{\gamma R_o}}\right)$$

The first term here is a delay: it displaces the second function by a fixed interval, T_d.

To find the step response, you must take the inverse transform of this transfer function (ignoring the delay multiplier) multiplied by the step transform $1/s$.

$$e_{out}(t) = \pounds^{-1}\left[\left(\frac{1}{s}\right)\epsilon^{-s^{1/2}\frac{Kl}{2R_o}}\right]$$

This function is listed in tables as the *complementary error function*. Back in the time domain,

$$e_{out}(t) = E_o\left[1 - erf\frac{lK}{4R_o t^{1/2}}\right]$$

where E_o is the amplitude of the input step; t begins after a delay l/v from the injection of the step into the line (at $t_o' = t_o + l/v$; v is the velocity of propagation in the cable).

Figure 3 is a plot of this function. Compare it to the typical response of Fig. 6, where the input Gaussian edge is fast enough to approximate a step: there's a fast rise to about 50% of final amplitude, a serious rounding-off of the upper-corner, and a long, slow dribble-up to flat-top.

If you define the time to reach 50% amplitude as T_o, then it takes almost $30T_o$ to reach 90%. *This is what causes the disastrous effect of long runs of cable on risetime.*

Risetime vs cable length

To relate risetime to the expression for e_{out} as a function of time, you set $e_{out} = E_o/2$, and solve for T_o.

$$\frac{e_{out}}{E_o} = 0.5 = 1 - erf\frac{lK}{4R_o T_o^{1/2}}$$

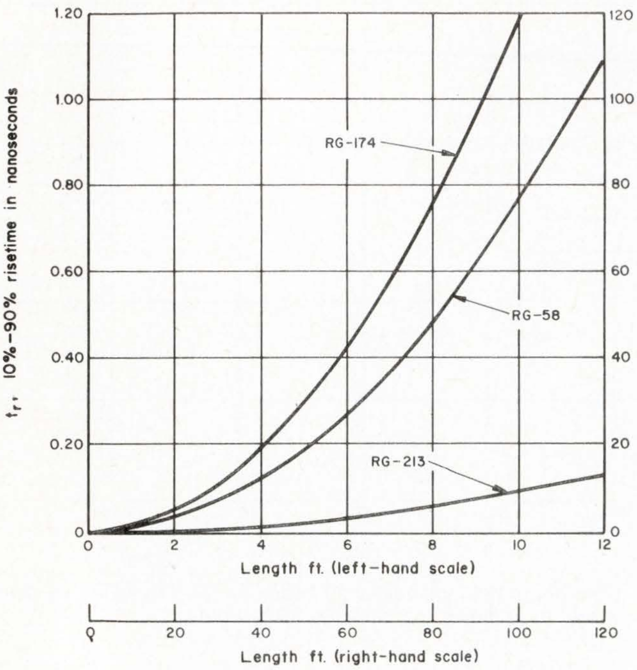


Fig. 4. Risetime vs length for common solid-poly cables. Risetime increases as the square of the cable length.

You can write the solution to this in a number of forms, but a very useful one is

$$T_o = (4.56 \times 10^{-7}) \left(\frac{\alpha_o^2}{f_o}\right) l^2 \text{ seconds,}$$

where α_o is the attenuation in dB/100 ft., at frequency f_o in Hz; and l is the cable length in ft.

Since the 10/90% risetime, t_r, is $28.8T_o$, it too varies as the square of cable length. Thus, the plot of risetime vs length is a parabola; it is shown in Fig. 4.

Adding risetimes

It is common practice in the pulse field to use the square-law addition rule to estimate the overall risetime of a system composed of several elements.

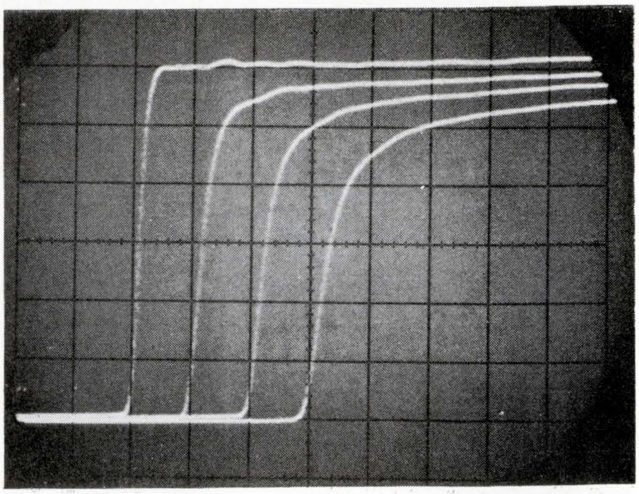
$$t_{r,out} = [t^2_{r,in} + t^2_{r1} + t^2_{r2} + \cdots + t^2_{rn}]^{1/2}$$

This rule is strictly applicable only to Gaussian or near-Gaussian edges. Such edges have the symmetrically-rounded shape of the integral of the familiar bell-shaped curve of normal, or Gaussian, distribution.

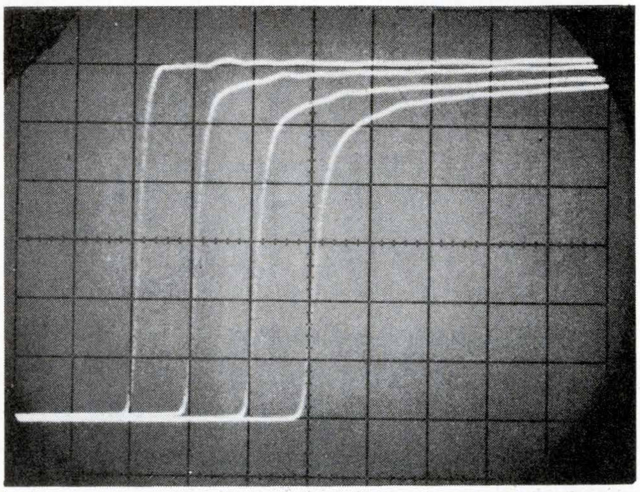
On edges such as those of the drive pulses of Figs. 5 and 6 (rounded corners with no pre-shoot, overshoot, or other bad habits), the rms addition rule does give you a good approximation. Thus, if you pass a step through two successive Gaussian elements with identical risetimes T, you will get an edge that rises in $\sqrt{2}\,T$.

But consider the effect of cable distortion. With risetime varying as the square of length, passing a step through two identical pieces of cable doesn't increase the overall risetime by $\sqrt{2}$, but by a factor of *four*. So the rms rule isn't valid for adding cable response times, or for estimating the usual case where coax connects Gaussian circuit elements.

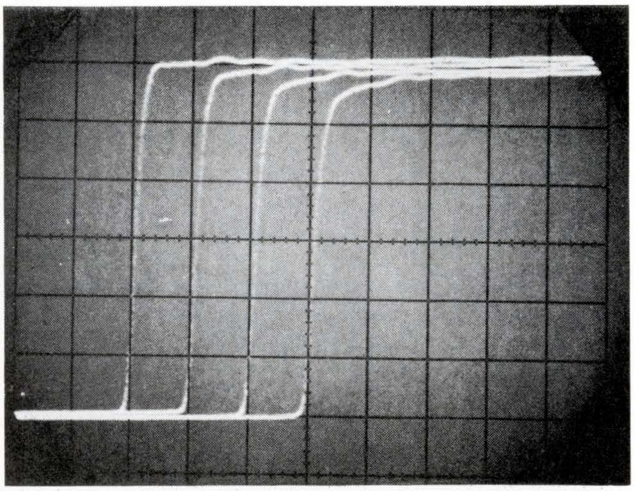
You must determine the effect of a length of cable



RG-174A/U

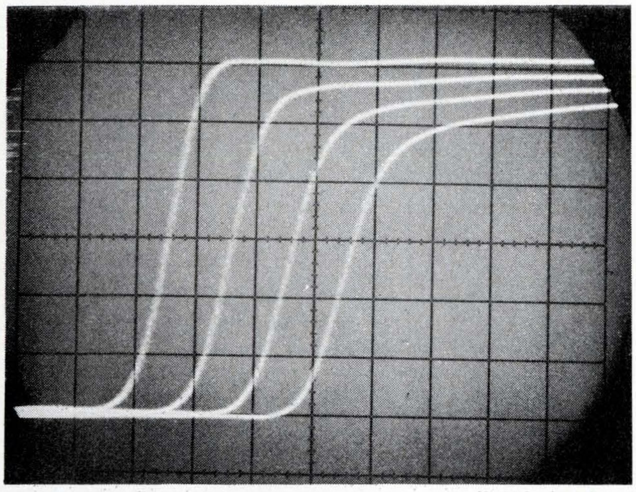


RG-58A/U

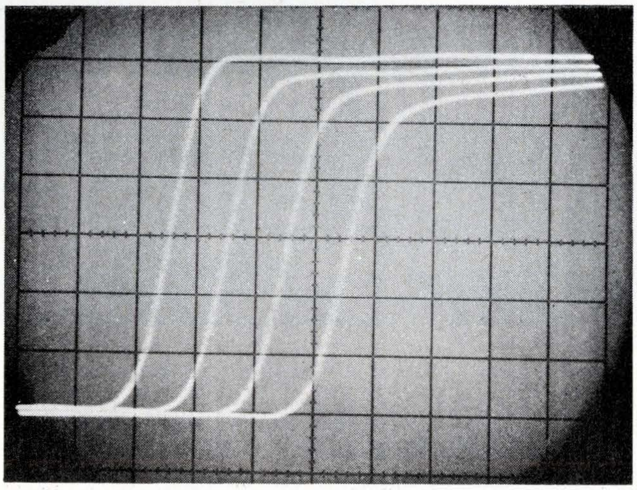


RG-213A/U

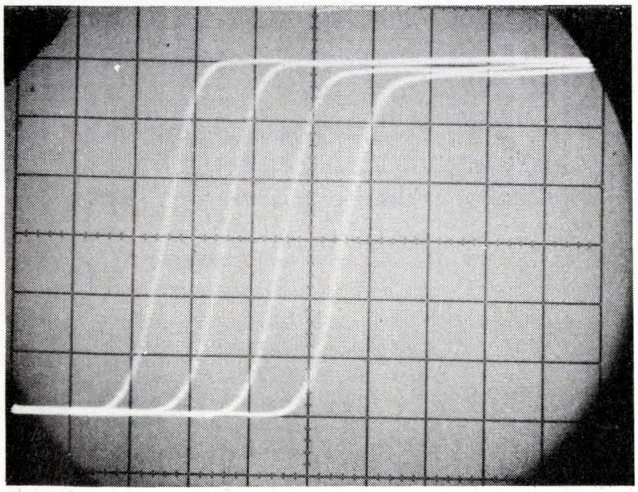
Fig. 5. Multiple-exposure scope photos show the response of standard lengths of RG-174/U, RG-58A/U, and RG-213A/U to a 250-ps step input (the first pulse on the left in each photo). The time scale here and in Fig. 6 is 1 ns/cm. The text describes the photos and how they were made.



RG-174A/U



RG-58A/U



RG-213A/U

Fig. 6. There is only one difference between these pictures and those of Fig. 5: the drive-pulse risetime was adjusted to 1 ns with a risetime-standard filter. What's the point? To pipe fast pulses, use large coax even for short runs.

in a system *experimentally* (as in Figs. 5 and 6); *graphically,* by combining two or more plots of time-response waveforms; or *analytically*, by convolution of the transfer functions associated with the excitation transform.

The real world

Figures 5 and 6 show the effects of standard lengths of coax on fast pulses. Each scope photo shows the drive pulse and three delivered pulses for 6.5, 13, and 19.5 ft. lengths of cable (from left to right in each photo). These lengths correspond to propagation delays of 10 ns, 20 ns, and 30 ns, respectively.

The equipment setup for Fig. 5 used an E-H Model 125 pulser terminated (through a short length of cable) in a 14-dB pad. This combination drove the cable section under test. The cable, in turn, was terminated in a 6-dB pad at the input to a 4-GHz sampling scope.

For Fig. 6, an E-H 122 replaced the 125, the pad positions were interchanged, and a risetime-standard filter was placed in the line at the source.

The main difference between the two figures is in the risetime of the drive pulses, 250 ps and 1 ns respectively, which are trimmed to be as close to ideal Gaussian as possible. In the case of the 250-ps edge, a short length of cable between the generator and the pad rounded off a sharp upper corner. The 1-ns edge was actually delivered from the generator at about 850 ps. A 500-ps risetime-standard filter slowed it to the desired 1 ns. It also rounded the upper corner to make it nearly the mirror-image of the lower. The coaxial pad at the drive end controls amplitude, while the pad at the scope isolates the sampling gate from the line.

A close look at these figures shows you the relative merits of the three diameters of cable. With a 1-ns drive, 20 feet of RG-213 shows a barely noticeable rounding to 1.2 ns, while the same length of RG-174 gives 4.4 ns with a poor waveshape.

The moral? For nanosecond pulses, you should use RG-213 or larger cable for any run longer than a few feet. If you have to get into a circuit board where space and torque are a problem, you should adapt down to a short pigtail of small line as close to the board as possible, making the long run with RG-213 or heavier line. For instance, you can go to RG-19 if necessary, or even to ⅞-in. styroflex cable.

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2. Kerns, Kirsten, and Winningstad, "Pulse Response of Coaxial Cables," File No. CC2-1B of UCRL *Counting Note* No. 3307. Issued Mar. 1, 1956, revised July 29, 1966.

Also: Kirsten and Proehl, "Physical Characteristics of Coaxial Cables," File No. CC2-2C of the same *Counting Note*

3. *Reference Data for Radio Engineers,* Fourth Ed., IT&T, New York, 1956.
4. Lewis and Wells, *Millimicrosecond Pulse Techniques,* Second Ed., Pergamon Press, 1959.
5. Goldman, *Transformation Calculus and Electrical Transients,* Prentice-Hall, 1945.

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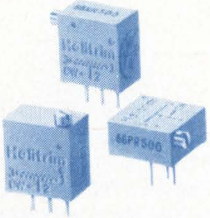

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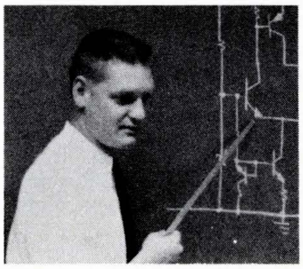
Here's how you voted

The winning Idea for the March 1969 issue is, "Voltage regulator has extended range, remote shutdown."



Walter G. Jung, our first two-time winner, is a Senior Engineer at MTI, in Cockeysville, Md. His July 1968 entry brought him a Simpson 270. This time around, Mr. Jung will receive a $50 honorarium.

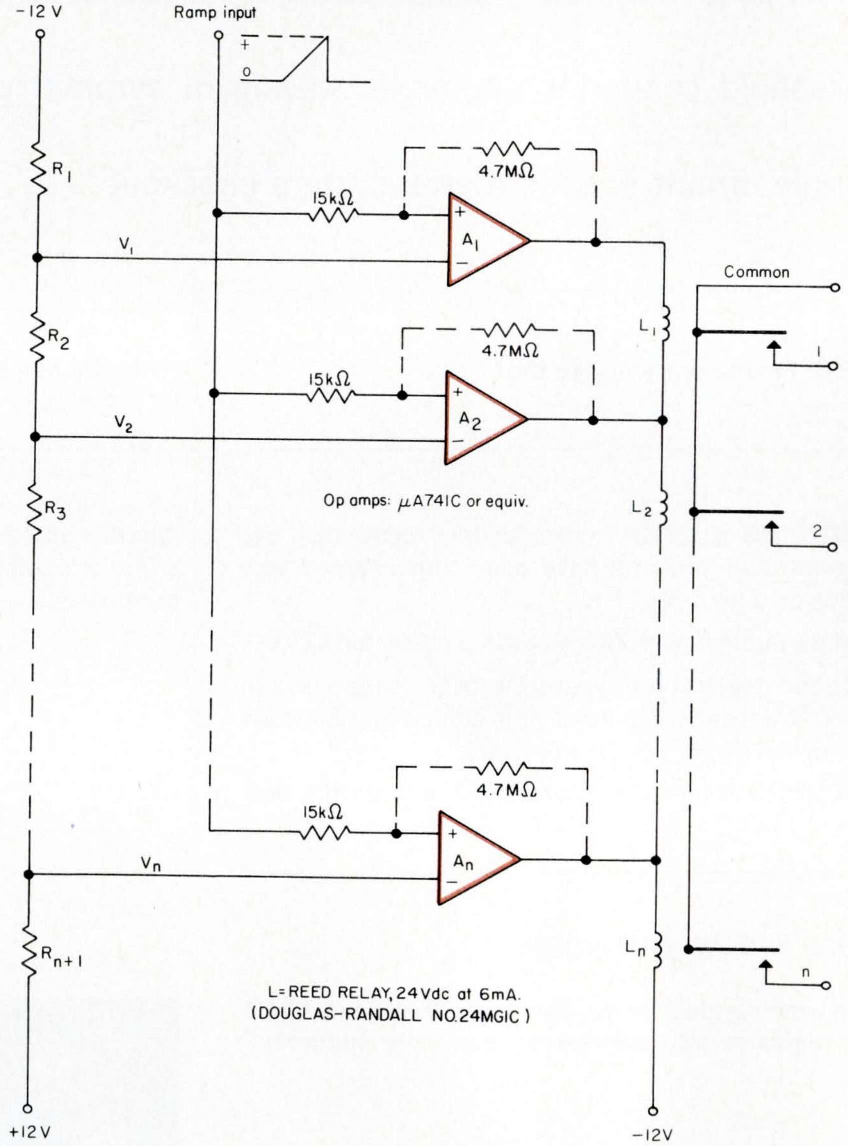
927 Op amps give mutually-exclusive digital sequencing

Maxwell Strange
NASA, Goddard Space Flight Center, Greenbelt, Md.

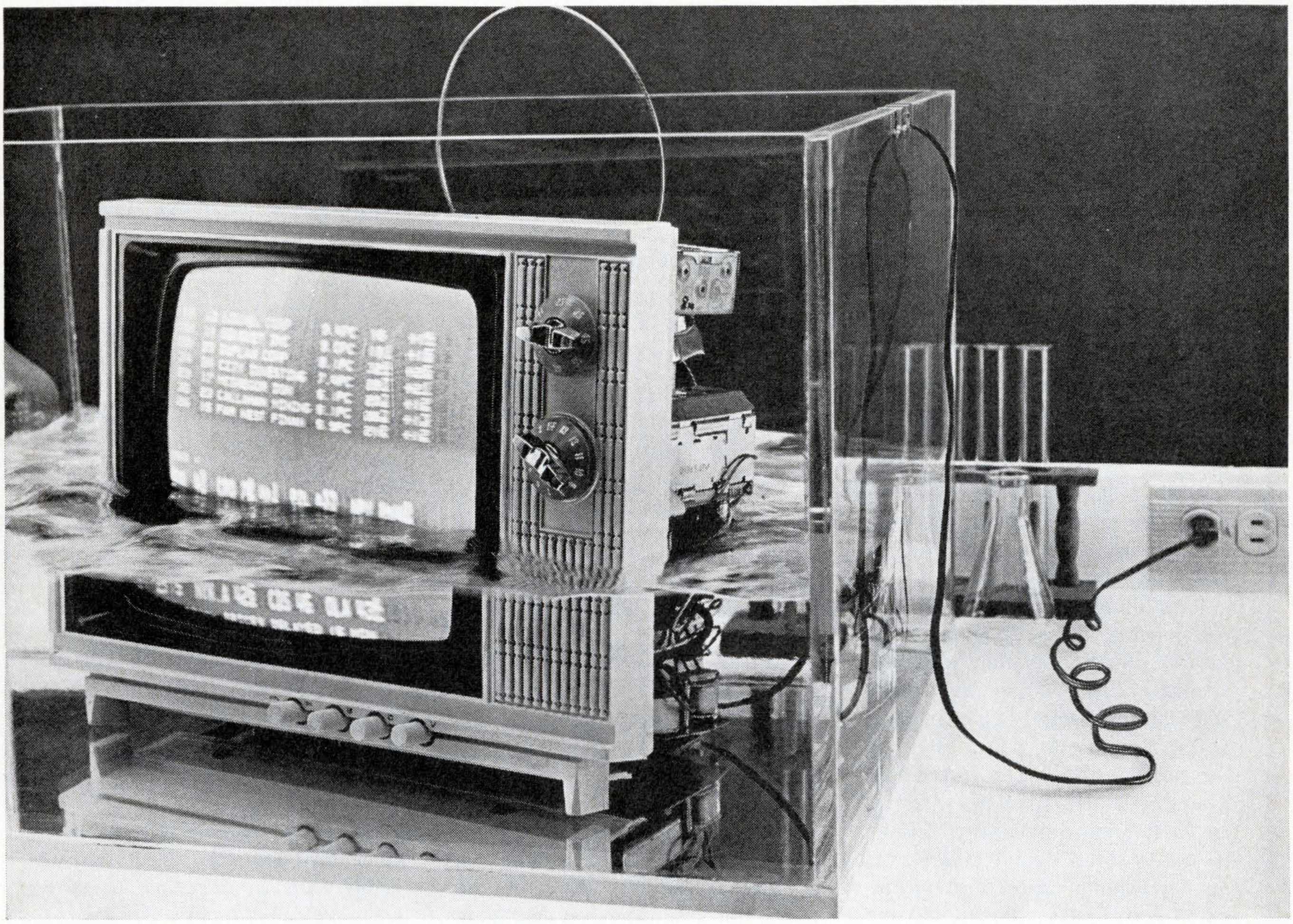
Here's a way to generate any number of sequential, mutually-exclusive outputs to isolated loads such as reed relays, miniature lamps, and so forth. The circuit is self-decoding, simple, and lower in cost than the usual digital approach that uses a clocked ring counter or a decoded ripple counter.

At the start of the input ramp, the outputs of all threshold detectors A_1 through A_n are negative, and the relays are not energized. When the ramp crosses level V_1, A_1's output goes to positive saturation, driving L_1 ON. As the ramp increases, it crosses level V_2, switches L_2 ON and, since A_1's output stays positive, simultaneously switches L_1 OFF. As the ramp reaches each successive threshold, the next relay is driven ON and the previous one switched OFF.

You can individually adjust the output pulse widths with threshold divider resistors R_1 through R_{n+1}. The ramp can come from a simple *RC* network or an operational integrator. For very slow ramps, 4.7 MΩ feedback resistors across the op amps provide hysteresis to prevent threshold chatter.



The variable-dwell feature makes this circuit useful as an event programmer. Or, as a data commutator, you can vary the sampling time to suit the data rate and give efficient synchronization. Further, the last output pulse can reset the ramp for continuous cycling or, by incorporating a simple SET-RESET flip-flop, return it to a standby mode until another START command appears to begin a new cycle.



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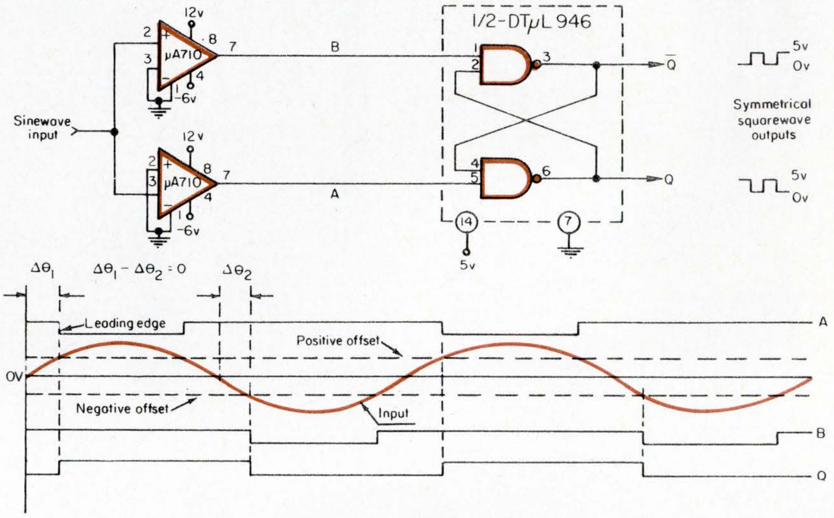
928 Threshold converter preserves waveform symmetry

George S. Oshiro
Teledyne Systems, Los Angeles, Calif.

This circuit converts sinewave inputs to symmetrical squarewave outputs, from practically dc to about 6 MHz. It operates from several millivolts to many volts peak (assuming limit protection), and in noisy environments over the MIL-spec temperature range.

Two Fairchild µA710 comparators operate in a complementary fashion. Such operation preserves symmetry by adding the phase shift caused by the negative offset (or threshold) to that caused by the positive offset (or threshold). The Fairchild DTµL946, wired as an RS flip-flop, implements this by its SET-RESET action, which occurs on the leading edges of the comparator outputs. Temperature changes do not affect input offset because of the inherent matched qualities of the comparators.



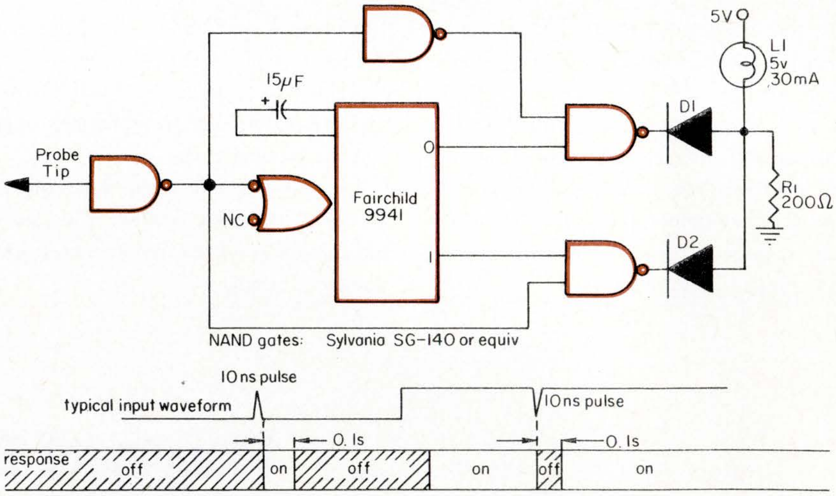
The source impedance should be as low as possible to allow the maximum useful input-amplitude range. But in any case, the effect of input bias current on symmetry is negligible, because of the complementary operation. And you can readily add adjustments to give threshold detection for any degree of noise immunity, without affecting output symmetry.

929 Simple circuit speeds digital system checkout

Jacob R. Jacobs
MIT Instrumentation Lab., Cambridge, Mass.

Often, in debugging DTL, TTL, or RTL circuits, you are interested only in the logic level of a signal, or the presence or absence of a pulse. You do not need quantitative information such as exact voltages or pulse durations. You can build such a tester with only two ICs. Our unit fits into a small plastic tube 6-in. long and about 0.5-in. in diameter. A probe tip extends from one end, and two wires at the other end connect to +5 V and ground.

When you touch the probe tip to a zero-level signal line, the lamp, L_1, extinguishes. Conversely, a logic HIGH (+2 to 5 V) lights the lamp. A positive pulse as short as 10 ns will cause the lamp to blink ON for 0.1 s; and a negative pulse winks the light OFF once for 0.1 s. A squarewave of 50% duty cycle will hold the lamp at half brilliance.



NAND gates: Sylvania SG-140 or equiv

The circuit uses a one-shot multivibrator to extend the width of short pulses, and cause the lamp to blink ON or wink OFF for a discernible period of time. Diodes D_1 and D_2 let you connect TTL NAND gates as a wired-OR. If you use DTL NAND gates, omit D_1 and D_2. Resistor R_1 maintains a small excitation current through the lamp to keep its filament warm, so that the lamp responds very quickly to the one-shot.

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Amplifiers

Common-mode rejection ratio: what the spec sheet doesn't say, Frederick Gans, IC Metrics, "Electronics," Vol. 42, No. 13, June 23, 1969, pp. 94-102. It turns out that CMR (common-mode rejection) of differential amplifiers can be a misleading specification, even while it is a very important one to the buyer. This article points out some of the "errors" in manufacturers' specs and how you can overcome the errors.

Applications for op-amp ICs, William S. Routh, National Semiconductor, "EEE," Vol. 17, No. 4, April 1969, pp. 62-73. This comprehensive article covers four types of applications: amplifiers, operational circuits, signal conditioners for transducers, waveshaping and power supply auxiliary circuits. It includes a total of 19 applications among all four types, all of them illustrated with well-detailed schematics.

Circuit Design

Designing stable Wein-bridge oscillators, B. J. Skehan, Hughes Aircraft, "EEE," Vol. 17, No. 4, April 1969, pp. 79-81. This article explains the basic condition for oscillation of this classic bridge oscillator with a stabilizing agc feedback stage, and gives a few design equations to calculate the agc resistors. The article includes an example of the resistors' calculation.

Don't waste drive power, Kenneth L. Ziegler, Raytheon Co., "Electronic Design," Vol. 17, No. 13, June 21, 1969, pp. 106-110. A method for reducing the power needed in high-power microwave switching applications is shown. Instead of dissipating energy stored in a magnetic field, and reversing it later, a capacitor is charged and the current is discharged back into the coil in the proper direction.

Designing with packaged analog multipliers, Tom Cate & Howard Handler, Burr-Brown Research, "EEE," Vol. 17, No. 5, May 1969, pp. 68-75. The analog multiplier is shaping up to be a wide use device like the op amp. The authors describe several applications for these modules, such as for signal generation and telemetry, replacement of electromechanical servos, and instrumentation applications.

Get something extra in filter design, Russell Kincaid and Frederick Shirley, Sanders Associates, Inc., "Electronic Design," Vol. 17, No. 13, June 21, 1969, pp. 114-121. High- or low-pass Chebyshev or Butterworth filters are designed by cascading two-pole circuit sections. A computer program calculates component values and plots a frequency response curve. N-pole filters can be designed, where N is even.

Go graphic with capacitive input filters, J. P. Stringham Jr., Ball Brothers Research Corp., "Electronic Design," Vol. 17, No. 12, June 7, 1969, pp. 106-109. Curves are given for optimizing the performance of capacitive input filters. Some cost criteria also result from the designer's knowing what portion of the curves he is on.

Don't experiment with ferrite beads, Robert B. Cowdell, Genisco Technology Corp., "Electronic Design," Vol. 17, No. 12, June 7, 1969, pp. 100-103. A method is given for predicting how ferrite beads will add high-frequency insertion loss to a circuit. Practical limitations are discussed.

Communications

"Portable War" electronics gets first Pacific test, John F. Mason, Military-Aerospace Ed., "Electronic Design," Vol. 17, No. 10, May 10, 1969, pp. 34-45. A 2,500 man joint Army-Air Force exercise in South Korea is covered. Men and equipment, ranging from communications and maintenance vans to infrared Starlight scopes, were parachuted into a simulated combat zone. Problems including size, weight, age, and performance of electronic gear are treated. Troposcatter communications gains the highest grades. Existing equipment is able to do the job, but improvements are outlined.

Components

Choose regulator op-amps with care, Don Kesner, Motorola Semiconductor Products, Inc.. "Electronic Design," Vol. 17, No. 13, June 21, 1969, pp. 98-103. This article illustrates why the loop gain of a feedback circuit is not the determining factor in dc regulator performance. Factors such as op-amp offset voltage, power supply rejection, common mode effects, voltage reference stability, and lead resistance are discussed.

Quartz crystals for frequency control, Daryl Kemper, CTS Knights, and Lawrence Rosine, Editor, "Electro-Technology," Vol. 83, No. 6, June 1969, pp. 43-50. The authors cover quartz crystals and quartz crystal oscillators and those factors pertinent to their application for frequency control. They discuss the popular crystal cuts, frequency stability and the factors that affect it, and finally some guidelines for selecting the crystal. Also included are a chart of typical characteristics of precision crystals and a listing of manufacturers.

Magazine publishers and their addresses

EDN
Cahners Publishing Company
3375 S. Bannock Street
Englewood, Colo. 80110

EEE
Mactier Publishing Co.
820 Second Avenue
New York, N. Y. 10017

Electronic Design
Hayden Publishing Co.
850 Third Avenue
New York, N. Y. 10022

Electronic Products
United Technical Publications
645 Stewart Avenue
Garden City, N. Y. 11530

Electronics
McGraw-Hill, Inc.
330 W. 42nd Street
New York, N. Y. 10036

Electro-Technology
Industrial Research Inc.
Industrial Research Bldg.
Beverly Shores, Ind. 46301

IEEE Spectrum
Institute of Electrical & Electronics Engineers
345 East 47th Street
New York, N. Y. 10017

The Electronic Engineer
Chilton Company
56th & Chestnut Streets
Philadelphia, Pa. 19139

*Reprints available free. Request them on your company letterhead.

***Understanding solid-state or static relays,** Michael Joyce, Ohmite Manufacturing Co., "The Electronic Engineer," Vol. 28, No. 8, Aug. 1969, pp. 43-46. Surprisingly, the decision of which type of relay to use is not very difficult if you understand their capabilities and limitations.

Computers and Peripherals

***CAD Graphics: Circuits made to order,** Stephen A. Thompson, Western Editor, "The Electronic Engineer," Vol. 28, No. 7, July 1969, pp. 49-57. Since the larger the system to be integrated, the fewer the chances of this circuit being standard, most users will have to go to an IC manufacturer and ask him to design their systems from scratch. To this end, many manufacturers, as well as large users, have implemented computer-aided design (CAD) of integrated circuits. CAD starts from the basic requirements for a large system, and analyzes whether or not it can be integrated. If it can, the computer helps the IC designer to select the characteristics of the components, a circuit or a systems diagram, and displays the components on a cathode-ray tube for the designer to arrange them on the IC chip. In addition, most computer programs provided also a test sequence for the finished circuit.

Computer simulation plays key role in design of satellite earth stations, Lee B. Zahalka, GT&E International Systems Corp., "Electronics," Vol. 42, No. 13, June 23, 1969, pp. 120-126. As you already know, computers are rapidly becoming a design tool for complicated circuits and systems. Here is another description of how a computer is applied to solving some knotty design problems.

Integrated Circuits

Voltage-regulator ICs with foldback current limiting, Douglas R. Sullivan and Hans W. Mamie, Transitron Electronic Corp., "EEE," Vol. 17, No. 6, June 1969, pp. 82-89. A detailed description of Transitron's TVR2000 monolithic IC regulator, including applications of this regulator such as current-expandable regulation, floating regulators, switching regulators, and regulation with remote shutdown. The circuit description includes an explanation of the foldback circuit which limits the output current under overload and short circuit. This foldback circuit is built in the regulator.

How reliable are MOS IC's? As good as bipolars, says NASA, Leon C. Hamiter, Jr., NASA, "Electronics," Vol. 42, No. 13, June 23, 1969, pp. 106-110. While MOS ICs and bipolars have different failure mechanisms, NASA says their reliability is comparable. The oxide layer in MOS ICs is the important area when looking at failures. Defects or imperfections in this layer are usually the main cause of any failures.

Designing with versatile high-current monolithic regulators, Edward L. Renschler, Motorola Semiconductor Prods,. "EEE," Vol. 17, No. 6, June 1969, pp. 98-109. A clear description of a rather complicated circuit, that of Motorola's MC1560 and 1561 voltage regulators, is followed by a discussion of voltage regulator specifications, thermal performance from the user's standpoint, as well as a description of six applications.

Active filters: part 10, Synthetic inductors from gyrators, Gerald Aaronson, General Telephone & Electronics Labs Inc., "Electronics," Vol. 42, No. 14, July 7, 1969, pp. 118-125. Gyrators should be available as reasonably priced ICs by early next year. These gyrator ICs are very appealing because they can be used in building highly selective filters.

Microwaves and Microwave Products

***Cabling fast pulses? Don't trip over the steps,** Thad Dreher, E-H Research Labs, "The Electronic Engineer,' Vol. 28, No. 8, Aug. 1969, pp. 71-75. The author tells our readers how to predict the amount of distortion that cables will introduce in a pulse and how to improve the transmission by selecting the proper cable.

Power Supplies

Designing smaller, lighter dc-to-dc converters, Thomas B. Mills, Fairchild Semiconductor, "EEE," Vol. 17, No. 3, March 1969, pp. 76-80. With the constant search for small-size power supplies, there is an increasing interest in dc-to-dc converters where the conversion takes place at a frequency high enough to minimize the size of magnetic components, yet not too high to keep the eddy current and hysteresis losses low. The author analyzes the problem from a practical design standpoint, and recommends using high frequency transistors for switching. He includes two complete design examples of 28-Vdc to 250-Vdc converters, one rated at 40 W, and the other at 100 W.

Reliability

Insulating materials, Charles A. Harper, Westinghouse Electric Corp., "Electronic Design," Vol. 17, No. 12, June 7, 1969, pp. 65-96. This report is adapted from a chapter of the author's "Handbook of Electronic Packaging," McGraw Hill, May 1969. Electrical, thermal, and mechanical performance is presented for four categories of insulators: thermosetting plastics; ceramics, ceramoplastics, and glasses, thermoplastics; and elastomers. Its aim is to give an understanding of basic design and selection guidelines. Effects of frequency and humidity are included.

Semiconductors

Solid-state optoelectronics, Bill Segallis, Western Editor, "Electronic Products," Vol. 12, No. 1, June 1969, pp. 28-39. Optoelectronics is one of today's fastest moving fields. Applications are snowballing as new technology emerges from the labs. This article is not a theoretical treatment or a design discussion. Its primary focus is on hardware and applications. The report surveys both emitters and detectors as well as recent developments in solid-state displays.

How not to measure FET gate current, Charles L. MacDonald, Siliconix, "EEE," Vol. 17, No. 7, July 1969, pp. 44-46. Apparently, the gate current I_G and the reverse leakage gate current I_{GSS} of a field-effect transistor correlate well for p-channel junction FETs, but not for the more modern n-channel type. The reason, says the author, is that in n-channel FETs the gate current breakpoint occurs at a lower voltage than BV_{GSS}, which is where the breakpoint of I_{GSS} occurs. He suggests, therefore, that you test for I_G under circuit conditions, not for I_{GSS}.

Systems

Color-tv wheel takes a spin in space, John D. Drummond, Assoc. Editor, "Electronics," Vol. 42, No. 14, July 7, 1969, pp. 114-117. This article describes how space TV pictures are converted from serial red, blue, green signals into standard parallel color TV format for home viewing. The combination of a magnetic disc recorder and digital ICs solved the problem.

PCM: A global scramble for systems compatibility, William Bucci, Assoc. Editor, "Electronics," Vol. 42, No. 13, June 23, 1969, pp. 94-102. Right now the world agrees on only one parameter for pulse-code modulation (PCM)—the sampling rate. Unfortunately, differences in almost every other parameter mean that in many cases PCM systems around the world cannot exchange information directly. Because we can expect commercial PCM satellites in the future, these technical differences must be resolved.

A multi-function satellite system for transoceanic service, Michael W. Mitchell, Jerome D. Barnia, and Leroy J. Tangradi, RCA Defense Electric Products, "Electro-Technology," Vol. 83, No. 6, June 1969, pp. 51-60. There is a growing need for improved navigation and air traffic control systems. The authors feel that this need can be effectively met by a multi-function satellite system. They discuss such a system and how it meets criteria based on high reliability, low cost, long life, ease of traffic control and navigation operations, conservation of rf spectrum, and growth potential.

Test and Measurement

***Calibration curves for temperature sensors,** Staff Report, "The Electronic Engineer," Vol. 28, No. 8, Aug. 1969, pp. 49-50. These graphs show the characteristics of thermocouples for high and low temperatures and of resistor thermometers for cryogenic temperatures. Anthough only a few typical sensor calibrations are represented, you can find a complete list of temperature measuring devices along with information on calibration in the Temperature Measurement Guide, a pull-out chart following the next page.

Helical transmission lines bend the beam, Alan J. DeVilbiss, Hewlett-Packard Co., "Electronics," Vol. 42, No. 14, July 7, 1969, pp. 90-95. A new 250 MHz scope operates at this frequency primarily because of a new CRT and some new deflection circuit designs. This article describes the new tube design and these sweep circuits.

Miscellaneous

***The undergraduate . . . or how come we can't talk to one another,** Roger D'Aprix, Contributing Editor, 'The Electronic Engineer," Vol. 28, No. 8, Aug. 1969, pp. 35-39. Engineers are often singled out for their inability to communicate both with their colleagues and with the business community. While the author does not think engineers' communications problems are different from those of others, he does point out the need for better communication in industry. Electronic engineers, for example, often have good ideas but are unable to explain them to non-technical management—so these ideas get wasted. Written as a lively play, the article gives good hints for effective communication.

Play your way to better decisions, Erwin Rausch, Wing Manufacturing Co., "Electronic Design," Vol. 17, No. 13, June 21, 1969, pp. 124-128. Another method of role-playing, sensitivity training, and so forth—called the Didactic Game—is discussed. If you thought a lot of the old stuff, you'll like this; if you didn't, this is also junk.

How to investigate a company, Richard L. Turmail, Management & Careers Editor, "Electronic Design," Vol. 17, No. 12, June 7, 1969, pp. 112-118. Several financial terms are explained and methods for computing seven key account ratios from balance sheets are given. The reader can apply the ratios to a sample company, and compare his evaluations against those of the author, who provides no buy or sell conclusion.

Holography: The reality and the illusion, Richard Einhorn, "Electronic Design," Vol. 17, No. 11, May 24, 1969, pp. 43-63. If you are not familiar with holography, where it stands today, some of its problems and what's expected, then this article should interest you. It is not "deep" technically, but will give you a broad overview.

A personal program of preventive maintenance, Thomas B. Stephenson, Western Ed., "EDN," Vol. 14, No. 6, Mar. 15, 1969, pp. 107-109. If you can't compete in the marketplace with the newer engineers, your professional life expectancy is probably short. And each engineer must define for himself his own marketplace. Furthermore, to protect yourself, you must follow a continuing program of self-evaluation, setting goals and ways to get to them.

Designing positive voltage regulators, Robert J. Widlar, National Semiconductor Corp, "EEE," Vol. 17, No. 6, June 1969, pp. 90-97. This article describes a positive voltage regulator (the National LM105) but it does not contain information on how to design positive voltage regulators, as the title suggests. It discusses the characteristics of the LM105, as well as applications. The article is almost a textual reproduction of National Semiconductor's application note AN-23, Jan. 1969.

Solid-state imaging is easy with MSI, Donald V. Femling, Fairchild Semiconductor, "EDN," Vol. 14, No. 10, May 15, 1969, pp. 53-58. The author describes a model of a facsimile system that uses phototransistors. He discusses the compatible mating of MSI and COA (complex optical array) devices.

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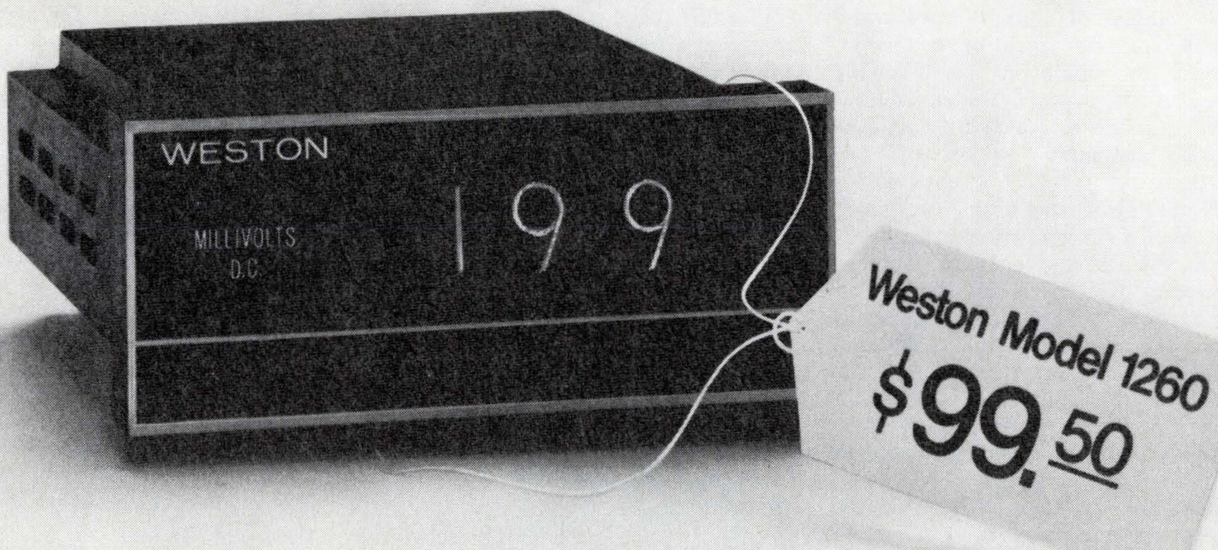

We brought out our 3½-digit compact DPM* just last March. It's the one that plugs into a panel slot only seven inches square, and pulls out for servicing or replacement. If you need the accuracy of 3½ digits, Model 1290 is still your best buy. But if you can settle for a digit less, you can have our new Model 1260 at less than half the price. Don't be fooled by the price tag, though . . . there's nothing "cheap" about this 2½-digit version. Housed in the very same plug-in case and fully compatible with its more sophisticated brother, Weston Model 1260 offers 0.5% ±1 digit accuracy—with far greater resolution capability than mechanical movements provide. Full scale reading is 199, with 25% over and under-range capability, remote command signal and Weston's usual high rejection characteristics. In addition to the convenience of front panel pluggability and circularly polarized viewing, we've included front panel calibration as a built-in bonus feature on the 1260. Write to the originators of the DPM. WESTON INSTRUMENTS DIVISION, Weston Instruments, Inc., Newark, N.J. 01774.

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New, cheaper waveforms at WESCON

The cost of a function generator is becoming comparable to that of an oscillator.

What's the difference between an oscillator and a function generator? **The number of output waveforms?** Yes. **Price?** Look again or, better yet, look at the chart on the following pages. At WESCON, Wavetek will introduce a line of function generators at prices comparable to those of oscillators.

Traditionally, the term "oscillator" has applied to an instrument based on the Wien bridge feedback circuit—developed by Hewlett and Packard in the early 1940s—which produces a clean sine wave. Function generators, on the other hand, deliver not only sine, but also square and triangular waveforms (and sometimes ramps). But they work on a principle different from that of oscillators.

First, a constant-current source drives an integrator to generate a triangular waveform. This triangle then drives a multivibrator to generate a square wave. The same triangle, passed through a diode-shaping network, generates a sine wave. (Note that this sine wave will, in general, have more distortion than a sine wave produced by an oscillator because it consists of discrete segments.) On the other hand, the output amplitude of a waveform generator stays fairly constant with frequency, whereas that of an oscillator tends to drop off at the higher frequencies.

Also, a function generator has traditionally cost more than an oscillator, because its circuit is more complicated. Not so now. Wavetek's new Model 130, the basic instrument in its new line, sells for $295, whereas the least expensive function generators available so far have been Wavetek's 110 and Exact 100, both selling at $445. Even though the $295 instrument does not strictly compare with the previously available, higher priced generators (since it does not cover the low frequency ranges), it does offer the user a new option in waveform generation.

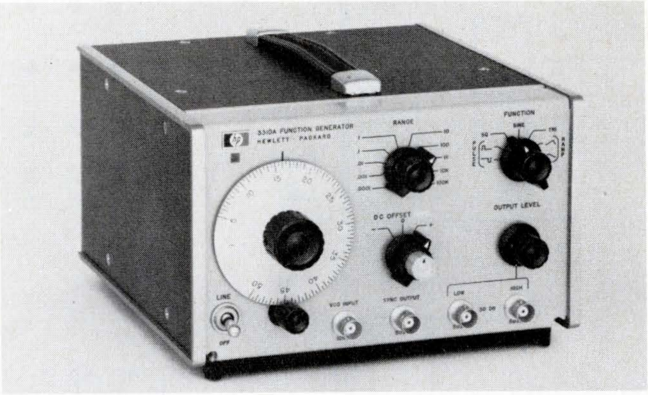
In addition to the 130, Wavetek is introducing Model 131VCG (similar to the 130, but voltage-controllable) and Model 134, which has its own internal ramp generator for voltage control.

As you can see from the charts, both the 130 and 131VCG are roughly in the same price class with popular oscillators such as the Hewlett-Packard 209A (sine-square), the H-P 204C, and the General Radio 1310A. But oscillator manufacturers are not standing still. General Radio is introducing, also at WESCON, a new oscillator, the 1310B, which is similar to the 1310A except for its slightly coarser dial accuracy (3%). Hewlett-Packard has a new model function generator, the 3310A. Also new at WESCON are the Data Royal models F270A and F280A digital function generators, the F321A and F322A sinewave oscillators, and the F323A and F324A sine-square oscillators.

The charts in the following pages compare the main characteristics of these new instruments with those of the most popular oscillators and function generators that cover roughly the 1-MHz to 10-MHz field. To make the comparison meaningful, the charts exclude instruments whose upper frequency limit is below 1 MHz. If, after examining the charts, you want more information on any of these instruments, simply circle in the inquiry card the numbers listed below.

Beckman Instruments	**201**
Exact Electronics	**202**
General Radio	**203**
Hewlett-Packard	**204**
Krohn Hite	**205**
Waveforms	**206**
Wavetek	**207**
Data Royal	**208**
Marconi Instruments	**209**

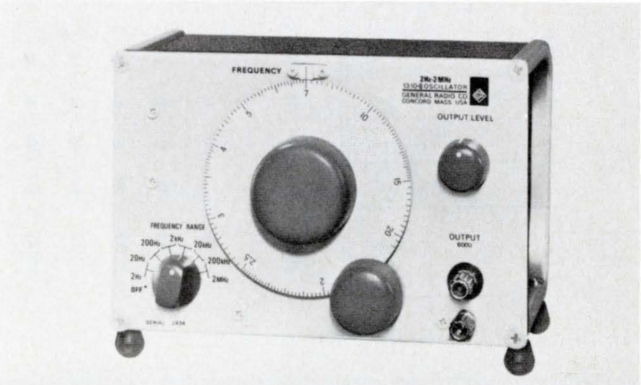
Data Royal's sine-square oscillators Models F323A ($660, shown) and F324A ($795) are only two of four new instruments in the 300 series. The other two, F321A ($585) and F322A ($720) are sinewave oscillators. All feature a frequency range from 10 Hz to 10 MHz, 0 — 90 dB output attenuation, and 7.32 V max. pk-pk output voltage into a 50Ω or 600Ω load. The 322 and 324 models have an X20 expand scale in the output monitor.



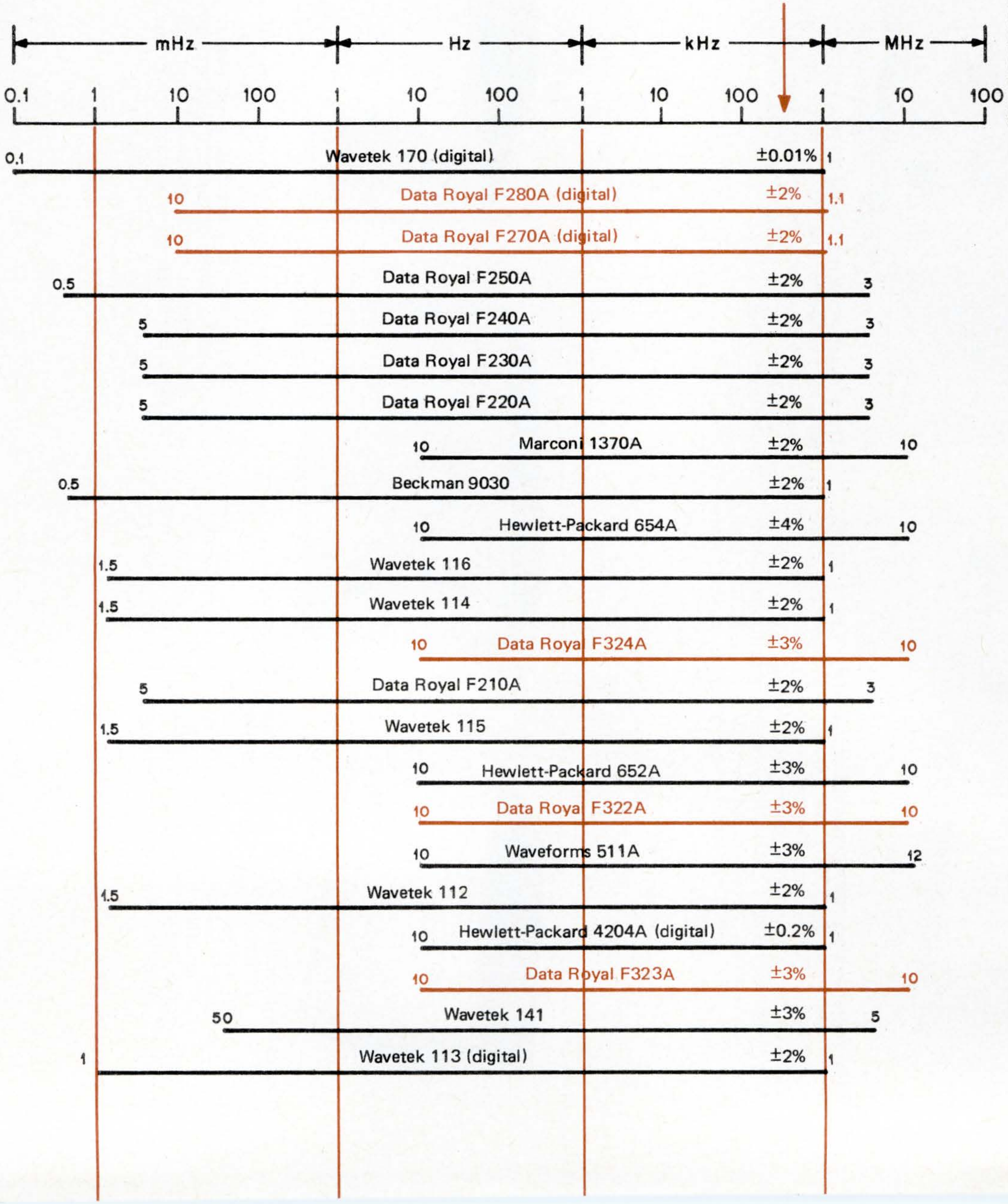
The Hewlett-Packard Model 3310A ($575) voltage-controlled function generator features ramp and pulse functions in addition to sine, square, and triangle, plus dc offset. It provides 15 V pk-pk output into 50Ω. Frequency range is 0.5 mHz to 5 MHz.

Wavetek's new line of function generators. Basic Model 130 (left) has six frequency ranges covering from 0.2 Hz to 2 MHz; output voltage of 20 V pk-pk into an open circuit, 10 V pk-pk into a 50Ω load; dial accuracy of ±2% of full scale; maximum sinusoidal distortion of 5% (26 dB down from fundamental). Price: $295. Model 131VCG (center) can be driven by an external ramp to sweep its frequency range, at about 2.5 V per decade of frequency. Its other characteristics are similar to those of Model 130, except for price: $345. The basic characteristics of Model 134 (right) are also similar to those of the 130, but this model includes an additional internal ramp generator that can either sweep or modulate the three basic waveforms. Price: $495.

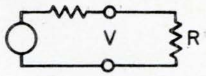
New oscillator by General Radio, Model 1310B, delivers sine waves from 2 Hz to 2 MHz in six decade ranges, at an output voltage of 20 V open, 10 V into 50Ω. Maximum distortion is less than 2% (34 dB down from fundamental.) These and all other characteristics are similar to those of G-R's oscillator Model 1310A, except for the dial accuracy (±3) and price, $275.



Oscillators and Function Generators

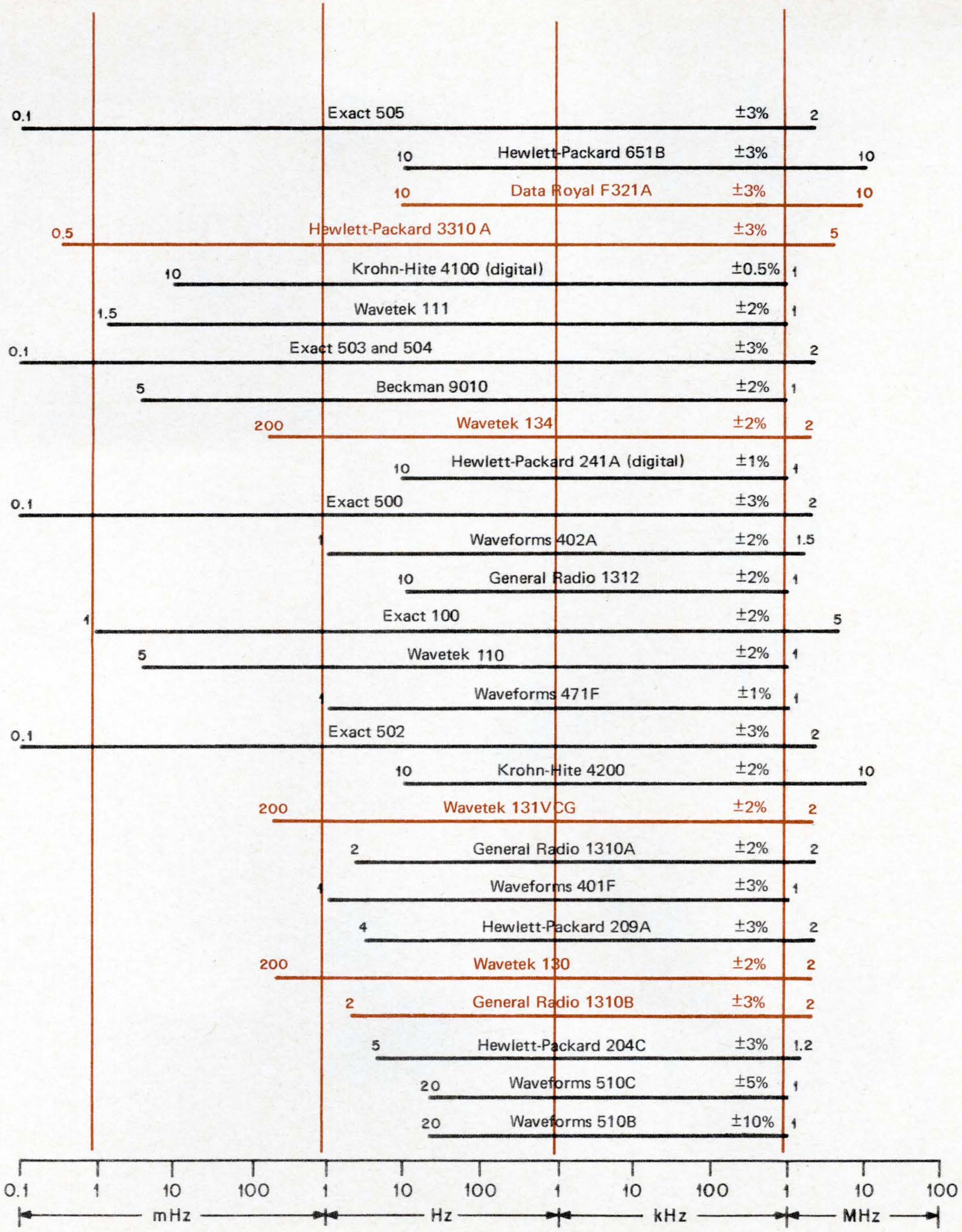


Output



Price $	Waveforms Sine	Square	Triangle	Ramp	Pulse	Frequency Range			Dial accuracy	Output V p-p	R Ω	Output Atten.	Offset
1995	●	●	●	●		0.1	Wavetek 170 (digital)	1	±0.01%	10	50	●	
1545	●	●	●			10	Data Royal F280A (digital)	1.1	±2%	11	50	●	●
1445	●	●	●			10	Data Royal F270A (digital)	1.1	±2%	11	50	●	
1145	●	●	●	●		0.5	Data Royal F250A	3	±2%	16.25	50	●	
1105	●	●	●	●		5	Data Royal F240A	3	±2%	16.25	50	●	●
1095	●	●	●	●		5	Data Royal F230A	3	±2%	16.25	50	●	●
1085	●	●	●	●		5	Data Royal F220A	3	±2%	16.25	50	●	●
935	●	●				10	Marconi 1370A	10	±2%	7	75-600	●	
895	●	●	●	●		0.5	Beckman 9030	1	±2%	15	600	●	●
875	●					10	Hewlett-Packard 654A	10	±4%	3	50-600	●	
845	●	●	●	●		1.5	Wavetek 116	1	±2%	10	50		
795	●	●	●	●		1.5	Wavetek 114	1	±2%	10	50		
795	●	●				10	Data Royal F324A	10	±3%	5	50	●	
785	●	●	●	●		5	Data Royal F210A	3	±2%	16.25	50	●	
745	●	●	●	●		1.5	Wavetek 115	1	±2%	10	50		
727	●					10	Hewlett-Packard 652A	10	±3%	9	50	●	
720	●					10	Data Royal F322A	10	±3%	5	50	●	
700	●	●				10	Waveforms 511A	12	±3%	3	50		
695	●	●	●	●		1.5	Wavetek 112	1	±2%	10	50		
695	●					10	Hewlett-Packard 4204A (digital)	1	±0.2%	10	600	●	
660	●	●				10	Data Royal F323A	10	±3%	5	50	●	
645	●	●	●			50	Wavetek 141	5	±3%	10	50		
595	●	●	●	●		1	Wavetek 113 (digital)	1	±2%	10	50		●

595	● ● ● ● ●	0.1	Exact 505	±3%	2	25	600		●
590	●	10	Hewlett-Packard 651B	±3%	10	9	50	●	
585	●	10	Data Royal F321A	±3%	10	5	50	●	
575	● ● ● ● ●	0.5	Hewlett-Packard 3310 A	±3%	5	15	50		●
550	● ●	10	Krohn-Hite 4100 (digital)	±0.5%	1	14	50	●	
545	● ● ● ●	1.5	Wavetek 111	±2%	1	10	50		
525	● ● ● ● ●	0.1	Exact 503 and 504	±3%	2	25	600		●
495	● ● ●	5	Beckman 9010	±2%	1	15	600		●
495	● ● ●	200	Wavetek 134	±2%	2	10	50		
490	●	10	Hewlett-Packard 241A (digital)	±1%	1	25	600		
485	● ● ● ● ●	0.1	Exact 500	±3%	2	25	600		●
450	●	1	Waveforms 402A	±2%	1.5	8	600		
* 445	●	10	General Radio 1312	±2%	1	10	600	●	
445	● ● ● ● ●	1	Exact 100	±2%	5	10	50		●
445	● ● ●	5	Wavetek 110	±2%	1	10	50		
385	●	1	Waveforms 471F	±1%	1	10	600		
385	● ● ● ● ●	0.1	Exact 502	±3%	2	10	600		
350	●	10	Krohn-Hite 4200	±2%	10	1 14	600 50	●	
345	● ● ●	200	Wavetek 131VCG	±2%	2	10	50		
* 325	●	2	General Radio 1310A	±2%	2	10	600		
325	●	1	Waveforms 401F	±3%	1	15	600		
320	● ●	4	Hewlett-Packard 209A	±3%	2	10	600		
295	● ● ●	200	Wavetek 130	±2%	2	10	50		
* 275	●	2	General Radio 1310B	±3%	2	10	600		
240	●	5	Hewlett-Packard 204C	±3%	1.2	4	600		
200	●	20	Waveforms 510C	±5%	1	2.5	600		
180	●	20	Waveforms 510B	±10%	1	5	600		



* Qty. discounts available

NOTE: New instruments are shown in color

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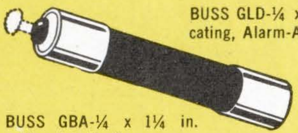
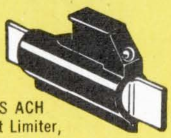
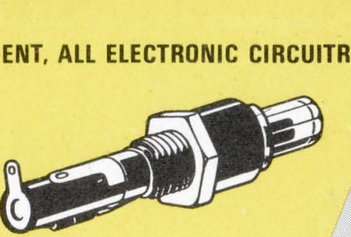


BUSS GLD-¼ x 1¼ in. Visual-Indicating, Alarm-Activating.

BUSS GBA-¼ x 1¼ in. Visual-Indicating.

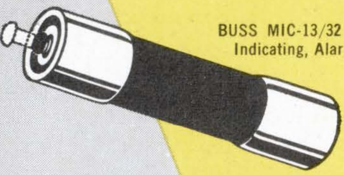


BUSS ACH Aircraft Limiter, Visual-Indicating



HKA panel mounted holder, lamp indicating-signal activating, for ¼ x 1¼ in. BUSS GLD fuse.

¾ to 5 amp.

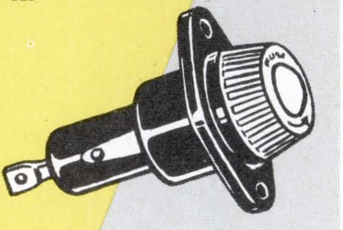


BUSS MIC-13/32 x 1½ in. Visual-Indicating, Alarm-Activating.

BUSS MIN-13/32 x 1½ in. Visual-Indicating.

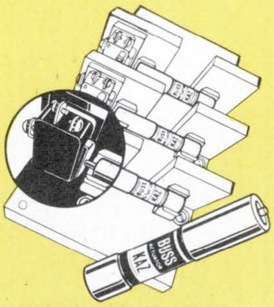
HLD panel mounted holder, visual-indicating, for ¼ x 1¼ in. BUSS GBA fuses (or GLD fuses)

¾ to 5 amp.

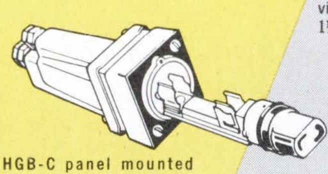


HPC-C panel mounted holder, visual-indicating, for 13/32 x 1½ in. fuses.

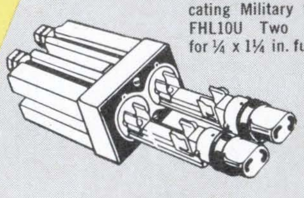
FNA FUSETRON Fuse 13/32 x 1½ in. slow-blowing, Visual-Indicating, Alarm-Activating. (Also useful for protection of small motors, solenoids, transformers in machine tool industry.)



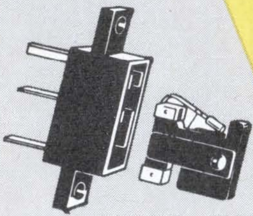
BUSS KAZ Actuator 13/32 x 2 in. Signal-Indicating, Alarm-Activating Device. Use to call attention to the opening of a fuse of 50 amp or larger. Can be mounted "piggy-back" on large fuse or in special block with micro-switch. Ask for Bulletin KAFS.



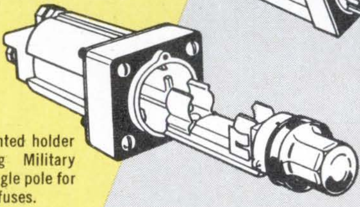
HGB-C panel mounted holder lamp indicating Military type FHL11U Single pole for ¼ x 1¼ in. fuses.



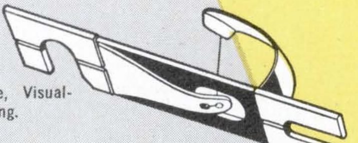
HGA-C panel mounted holder lamp indicating Military type FHL10U Two pole for ¼ x 1¼ in. fuses.



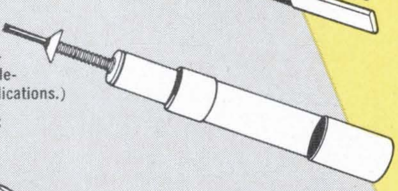
BUSS GMT and HLT holder, Visual-Indicating, Alarm-Activating.



HGC panel mounted holder lamp indicating Military type FHL12U Single pole for 13/32 x 1½ in. fuses.

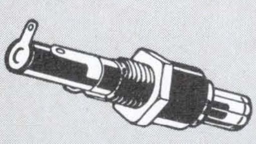


BUSS Grasshopper Fuse, Visual-Indicating, Alarm-Activating.

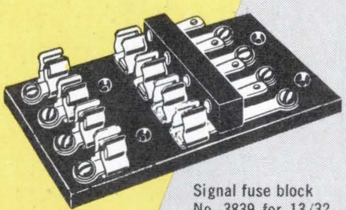


BUSS Series 70. Visual-Indicating, Alarm-Activating. (Used in telephone and similar applications.)

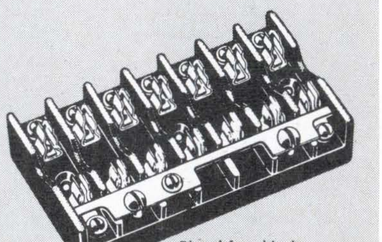
Ask for Bulletin 70S-C



HKL panel mounted holder, lamp indicating, for ¼ x 1¼ in. fuses.



Signal fuse block No. 3839 for 13/32 x 1½ in. indicating fuse.



Signal fuse block No. 4178 for ¼ x 1¼ in. indicating fuse.

Write for BUSS Form SFB

BUSSMANN MFG. DIVISION, McGraw-Edison Co., St. Louis, Mo. 63107

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COVER STORY

General-purpose scope has 250-MHz response

Right now, monolithic ICs in the vertical amplifier limit this instrument to 250 MHz. But improvements in LIC technology would let you use this same scope to 500 MHz.

The newest member of Hewlett-Packard's 180-series oscilloscope family is the Model 183A. It is also the fastest real time scope you can buy (see box).

Many scopes with vhf realtime response have heretofore suffered from insufficient viewing area, low brightness, or low sensitivity. Often, they have been specialized instruments without the versatility of plug-in options. The HP-183A changes all this; it is an easy-to-use, dual trace, modular scope with a dc to 250-MHz response. And it has a bright trace on a standard 6 x 10 cm viewing area.

Where it shines

Realtime response to 250 MHz means that you have an instrument with less than 1.5-ns risetime (from a 50-Ω source). This in turn means that you can view digital words or other groups of short duration, fast-rise pulses such as those now prevalent in the newer computers and high speed digital systems. Furthermore, the 183A lets you see such pulse groups even where sampling scopes often fall down on the job: digital words presented at slow rep-rates.

Similarly, you can see single, short pulses at low rep-rates, such as those generated by laser-beam detectors. And because the crt has an internal flood gun to increase the photographic writing speed to about 4 cm/ns (with ASA 3000 film, P11 phosphor, 1:0.5 reduction ratio, and an f/1.3 lens), you can more easily capture single-shot transients on film. As a further aid in such hunts, you can leave the camera shutter open—the flood gun will flash in synchronism with the horizontal sweep.

In communications systems analyses, the 183A's 250-MHz response makes possible, among other things, undistorted pre-detection displays of modulation envelopes on rf carriers.

You can realistically think of the 183A as a 500-MHz realtime scope, only temporarily limited to 250 MHz by its vertical amplifier plug-ins. The main-frame (183A/B), while compatible with all existing 180-series plug-ins, can actually operate to beyond 500 MHz. Such a capability implies unusual performance by the crt and the sweep circuits as well. And they have it!

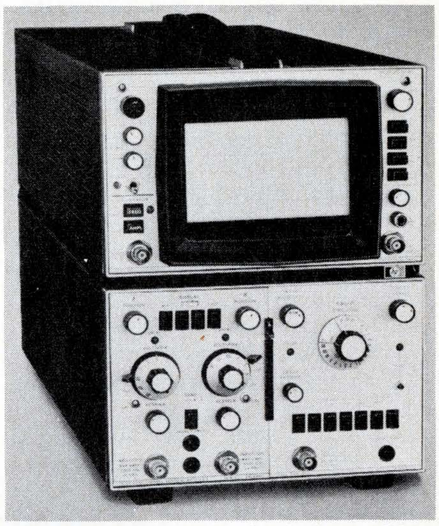
A computer-aided design optimized the crt's many electrical and mechanical parameters to give a bright, fast-writing spot. Further, the crt has distributed deflection electrodes in the form of flat ribbon helices, which, together, behave electrically as a single, distributed-constant transmission line. Signals propagate along the helices at the same rate as that of the electrons in the crt's electron beam, which is alongside. (See our cover picture.)

A 500-MHz crt

In effect, the beam passes a series of short deflection-electrodes, with appropriate signal delay from electrode to electrode. The short transit time of the beam past each electrode gives the crt a response well beyond 500 MHz, while the series of time delayed electrodes gives it a sensitivity equivalent to that of a crt with a single, long electrode.

A domed, mesh electrode on the exit side of the deflection region gives a further increase in sensitivity by magnifying beam deflections three times. The vertical deflection factor of the crt is 3 V/cm, making it IC-compatible.

The vertical amplifier's active devices are indeed ICs, designed specifically for this instrument by HP's own Santa Clara division. The instrument's designers use ICs not primarily for low cost or small size, but to shrink signal paths for better high-frequency performance, and for uniformity among the active devices. So, as the state of the IC art improves, look for a 500-MHz vertical amplifier plug-in to round-out the 183A's performance.



The present 250-MHz plug-in, Model 1830A, is a dual-trace module (A, B, A+B, A−B, ALTERNATE, CHOPPED) with seven sensitivity ranges from 10 mV/div to 1 V/div, and a 2.5:1 continuously variable vernier with a calibrated position. The 50-Ω input VSWR at 250 MHz is better than 1.25 at 10 mV/div, and better than 1.15 from 20 mV/div on up. A built-in, 55-ns delay lets you see the leading edge of a pulse.

A 500-MHz sweep, too

The sweep circuits trigger to 250 MHz from signals fed to them from the 1830A vertical amplifier, or from

Take a look around. In terms of realtime performance, the closest competitor to HP's new scope is the **Iwatsu SS-211**, a Japanese product marketed here by **E-H Research.** Introduced early this year, the 211 boasts a 200-MHz response and a 10-mV/cm sensitivity. With a 1.75-ns risetime FET probe, it sells for about $3100.

But probably the best-known and most widely used wideband scope is the **Tektronix 454**—a 150-MHz instrument that goes for $2600. And to tempt you still more, this maker is introducing a brand-new line at Wescon: the 7000 series. This is a full measurement system of two main-frames, 13 plug-ins (six amplifiers, four time-base units, three sampling units), and accessories.

Of most interest to us here is the **7704.** This is a dc- to 150-MHz scope with a 2.4-ns risetime, and a 5-mV/div sensitivity.

The maximum calibrated sweep rate is 2 ns/div, and the visual and photographic writing rates are high. Among its many conveniences is the AUTO SCALE-FACTOR READOUT, which uses the crt itself to display deflection factors, polarity, and so forth.

As for cost, the 7704 mainframe is $2600, and a 7A16 wideband amplifier plug-in is $600, as is the 7B70 delayed sweep. So a fairly representative low-end price is $3700.

For more information:
Tektronix, Inc., Box 500, Beaverton, Ore. 97005. (Booths 2101-04, 2129-32.) Or, circle **308** on Inquiry Card. E-H Research Labs., Inc., 515 11th St., Box 1289, Oakland, Calif. 94604. (Booths 1033-36.) Or, circle **309** on Inquiry Card.

DVM offers computed true-rms option

These five-digit instruments offer precision measurements of dc voltage, ac voltage, dc/dc ratio, and resistance. Series 5500 digital voltmeters feature a dc accuracy of ±0.005% of reading plus one digit. The effect of temperature changes on this figure is less than ±0.0005% of reading and ±0.0002% of full scale, per °C. And an internal voltage reference with six-month stability means fewer trips to the calibration lab.

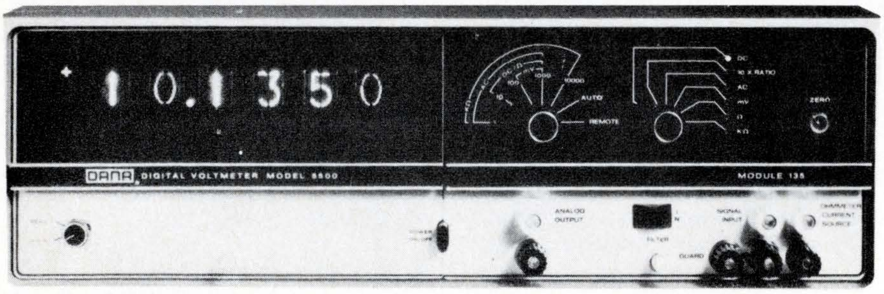
A guarded input contributes to the 60-Hz common-mode rejection figures of 120 dB (dc ranges) and 90 dB (ac ranges), with 100-Ω unbalance. There is also a five-pole, active filter to push the normal-mode rejection at line frequency to 80 dB.

Three dc ranges span ±10.9999 V to ±1099.99 V, and can resolve to 100 µV. Input impedance is 10,000 MΩ on the 10-V range, 10 MΩ on the upper two ranges. Settling time to 0.01% is 500 ms in the dc mode, or 25 ms in the dc fast mode, with up to 10-kΩ source resistance. Two low-level dc ranges, ±109.999 mV and ±1099.99 mV, resolve to 1 µV.

You can make ac measurements from 50 Hz to 100 kHz by adding the Model 21 average-responding converter. Four ranges cover 1.09999 V to 1099.99 V (rms calibration) with a 10-µV resolution and a 300-ms settling time to 0.1%. The input resistance is 1 MΩ shunted by a capacitance (with front input only) of less than 100 pF.

An interesting option for the Series 5500 DVMs is the Model 31 computing ac converter. It uses high speed, analog computer techniques to measure the rms values of sawtooth, triangle, square, and sine waves, without sacrificing speed or sensitivity. There is no thermocouple element. But even with 10% waveform distortion, the computed rms value is identical to that measured by a thermal-type unit. The converter measures to 0.1% accuracy in 300 ms, with 10-µV resolution.

Resistance measurements require use of the Model 01 ohms converter. Eight ranges cover 10.9999 Ω to 10.9999 MΩ, with a 100-µΩ resolution. You can measure small resistances, accurately, by using the four-wire ohms configuration.



The accuracy of the real-time dc/dc ratio measurements is independent of the stability of the external dc source. This is so because the instrument simultaneously detects both the input signal and the reference. The input signal (numerator) can be from −1000 V to 1000 V, while the reference signal (denominator) is from 2 V to 11 V. A special-option reference spans 20 V to 110 V.

Front-panel output terminals provide a 10-V full-scale dc level proportional to any input signal on any range. This is useful for recording, high-low alarms, and so forth. An optional digital-output accessory gives you an isolated BCD output. The isolation preserves the instrument's common-mode rejection when you connect it to a grounded-output device.

A remote-programming accessory lets you program function, range, and read commands. Delay circuits in this device automatically allow for settling times, and isolation relays let you reference the commands to ground.

The prices of the Series 5500 instruments vary according to the measurement capabilities of the particular model, from $2850 to $3540. Model 5500/135/21/01, a full multimeter, costs $3985; for $200 more you can get true-rms measurements with the Model 31 computing ac converter. Dana Laboratories, Inc., 2401 Campus Dr., Irvine, Calif. 92664. (714) 833-1234. (Booths 2008-2011.)

Circle 269 on Inquiry Card

(continued from page 93)

20-mV pk-pk external signals. But if you can spare another 30 mV, you'll find that a 50-mV pk-pk external trigger extends the trigger rate to 500 MHz, without any double triggering.

The Model 1840A time base has a variable hold-off control that gives you a stable display of pulse groups. This control allows you to trigger repeatedly on a particular pulse in the group. Sweep times range from 10 ns/cm to 0.1 s/cm. A X10 position on the main-frame takes you to 1 ns/cm.

And a 500-MHz probe

Signal inputs to the vertical amplifier terminate in 50Ω, because of the difficulty of conducting high-frequency signals on anything but transmission lines. Thus, you can feed such signals into the scope without having them degraded by capacitive effects.

But in keeping with the 183's general-purpose nature, there are optional, passive, resistive-divider probes. These trade sensitivity for high impedance, and are useful for general circuit probing.

There is also an active probe. Model 1120A has unity gain from input to output, and a frequency response to 500 MHz. Its input impedance is 100 kΩ/3 pF, which the probe translates to 50Ω for the scope input. This means that for a 250-MHz response with this probe, your circuit resistance can be as high as about 200Ω.

Built-in calibrator

The 183's main-frame has a calibration port that gives you a signal specified three ways: in amplitude, frequency, and risetime. It is a 10% duty cycle, negative-going pulse train. Each of its pulses has an 0.8-ns risetime. You can select either −50 or −500 mV amplitudes, and 2 kHz or 1 MHz rep rates. The waveform lets you quickly confirm all aspects of the scope's performance.

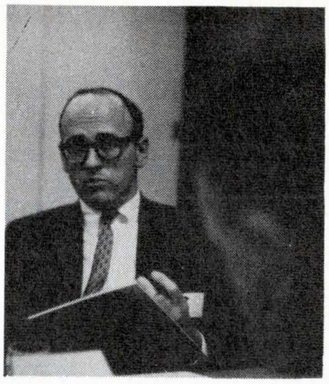
If you wish, you can drive the calibrator's shaping network with an external signal at rates to 10 MHz.

November delivery

Deliveries of the new scope are scheduled to start in about ten weeks. A complete 183A costs, tentatively, $3150. The price breaks down this way: 183A/B main-frame, $1750; 1830A dual-trace, 250-MHz plug-in, $850; 1840A time base, $550. The Model 1120A active probe is $350. For more information, call or write Inquiries Manager, Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 326-7000. See it at Booths 1001-05, 1040-46.

Circle 270 on Inquiry Card

SWITCH CRAFT FORUM



on Jacks and Plugs

Jacks and plugs, yet! How can I get excited about them, considering their relative cost in the overall equipment package?

One sure way to get excited is to suffer costly downtime and repairs on an expensive piece of equipment due to jack or plug failures. While jacks or plugs seldom play the "glamour" roles, you'll find plenty of engineering considerations in their design and application worth looking into from a reliability standpoint.

I'm willing to be convinced. What should our engineers be most concerned about in specifying dependable plugs and jacks?

First of all, they should think "total connection" rather than just plugs or jacks. A good percentage of reliability problems stem from mating plugs and jacks from different manufacturers. A case in point is the concentricity of the plug tip. (See Fig. 1.) On the smaller jack designs, where contact gaps are minimal, it is possible to open or close the circuit by *rotating* the plug if the tip is not perfectly concentric. Most cases of erratic operation may be traced directly to these manufacturing or tolerance differences. Other basic design and manufacturing techniques are involved, too. For instance, on plugs, Switchcraft uses a one-piece tip rod machined to close tolerances instead of the less-reliable threaded shank and screw-on tip. Also, certain jack designs employ notched insulating washers that positively interlock with the springs to prevent shifting and possible shorts. These are quality design considerations that the specifying engineer should be looking for.

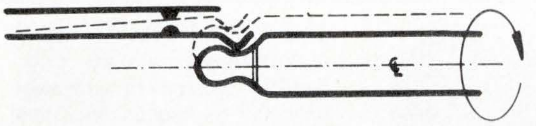


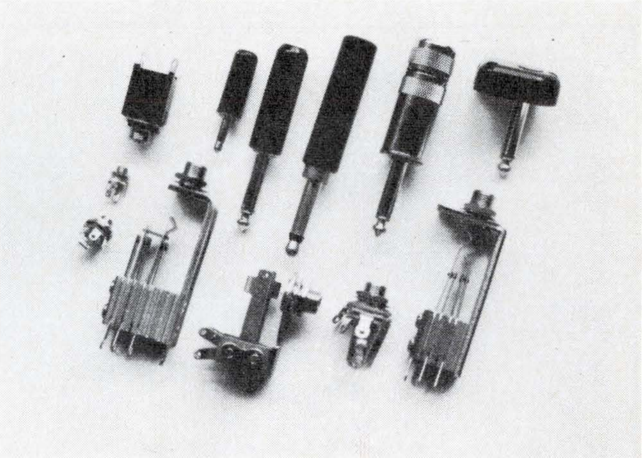
Fig. 1 Non-concentric plug tips or jack collars can cause intermittent operation.

That covers the mechanical side, but how about some of the electrical design features that make a difference in reliability?

Surface contamination of contacts is another major threat to reliable performance. Spring forming and flexure characteristics with respect to contact pressures are also critical. Solutions to these problems are found in the proper selection of materials and strict adherence to specifications.

Contact resistance is another area. Certain jacks are designed for lighter insertion and withdrawal forces. This creates a problem in maintaining sufficient spring forces for minimal contact resistance. Switchcraft solves this by utilizing silver plated contact springs to compensate for the relative decrease in contact pressures.

The point is, Switchcraft pays strict attention to every design characteristic which is why we have the most extensive, highest quality jack and plug line on the market . . . and that's a plug, Jack!



Surrender! Just tell me how my circuit designers can get all the Switchcraft jack and plug information they'll need.

All we need is their request on your company letterhead for our "FORUM FACTS on Jacks and Plugs" handbook. We'll also add their name to our TECH-TOPICS mailing list. 10,000 design engineers find these technically oriented application stories on switches and related products extremely valuable.

"See us at
WESCON BOOTHS
3909-3910,
Cow Palace."

SWITCHCRAFT® INC.

5529 N. Elston Ave.
Chicago, Ill. 60630

Circle 43 on Inquiry Card

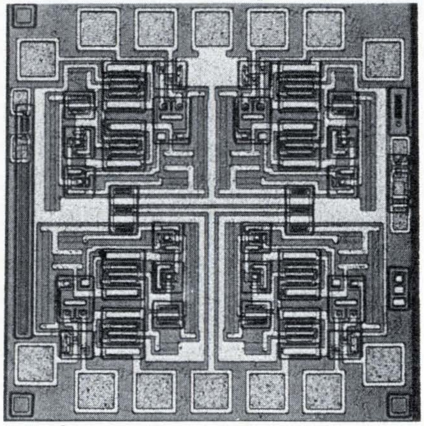
Hardened IC line adds new members

A family of high-speed logic elements for use in hardened digital systems will be introduced this month at Wescon. Functionally equivalent to conventional Series 54H circuits, the five new TTL elements augment their maker's existing line of off-the-shelf, radiation-hardened ICs. (Eight Series DTL-930 circuits and an RA-709R op amp announced last March at IEEE.)

Radiation Incorporated claims that their new ICs have two orders of magnitude more resistance to degradation in a radiation environment than do conventional Series 54H circuits.

According to the manufacturer, the added radiation-resistance is attributable to the production processes. Such processes include the use of dielectric isolation with small-geometry devices, low-resistivity materials, thin-film resistors, and special circuit design techniques. All of these factors taken as a whole give minimum sensitivity to gamma and neutron bombardments.

Assembly techniques — developed by the company specifically for hardened circuits—further reduce radiation sensitivity. In particular, there is no gold or other high atomic number elements inside the package. This significantly lessens the amount of radiation energy absorbed by the packaging materials.



Among the new ICs is a dual, Type D flip-flop, the RD-54H74R, with a 25-ns (typ.) propagation delay. This delay spec is for input data present at least 15 ns prior to the positive-going clock pulse edge.

Two NAND and two AOI (AND/OR/INVERT) gates round out the five-member family. The RD-54HOOR and RD-54H2OR are quad 2-input, and dual 4-input NAND gates, respectively; the RD-54H51R and RD-54H54R are dual 2-input, and quad 2-input AOIS, respectively.

Each gate has a 13-ns (avg.) propagation delay when working into a 150-pF load, and about 22-mW power consumption. All circuits satisfy worst-case fan-out rules and meet guaranteed noise-immunity specs at temperatures from —55° to 125°C.

The price of these TTL circuits will be announced at Wescon, and delivery from stock is to begin September 1st. Radiation Incorporated, P.O. Box 37, Melbourne, Fla. 32901. (305) 727-4295. (Booths 4503-05.)

Circle 271 on Inquiry Card

Microwave pulse height detector

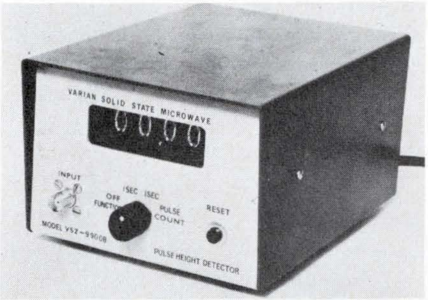
Here's an instrument that helps you to determine spike power leakage in TR tubes, detect missing pulses (in magnetrons, for instance), make peak power measurements on pulsed transmitters, and so forth. It works in conjunction with a tuned crystal detector and a precision attenuator, and triggers on a very small amount of power. The device detects fast risetime, narrow pulses and registers such occurrences on its internal counter, or on an external indicator.

The VSZ-9900 needs only a 30-mV input signal to trigger, but accepts levels as high as 2 V peak. You can detect pulses that have durations as short as the risetime of the instrument itself—500 ps—at rep rates to 20 kHz. The maximum detectable pulse width is 40 μs.

Three models are available. The VSZ-9900A has a detector and power supply, and generates a 1-Vdc output pulse, 1 μs long. You can select either positive or negative outputs. This model needs an external digital counter.

The VSZ-9900B includes a counter which can display both rep rate and total pulse count, while the VSZ-9900C consists of the detector only, and has a positive output. Both the "A" and "B" models operate from the 115-Vac power line, but the "C" model needs a 20-Vdc power supply.

In use, a test set-up for transient measurements includes an rf source, the device under test, an attenuator, and a crystal detector. The detector feeds the VSZ-9900, and its output, in turn, connects to its internal counter or to an external indicator, depending on the model. The crystal detector is optional; a simple calibration technique adapts most positive-output detectors for use with the VSZ-9900.



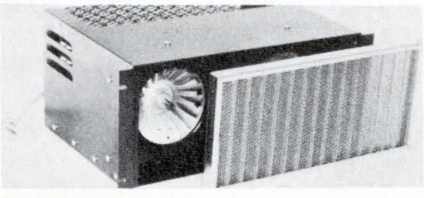
For more information, including price and delivery, contact Varian Solid-State Division, Salem Rd., Beverly, Mass. 01915. (617) 922-6000.

Circle 272 on Inquiry Card

A breath of fresh air

The next time you specify a cabinet panel blower your task may be simplified by a new line of cooling units from Rotron. Centraxial® wheels, the key element in the design of these unconventional blowers, allow the units to deliver a large volume of turbulent air with a discharge pattern that is uniform across the entire panel opening. This uniform pattern eliminates the need to consider alternate discharge positions or housing variations when specifying cabinet panel blowers. In most applications, moreover, the approach eliminates hot spots within the cabinet without the need to direct the air blast.

The new blowers are Rotron's entry into an area that, up to now, has been the domain of such firms as Kooltronic Fan of Princeton, N.J. and McLean Engineering Labs of Princeton Junction, N.J.



Model MB 8100 uses two Centraxial wheels for a delivery of 650 ft^3/min from a package only 8¾-in. high. Types 175 and 275 are variations that are recessed and require only 7 in. of panel space. Model MB 7100 also uses Centraxial wheels and, for less critical applications, three other models have other types of impellers for lower air delivery at lower cost.

The five models that comprise the line offer a choice of air delivery from 240 to 650 ft^3/min. These performance figures are the actual air delivery of the units—not the theoretical performance of the impeller and motor.

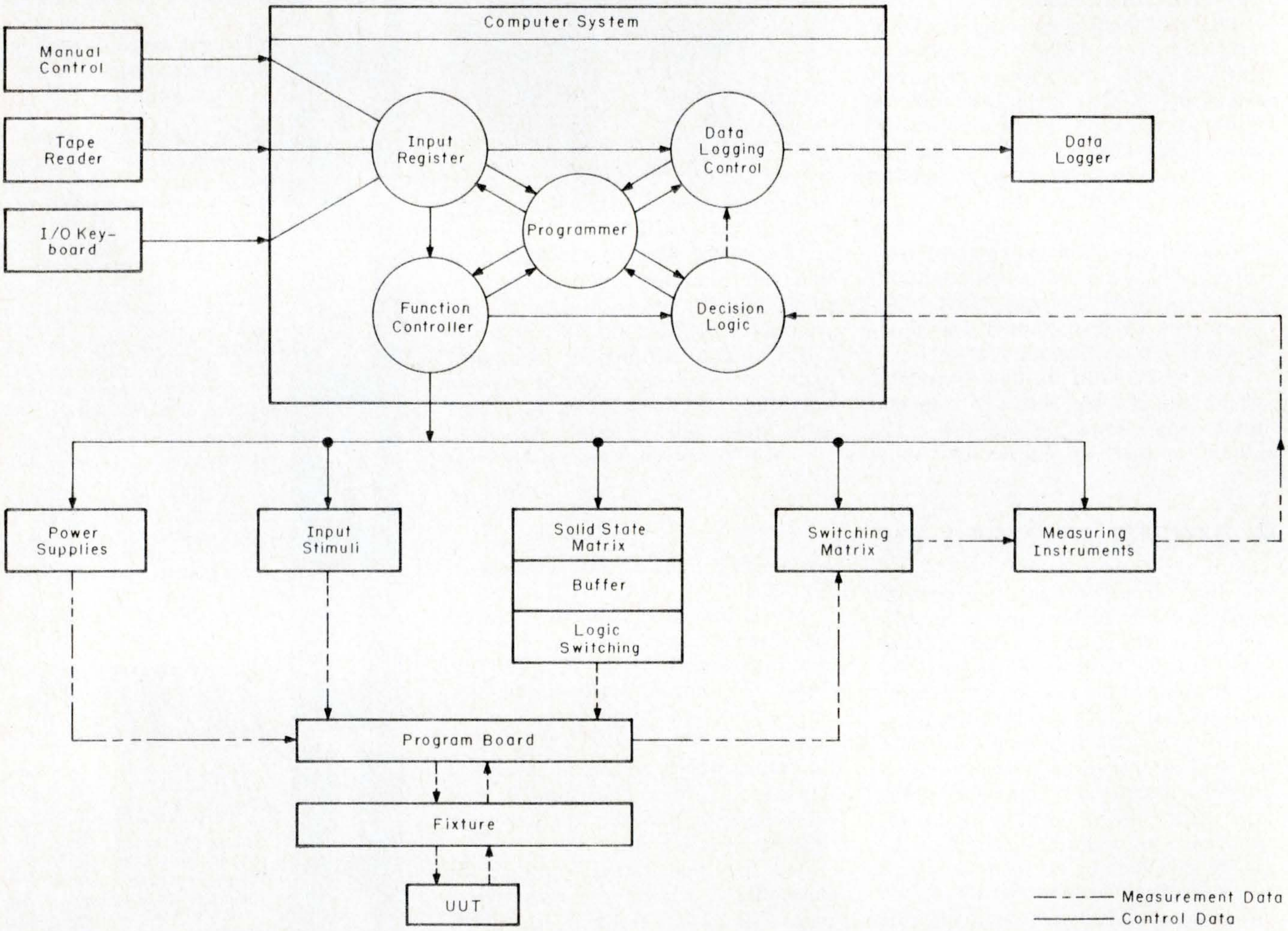
For applications where electromagnetic interference is a problem, RFI/EMI-shielded units are available. All models in the line are equipped with low-impedance, washable, porous filters enclosed in a rigid aluminum frame.

Rotron, Inc., Woodstock, N.Y. 12498. Booths 3901-03.

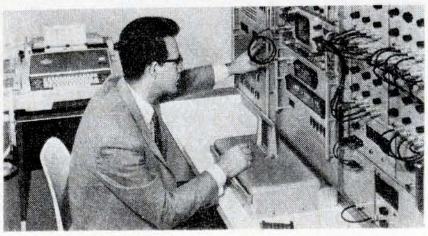
Circle 273 on Inquiry Card

A system approach to logic testing

Along with the need to miniaturize electronic systems has come, ironically, the need for larger systems (see **The Electronic Engineer,** May 1969, pp. 73-78). A good example of this paradox is the QC 363 Automated Logic Test System, which has evolved as a relatively large and sophisticated logic tester. It is large in the sense that the manufacturer has integrated digital test equipment, traditionally used as individual units. It is considered uniquely sophisticated by the manufacturer because neither is it an IC tester nor is it controlled by an external computer: it makes absolute tests within programmable limits.



As an instrumentation system, the Series 363 combines many of the functions of a real-time computer. The end product is a papertape programmed system that provides both static and dynamic testing of digital logic-card sub-assemblies, modules, or complete logic systems of virtually every type of logic.



Programs are read into the system photoelectrically at 300 char/s. An I/O console and data logger provide program editing and hard copy output of tests. Typing and punching rates are 600 char/s (1 in. tape; ASCII 8-level code; 60-char keyboard). Output printing, 10 char/in. on 8-in. paper.

To protect the unit under test (UUT), as well as the test set up, a static test is almost mandatory to verify that the circuits and terminations being tested do not contain any non-specified grounds or V_{ee}. During static testing, the current drain is measured against preset acceptable limits. The system stops further tests if a fault occurs during static testing.

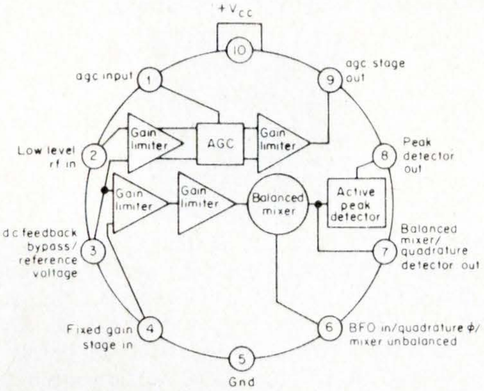
Dynamic testing measures rise, fall, and propagation delay times, as well as logic levels. Stimuli (clock or test patterns) are connected to the inputs of the buffer gates on the interfacing program board. These gates are enabled one at a time, sequenced by the program, and controlled by the switching matrix. A programmable oscilliscope measures and compares the input/output waveform. Miniature reed relays perform multiple test termination switching. The outputs of the UUT are terminated with the proper loads during the dynamic test.

Basic system capacity is 64 or 80 pins in groups of 80 pins. Test speed depends on the test performed, the number of test steps, and the number of points to be scanned per test. Verification time of a complete truth table for 48 logic inputs in 36 combinations is less than three seconds. The price of a complete system is about $77,000. A variety of options, including software custom interfaces, and expanded-pin increments are available upon request. Automation Dynamics Corp., Industrial Pkwy., Northvale, N.J.

Circle 274 on Inquiry Card

MULTIPLE-MODE, MONOLITHIC I-F STRIP

For a-m, fm, and ssb i-f's, and broadband video amps.

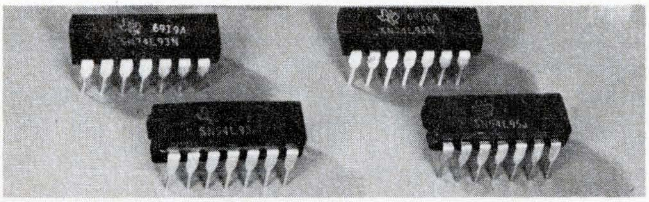


The LM373 serves a multitude of functions, and allows you to switch, economically, from one transmission mode to another within a receiver. Two functional sections give you a 32-dB gain, 57-MHz video bandwidth, and 80-dB agc range in one; 36-dB gain and 15-MHz response in the other, with a balanced mixer and a peak detector. For 0° to 70°C, the LM373 costs $4.73 ea., 1-24 pcs. See "Jack-of-all-trades: monolithic i-f is a universal sub-system," by Robert A. Hirschfeld, **THE ELECTRONIC ENGINEER,** Vol. 28, No. 6, June 1969, pp. 97-102, for complete details on the 373's operation and application. National Semiconductor Corp., 2950 San Ysidro Way, Santa Clara, Calif. 95051. (408) 245-4320.

Circle 284 on Inquiry Card

LOW-POWER MSI TTL CIRCUITS

Power requirements are one-tenth those of standard ICs.



The SN54L95/74L95 4-bit right-, left-shift register dissipates 19 mW; the SN54L93/74L93 4-bit binary counter, 16 mW. Speeds are twice those of other circuits with similar dissipation. In 100-pc. lots, unit prices of the 54L95/74L95 are $46.41/$29.40, flat-pack and DIL ceramic housings; $31.51/$14.62, DIL plastic packages. The 54L93/74L93 costs $36.18/$23.31 and $25.07/$13.30. Texas Instr. Inc., Components Gp., P.O. Box 5012, Dallas, Tex. 75222. (214) 238-3741.

Circle 285 on Inquiry Card

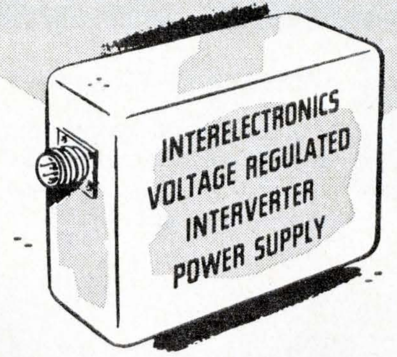
POWER REGULATORS

Can handle up to 20 W.

These "series-pass" linear regulators come in their maker's standard 0.5-in.^{3} module. The "R"-type dc/dc regulators are available for inputs from 10 to 150 V, corresponding to regulated outputs from 4 V, 4 A (max.) to 110 V, 10 mA. Short-circuit and overload protected, the devices also have zener-protected inputs. Ripple rejection, 40 dB; I/O differential as low as 1 V. $225 ea., 1-9; $170 ea., 100-up. Powercube Corp., 214 Calvary St., Waltham, Mass. 02154. Wescon Booth 4516.

Circle 286 on Inquiry Card

PROVEN RELIABILITY—
SOLID-STATE POWER INVERTERS,
over 260,000 logged operational hours—
voltage-regulated, frequency-controlled,
for missile, telemeter, ground support,
135°C all-silicon units available now—



Interelectronics all-silicon thyratron-like gating elements and cubic-grain toroidal magnetic components convert DC to any desired number of AC or DC outputs from 1 to 10,000 watts.

Ultra-reliable in operation (over 260,000 logged hours), no moving parts, unharmed by shorting output or reversing input polarity. High conversion efficiency (to 92%, including voltage regulation by Interelectronics patented reflex high-efficiency magnetic amplifier circuitry.)

Light weight (to 6 watts/oz.), compact (to 8 watts/cu. in.), low ripple (to 0.01 mv. p-p), excellent voltage regulation (to 0.1%), precise frequency control (to 0.2% with Interelectronics extreme environment magnetostrictive standards or to 0.0001% with fork or piezoelectric standards.)

Complies with MIL specs. for shock (100G 11 mlsc.), acceleration (100G 15 min.), vibration (100G 5 to 5,000 cps.), temperature (to 150 degrees C), RF noise (I-26600).

AC single and polyphase units supply sine waveform output (to 2% harmonics), will deliver up to ten times rated line current into a short circuit or actuate MIL type magnetic circuit breakers or fuses, will start gyros and motors with starting current surges up to ten times normal operating line current.

Now in use in major missiles, powering telemeter transmitters, radar beacons, electronic equipment. Single and polyphase units now power airborne and marine missile gyros, synchros, servos, magnetic amplifiers.

Interelectronics—first and most experienced in the solid-state power supply field produces its own all-silicon solid-state gating elements, all high flux density magnetic components, high temperature ultra-reliable film capacitors and components, has complete facilities and know how—has designed and delivered more working KVA than any other firm!

For complete engineering data, write Interelectronics today, or call 914 ELmwood 8-8000 in New York.

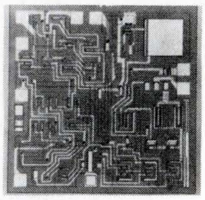
INTERELECTRONICS CORP.
600 U. S. Route 303, Congers, N. Y.

Circle 28 on Inquiry Card

EE NEW MICROWORLD PRODUCTS

HIGH-SPEED OP AMP

For high slew rate, wideband applications.

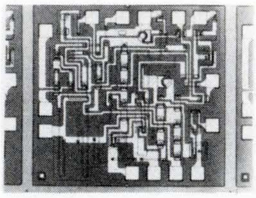


A 300-ns settling time and a unity gain, non-inverting slew rate of 20 V/μs give the μA715 an 800-μs acquisition time. It has a 30-ns risetime and operates from dc to 65 MHz; supply voltages can be ±6 to ±18 V. Openloop gain is 92 dB, input-voltage range, ±10 V, output swing, ±12 V. A TO-5, −55° to 125°C version costs $48 ea., 100-999 pcs., while the 0° to 70°C unit costs $15 ea., 100-999 pcs. Fairchild Semiconductor, 313 Fairchild Dr., Mountain View, Calif. 94040. (415) 962-3563.

Circle 287 on Inquiry Card

FLOATING VOLTAGE/CURRENT REGULATOR

Capable of kilovolt operation.

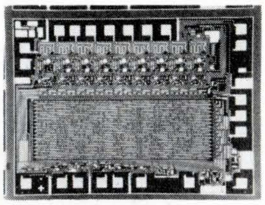


Designed to control an external power transistor, the MC1566L operates at any voltage or current level that the power transistor can handle. Features include: voltage and/or current adjust to zero; automatic crossover, constant-voltage to constant-current regulation; remote programming/sensing; 0.004%/°C TC. Regulation: 0.01% + 1 mV, line/load; 0.1% + 1 mA, current. $24.50, 100-up. Technical Info. Ctr., Motorola Semiconductor Prod. Inc., Box 20924, Phoenix, Ariz. 85036. (602) 273-6900.

Circle 288 on Inquiry Card

READ-ONLY MEMORY

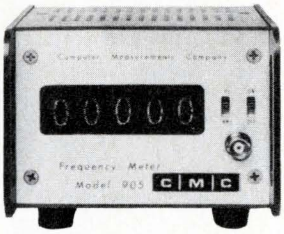
Organized as 256, 9-bit words; 2304 bits total.



The EA 3000 can drive bipolar loads directly. It has a 1-μs access time from −55° to 85°C, and is a low-power device: 90 mW at 1 MHz (MOS loads). Output control lines allow 512 x 4, or 256 x 4 and 256 x 5 expanded memory organization. The 24-lead device comes in a metal/ceramic, hermetic, dual in-line package. Delivery is six weeks after receipt of your bit pattern. In 100-pc. lots, the EA 3000 costs $76 ea. Electronic Arrays, Inc., 501 Ellis St., Mountain View, Calif. 94040. (415) 964-4321.

Circle 289 on Inquiry Card

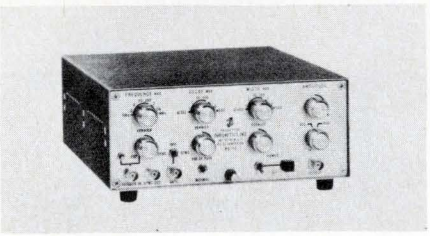
MINI FREQUENCY-METER



Model 905 is a 15-MHz counter which incorporates a 1-MHz crystal oscillator and a 5-digit readout. The unit comes in a 3½ x 5 x 7 in. package with tip-up stand for easy visibility in bench work. It sells for $395. Computer Measurements Co., 12970 Bradley Ave., San Fernando, Calif. 91342. Booths 1006-08.

Circle 290 on Inquiry Card

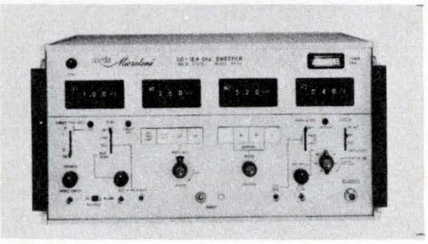
PULSE GENERATOR



Model PG-11 provides single (delayed) pulses, pairs, sync pulses, and manual single-shots at amplitudes to ±15 V, and with 4-ns rise-times. Repetition rates are variable from 10 Hz to 20 MHz; pulse widths from 30 ns to 10 ms; delay from 40 ns to 10 ms. Chronetics, Inc., 500 Nuber Ave., Mt. Vernon, N.Y. 10550. Booth 1419.

Circle 291 on Inquiry Card

BROADBAND SWEEPER



Model 9500 sweeps between, or any segment of, 1 to 12.4 Ghz in either direction without plug-in heads. Programmable output has 30-dB dynamic range for 0- to 2-V input. Frequency controls are digital thumbwheel readouts with 200-kHz resolution. Narda Microwave, Commercial St., Plainview, N.Y. 11803. Booths 2106-08.

Circle 292 on Inquiry Card

FET OP AMP

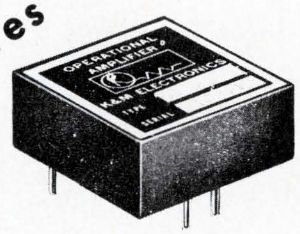
10 μV/°C

$16.00

SINGLE LOTS

10 Picoamperes

GAIN - 10^6



Model KM 45

INPUT IMPEDANCE: 10^{12} Ω
OUTPUT: ± 11 VOLTS @ 5 MILLIAMPERES
COMMON MODE REJECTION (CMR): 10,000
COMMON MODE VOLTAGE (CMV): ± 10 VOLTS MAX.
DIMENSIONS: 1.12" x 1.12" x 0.4"

AVAILABLE FROM STOCK

from K and their NATIONWIDE DISTRIBUTORS

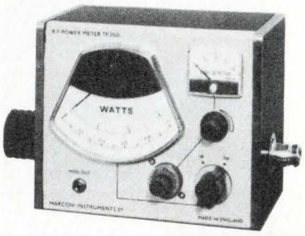
K and M ELECTRONICS Corp.

408 PAULDING AVENUE
NORTHVALE, NEW JERSEY 07647

(201) 768-8070

Circle 46 on Inquiry Card

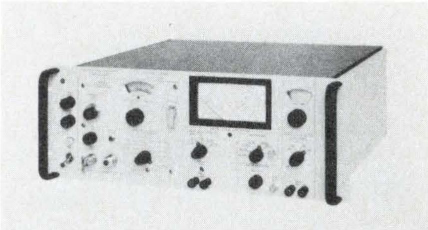
RF POWER METER



Models 2501, -02, and -03 (1-100 W) use both thermocouple and diode methods to measure true rms power for any wave form. Thin-film techniques in load network give a 1.1 VSWR from dc to 1GHz. Load itself operates to 5 GHz. Marconi Instruments, 111 Cedar La., Englewood, N.J. 07631. Booths 1824-26.

Circle 293 on Inquiry Card

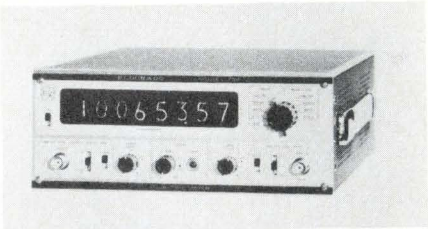
SIGNAL GENERATOR



Model 6301 with 63081 rf plug-in covers 220 to 410 MHz. Stability is 10 ppm/10 min. after 30 min. Modulation: a-m to 80%, fm to ±100 kHz, or phase. RF output to +19 dBm. For testing communications and telemetry receivers, antennas, etc. Wilton Co., 930 E. Meadow Dr., Palo Alto, Calif. 94303. Booths 1138-39.

Circle 294 on Inquiry Card

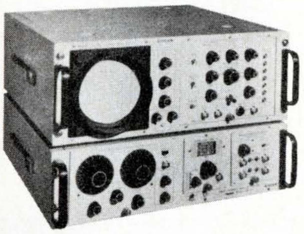
INTERVAL COUNTER



Model 784 measures time between events, duration of input cycle, pulse width, and pulse risetime (input resolution 10 ns, 0.1 to 999999.99 μs range). Unit accuracy is ±1 count ± time base accuracy ± trigger error. Eldorado Electrodata Corp., 601 Chalomar Rd., Concord, Calif. 94520. Booths 1722-23.

Circle 295 on Inquiry Card

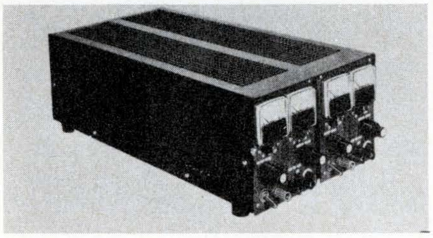
SPECTRUM ANALYZER



Model SSB-50-1 has a frequency range of 10 Hz to 40 MHz, usable to 200 MHz, and a 70-dB distortion-free dynamic range. Sweep width, 0-100 kHz, adj.; sensitivity, 5 μV; resolution, 10 Hz. Two-tone IM test. Markers. $6810. Singer Co., Instr. Div., 915 Pembroke St., Bridgeport, Conn. 06608. Booth 2015.

Circle 296 on Inquiry Card

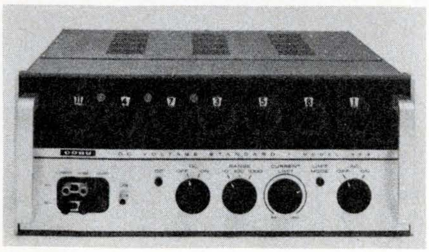
MINI DC POWER SUPPLY



PVC-100 has a 100-W output, rated from 0 to 10, 20, and 50 V and 8-, 4-, and 2-A output, respectively. Unit has remote sensing, and remote current/voltage programming by resistance and voltage source. Designed as an instrument-type power supply. NJE Corp., 20 Boright Ave., Kenilworth, N.J. 07033. Booths 1332-33.

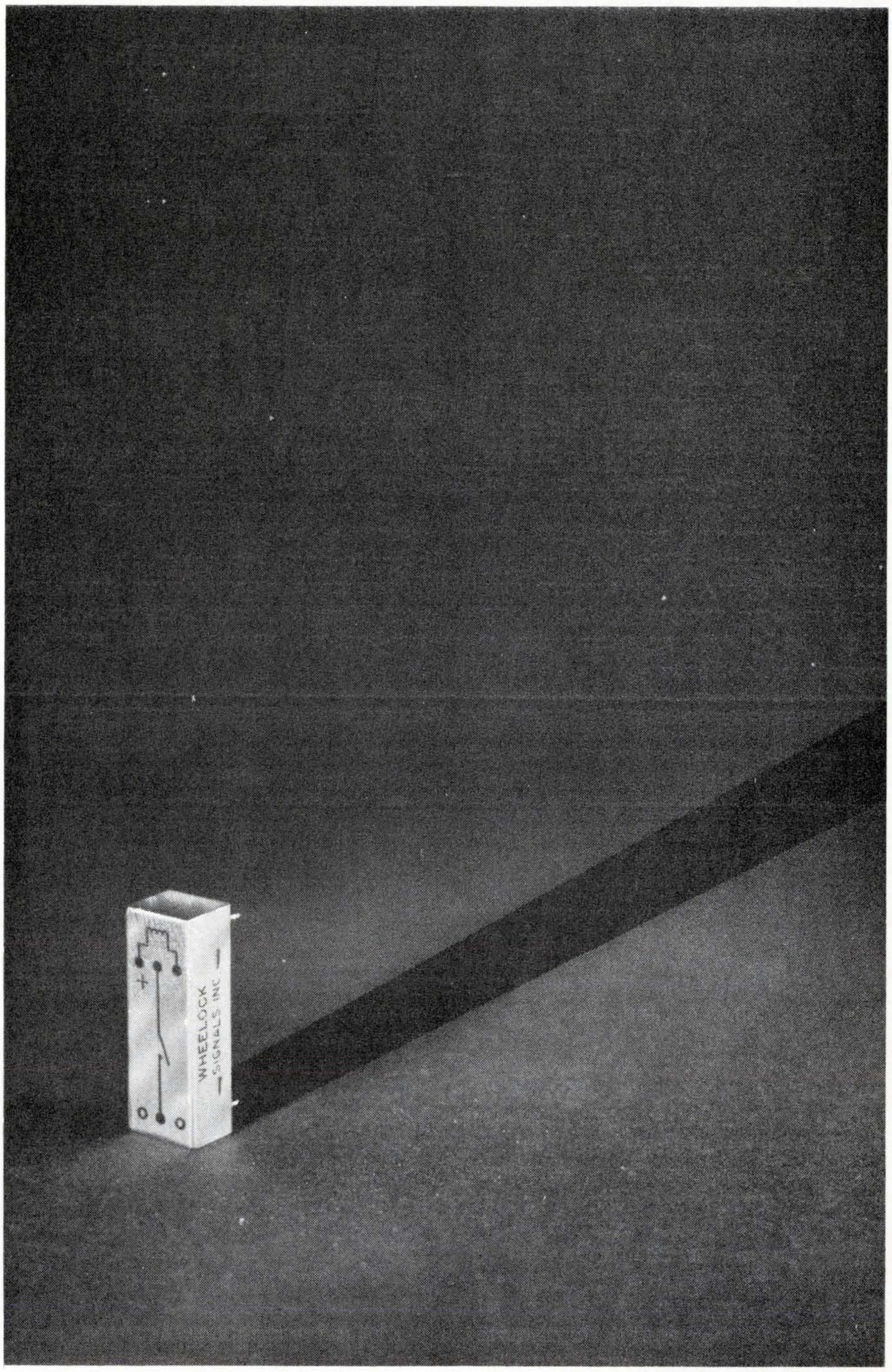
Circle 297 on Inquiry Card

DC VOLTAGE STANDARD

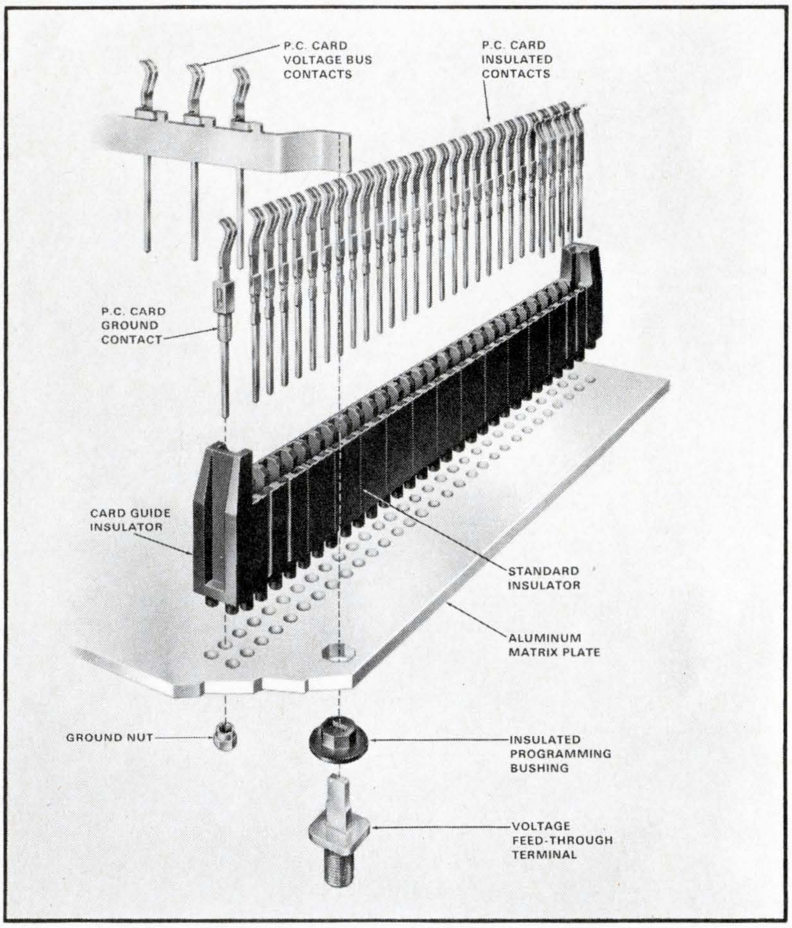


Model 353 is accurate to within 0.002% for 6 months, including stability variations. Less than 15 μV rms noise on the 10-V range. Output current to 50 mA at any 7-place voltage setting in the three decades from zero to 1.2 kV. $2400. Cohu Electronics, Inc., Box 23, San Diego, Calif. 92112. Booth 2001.

Circle 298 on Inquiry Card



CARDEC® 125



CARDEC 125, the exciting new card edge plate connector system, is tailored to fulfill your individual requirements. It provides maximum packaging density with instantaneous reaction to ground and power distribution, without wiring, for low noise high speed circuits. In one complete package, compatible with IC's, LSI's or any other type circuit, CARDEC 125 offers all the built-in extras you need, plus the advantages of modular component design for inexpensive and flexible replacement capability. Standard features include a base plate coupled with Malco's unique screw-in ground which provides nearly perfect "ground" or zero voltage, the availability of card-to-card voltage bussing with Malco in-line buss contact strips, power distribution, stiffener bars and card guides to insure ease of module changing and exact card alignment. Of course, the system is designed for automatic wire wrapping without any extra "in house" costs.

CARDEC 125 is completely adaptable to your needs with its modular connector system which fits your card regardless of the number of card contacts, whether single or dual readout. With flexible ground and bussing pin positions, card slots on .250", .500" or any multiple of .125" centers, the aluminum base plate/ground plane is available in any size or shape up to 24" by 24"

Don't miss the opportunity to reduce your total packaging cost with this amazingly economical system—let us fill you in with the details, specifications and costs. Write or call for further information.

MALCO®

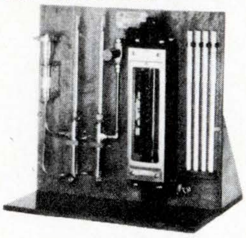
PRECISION ELECTRONIC TERMINALS AND CONNECTORS

MALCO MANUFACTURING COMPANY INC
5150 W. ROOSEVELT RD. · CHICAGO, ILLINOIS 60650 · PHONE (312) 287-6700

Circle 49 on Inquiry Card

EE WESCON PRODUCTS

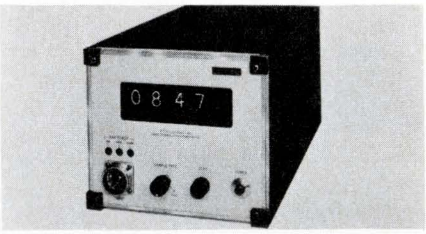
RF CALORIMETER



Model 6070 measures power in 50-Ω coaxial systems to 5 kW with 3% accuracy. Self-checking at dc or 60 Hz, it eliminates half the uncertainties to give 1½% accuracy. The VSWR is 1.1 max. to 1 GHz, 1.2 max. to 2 GHz. $1275. Bird Electronic Corp., 30303 Aurora Rd., Cleveland (Solon), Ohio 44139. Booths 1733-34.

Circle 299 on Inquiry Card

DIGITAL POWER METER



D6685 gives 4-digit, auto-ranging readout of cw, pulse, a-m, or fm signals; use with Series 685 calorimeters. Ranges, 30 nW-100 mW (cw), momentarily to 300 mW. Meter, ±0.5% of reading ±1 count; sensor, 1 to 2%. From $1350. PRD Electronics, 1200 Prospect Ave., Westbury, N.J. 11590. Booths 1714-15.

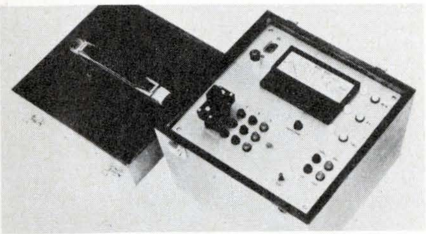
Circle 300 on Inquiry Card

DIGITAL MULTIMETER

Type 340 is compact, self-contained, uses one probe for all measurements. Ranges are 1 to 1000 V f.s. (ac/dc); 1 kΩ to 10 MΩ; 100 μA to 1 A (ac/dc); all 100% overrange. Overvoltage-protected to x100 overrange. Response time, 20 ms. $345. Digilin, Inc., 6533 San Fernando Rd., Glendale, Calif. 91201. Booth 1014.

Circle 301 on Inquiry Card

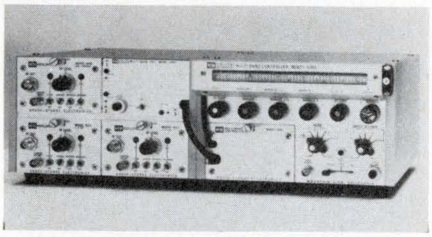
TRANSISTOR TESTER



Model 800 finds and indicates base, emitter, and collector leads, performs seven basic tests in less than 1 s. Shows go/no-go results, dc beta, breakdown voltage, and leakage. Determines npn/pnp and Si/Ge construction. $495. Miracle-Hill Electronics, Inc., 320 Martin Ave., Santa Clara, Calif. 95050. Booth 1608.

Circle 302 on Inquiry Card

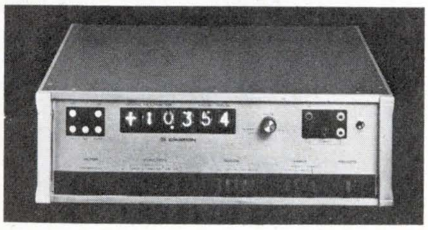
POWER UNIT AND CONTROL



Models 5090 and 5091 simplify multiband programmed, cw, or sweep testing when used with the Model 5000 sweeper and plug-ins (10 MHz to 12 GHz). The 5090 is a wideband source; the 5091 connects sweeper with 5090s. Kruse-Storke Electronics, 790 Hemmeter La., Mountain View, Calif. 94040. Booth 1023.

Circle 303 on Inquiry Card

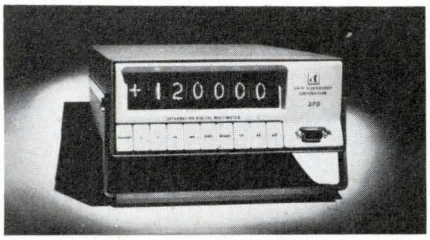
DIGITAL MULTIMETER



The 6653A is a 4½-digit DMM with ±1-digit accuracy, 0-1099.9 V; 10% overrange. Measures dc and dc/dc ratio. Plug-in options: ac, ohms, mV, and sample-and-hold. Print-out options. Digitize at 1000 readings/s. $1740. Cimron Div., Lear Siegler, Inc., 1152 Morena Blvd., San Diego, Calif. 92110. Booths 716-718.

Circle 304 on Inquiry Card

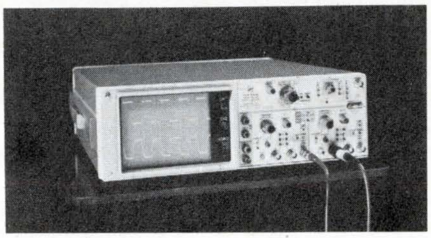
FIVE-DIGIT DMM



The Model 370 is a five-range (±0.1-1000 V f.s.) dc instrument with 0.0025% accuracy. Plug-in modules measure ac volts (to 100 kHz), ohms (to 1-MΩ resolution) and ratio (0.9999:1). Unit has 20% overrange (except 1000 V). Data Technology Corp., 1050 E. Meadow Circle, Palo Alto, Calif. 94303. Booth 1827.

Circle 305 on Inquiry Card

DUAL-BEAM OSCILLOSCOPE



Type 5030 has a 10 μV/div. sensitivity, differential inputs for each beam, current-probe inputs for each beam with deflection factors of 1 mA to 200ma/div., and a constant, 1-MHz response. Scale factors appear via fiber optics. $1850. Textronix, Inc., Box 500, Beaverton, Ore. 97005. Booths 2101-04, 2129-32.

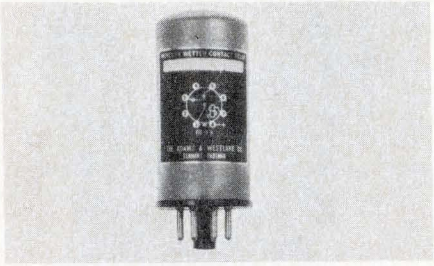
Circle 306 on Inquiry Card

FM SIGNAL GENERATOR

Model 1522 is for L- and S-band telemetry. Stability, better than ±15 kHz for 1 hr; accuracy, ±0.002%, calibrated after 30 min. Peak fm deviation to ±3 MHz; fm response to 2 MHz (+2, −3 dB); output, 0 to −120 dBm. Kay Electric, 12 Maple Ave., Pine Brook, N.J. 07058. Booths 1613-14.

Circle 307 on Inquiry Card

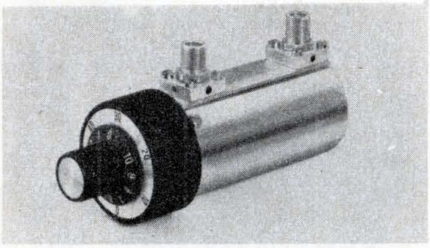
FORM K MERCURY RELAY



A contact, Form K, center off, mercury wetted contact relay is available in plug-in or PC board style with either single or dual wound coils. A magnetic circuit principle developed by the manufacturer permits the use of the highly reliable mercury wetted contact capsule in a relay of this type. The Adams & Westlake Co., 1025 N. Michigan St., Elkhart, Ind. 46514. Booth 4708.

Circle 210 on Inquiry Card

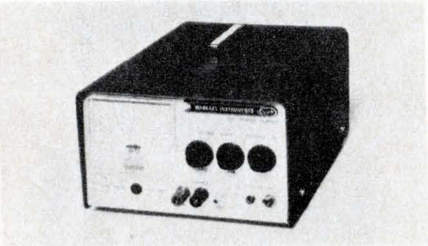
PRECISION ATTENUATOR



Model LA-54 gives 0-60 dB attenuation in increments of 1 dB. It is for use in the dc to 500 MHz band. It has an accuracy of ±0.2 dB from dc to 30 MHz; ± 0.3 dB from dc to 250 MHz; and ±0.5 dB from dc to 500 MHz. Texscan Corp., 2446 N. Shadeland Ave., Indianapolis, Ind. 46219. Booths 1314-15-16.

Circle 211 on Inquiry Card

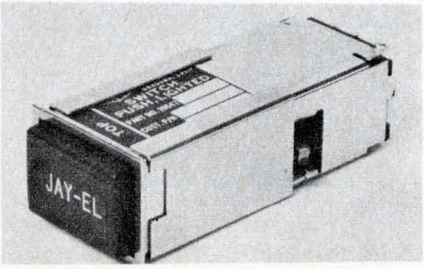
DC POWER SUPPLY



This supply uses the company's Paraformer to provide ¼% reg. to the basic dc unit. Input can drop as low as 60 Vac and go as high as 150 Vac without affecting performance of the dc output. There is 80 dB of noise attentuation and normal mode rejection to 1 MHz. Wanlass Instruments, 1540 E. Edinger Ave., Santa Ana, Calif. 92707.

Circle 212 on Inquiry Card

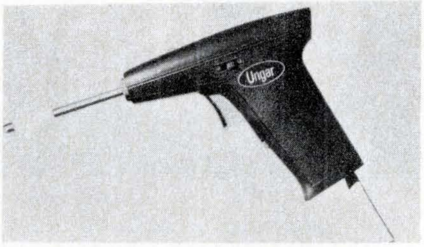
ILLUMINATED SWITCH



Mark Nine rectangular switch (P/N 10647) has 1 in. mounting centers horiz. or ¾ in. mounting centers vert. It is an environmentally sealed double make double break switch package. It has rhodium plated switch contacts for low level, high env. long life switching in the 1 mA 2 Vdc range. Jay-El Products Inc., 1859 W. 169 St., Gardena, Calif. 90247. Booth 4515.

Circle 213 on Inquiry Card

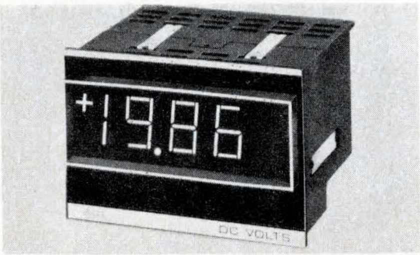
SS SOLDER GUN



Transformerless gun, with a high/low temp selector switch, weighs only 5 oz exclusive of its three-wire cord set. It assures damage-free soldering of ICs and FETs by electrically isolating the soldering tip from the heating element. Ungar, Div. of Eldon Industries, Inc., 233 E. Manville, Compton, Calif. 90220. Booths 2902-03.

Circle 214 on Inquiry Card

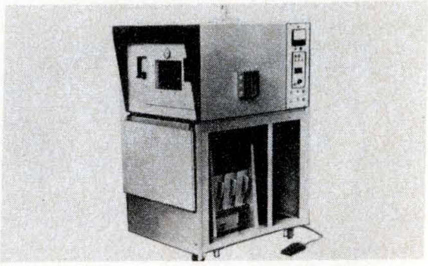
DIGITAL PANEL METER



Model 4304, with four digits for a display to 1999, features small size and large up-front display. A to D conversion is done by dual slope integration. Display can be read from 40 ft at angles to 140° without parallax or tunnel effects. Accuracy is 0.1% and res. 1 part in 4000. API Instruments Co., Chesterland, Ohio 44026. Booths 1404-05.

Circle 215 on Inquiry Card

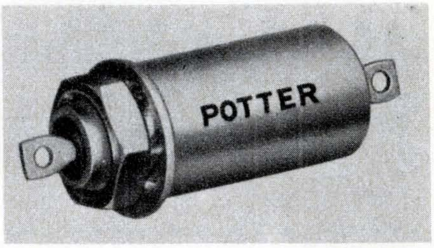
IC HANDLING SYSTEM



Supercharger-72 is a mechanized system for continuous testing of ICs in a precisely controlled temp environment (±¼°C). It handles a combination of TO-5, flatpack, or DIP devices in temps from −65°C to +150°C. Seventy-two units, in carriers, are stored in the environment. Delta Design, 8000 Fletcher Pkwy., La Mesa, Calif. 92041. Booths 1327-28.

Circle 216 on Inquiry Card

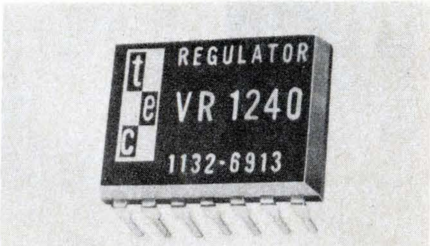
EMI FILTER



Micro-Brute Series 8330 subminiature EMI suppression filters can be developed to fulfill the requirements of any EMI situation where size and weight must be held to a minimum. They are good for low voltage ac or dc application. The Potter Co., 500 W. Florence Ave., Inglewood, Calif. 90301. Booth 5112.

Circle 217 on Inquiry Card

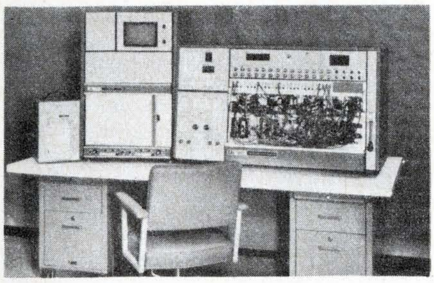
VOLTAGE REGULATOR



VR Series hybrid line includes 20 new products with fixed output voltages from +5.0 to +36 V and −15 to −36 V. All units are capable of 500 mA output current with a volt. reg of 0.01%. Attenuation of noise and ripple is typ. 10,000:1 (80 dB). Transformer Electronics Co., Box 910, Boulder Ind. Park, Boulder, Colo. 80302. Booths 3601-2.

Circle 218 on Inquiry Card

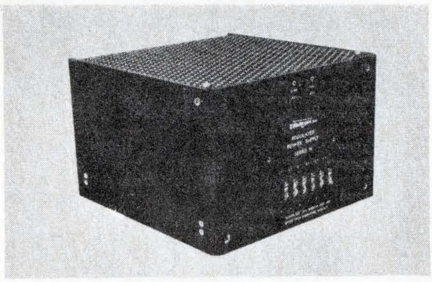
ANALOG/HYBRID COMPUTER



The EAI 380 is a compact, lightweight system which can be expanded from 10 to 50 amplifiers. Basic configuration includes electronic mode control, two-mode timer, over-range hold/store capabilities and easy-to-use manual, diode function gnerators. EAI Electronic Associates, Inc., West Long Branch, N. J. 07764. Booth 5522.

Circle 222 on Inquiry Card

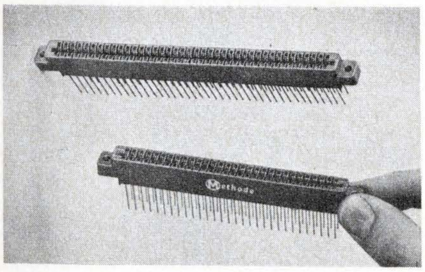
POWER MODULES



"N" Series modules with IC regulation system provide an effective system for minimizing load and line induced thermal drift. It has 0.005% reg., adj. current limiting, convection cooling to 71°C and electrostatically shielded transformers. Deltron Inc., Wissahickon Ave., North Wales, Pa. 19454. Booth 1508.

Circle 223 on Inquiry Card

PC BOARD CONNECTORS



These connectors have 0.025 in.^{2} contact terminations. Designed for both hand and automatic solderless wrap, they are available in a 60 contact dual readout, Part 186-249 and an 80 contact dual readout configuration, Part 186-256. Methode Electronics, Inc., Connector Div., 7447 W. Wilson Ave., Chicago, Ill. 60665.

Circle 224 on Inquiry Card

ABRASIVE MACHINE

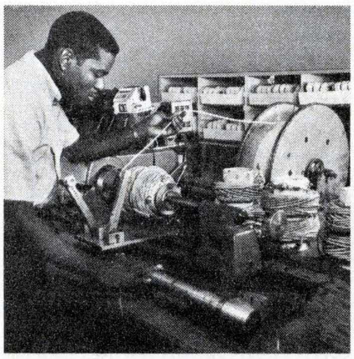
Micro-Blaster, a miniature abrasive-blasting machine uses compressed gas as the abrasive propellant. It can be used for thick-film resistor-trimming, stripping varnish from leads and windings, scribing, drilling and cutting crystals such as germanium, silicon, ceramics, and glass. Comco Supply, Inc., 1222 W. Olive Ave., Burbank, Calif. Booth 3023.

Circle 225 on Inquiry Card

LIGHTED PUSHBUTTONS

Series 2W pushbuttons are available in operator/indicator or indicator-only units. Modular in construction, they comes in two- and four-pole setups. They feature projected light, single, and two- and three-split screens, and are relampable from the front without tools. Micro Switch, div. of Honeywell Inc., Freeport, Ill. 61032. Booths 3915-16.

Circle 226 on Inquiry Card



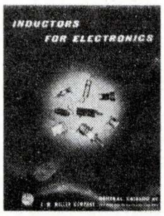
Heavy Duty Filter Chokes *In Stock*

Custom Filter Chokes *In 10 Days*

Series 7830 heavy duty line filter chokes provide up to 250 uh, carry up to 75 amps; widely used for RFI filters and reducing transient surge peaks; available from L.A. shelf stock; see Catalog 69.

Special RF chokes and coils designed to meet your requirements are shipped within 10 days to 2 weeks; production quantities start within 3 to 4 weeks after sample approval.

Intensive specialization in coil design and manufacture assures excellent operating results with a high degree of reliability. Engineering assistance helps achieve optimum performance.



Write for your copy of Catalog 70 containing specifications and prices for the complete line of J. W. Miller Co. RF chokes, RF and IF coils, transformers, filters, coil forms and components.

Call a Miller coil design specialist for your special coil requirements — (213) 537-5200.

MILLER QUALITY PRODUCTS

J. W. MILLER COMPANY

19070 REYES AVE. • P.O. BOX 5825 • COMPTON, CALIF. 90224

See your local distributor for the full line of standard coils and chokes

Circle 53 on Inquiry Card

Electrical/Electronic
Engineers
Design/Analysis/Test

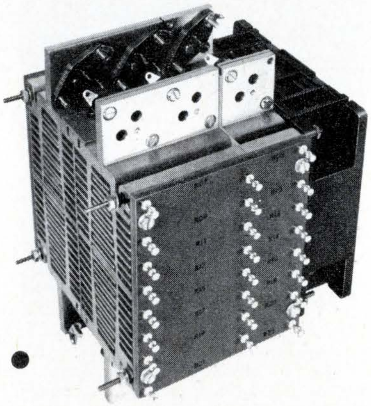
LOCKHEED
MISSILES & SPACE COMPANY
A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

BSEE, plus appropriate experience in any of the following areas:

Communications – RF
Computer Software
Sensors
Antennas
Circuits/Systems
Test
Electro-optics
Microwaves
Power Systems
Instrumentation
Guidance & Controls

For complete information, write Mr. H.W. Bissell, Professional Employment Manager, P.O. Box 504, Sunnyvale, California 94088. An equal opportunity employer.

Circle 51 on Inquiry Card (Please Use Home Address on the Card)



Have Dovetails, Will Cool...

• **with greater efficiency!*** • **in less space!**

FOR EXAMPLE — Astrodyne forced air units can cool 20 diodes each dissipating 100 watts and limit temperature rise above ambient to 74°C. Total length of package, including fan, is less than 10" versus 12" to 15" required with conventional heat sinks.

Up to 50% more fin area on Astrodyne dovetailed modular forced air assemblies *reduces thermal resistance of each module by over 35% with same air flow.*

*Based on published technical data

FLEXIBILITY permits easy design of custom packages using side panels as terminal boards or for component mounting.

ACCESSIBILITY of mounted components is excellent and quadrants may be turned 90° to increase accessibility of shelves where space permits.

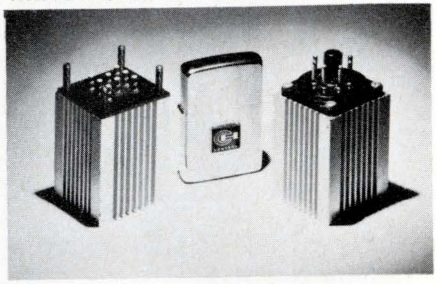
WE'RE READY to help reduce the size of your cooling unit and increase its efficiency in a package which will precisely meet your specifications. Please call: (617) 272-3850

astrodyne, inc.
SUBSIDIARY OF ROANWELL CORP.
207 CAMBRIDGE ST., BURLINGTON, MASS. (617) 272-3850

Circle 52 on Inquiry Card

EE WESCON PRODUCTS

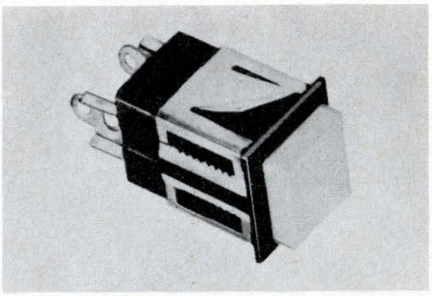
MINIATURE SS RELAYS



These SS relays (SX3 series) have an electrical life of 100 million operations. Their amb. range is from −40°C to +100°C, with a max op time of 1 ms. They are rated 2.5 A 3PST, 4 A DPST, and 8 A SPST normally open. Specialty Products Div. Cutler-Hammer, Inc., 4201 N. 27 St., Milwaukee, Wis. 53216. Booths 1110-12.

Circle 219 on Inquiry Card

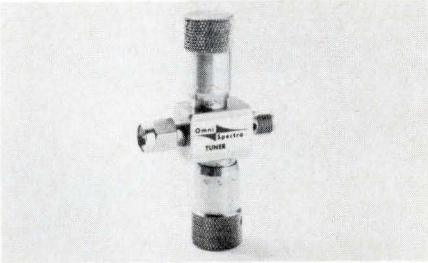
PUSHBUTTONS



"Uniswitch" a compact, momentary action pushbutton switch, is now offered with pushbuttons in red, white, blue, green, and yellow. It comes in both illuminated and nonilluminated types. Both snap in mounting holes from the front of the panel. Switchcraft, Inc., 5555 N. Elston Ave., Chicago, Ill. 60630. Booths 3909-10.

Circle 220 on Inquiry Card

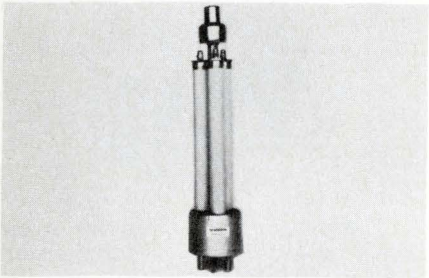
COAXIAL TUNER



Model 203670 10 GHz to 18 GHz tuner matches out reflections from connectors, adapters, coaxial terminations and measuring instruments. The match is relatively freq insensitive. Characteristic imp is 50Ω nominal. Omni Spectra, Inc., 24600 Hollwood Ct., Farmington, Mich. 48024. Booths 5418-20.

Circle 221 on Inquiry Card

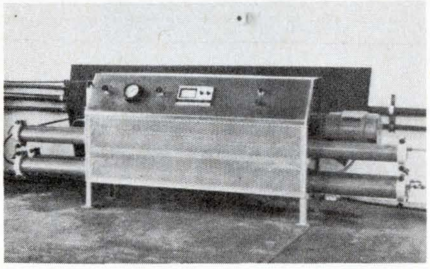
SS RECTIFIER STACK



HSK 869B is a SS direct replacement for the #869B H-V rect. tube. With it, filament heating, balancing network, and protection against voltage and current surges are not needed. It features controlled avalanche characteristics over the entire op temp range. Semikron International, Inc., Box 323, Scarsdale, N.Y. 10583. Booth 4915.

Circle 275 on Inquiry Card

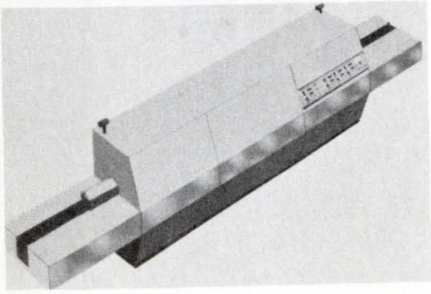
PURE WATER SYSTEM



Model M1530 processes 6500 gal./day. Reverse osmosis systems (with deionization polishing) provide ultra high purity water for the semicontor industry. Other uses include microwave, PC board, memory core, and vacuum tube manufacture. Polymetrics, 810 Cherry Lane, San Carlos, Calif. 94070. Booth 3106.

Circle 276 on Inquiry Card

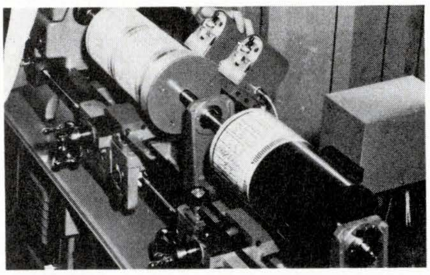
LIDDING FURNACE



New continuous-belt furnace has two gas barriers, one each at the entrance and exit ends, which permits you to maintain a very dry atmosphere inside the muffle, a prerequisite for successful soldering with low temp. solder. BTU Engineering Corp., Bear Hill, Waltham, Mass. 02154. Booths 2301, 2401-02.

Circle 277 on Inquiry Card

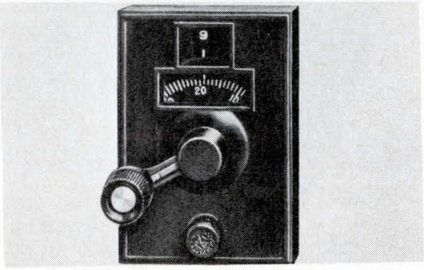
ENGRAVING MACHINE



Gemini machine lets you make PC boards electronically. One person can operate as many as ten machines because they are automatic even to shutting off their own switches upon completion of the work. This electronic device eliminates the need for camera, film, darkroom or chemicals. Graphic Electronics Inc., La Salle, Ill. 61301.

Circle 278 on Inquiry Card

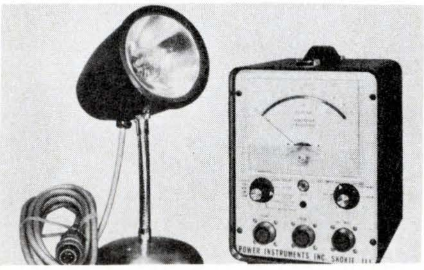
COUNTER DIAL



The #10031 is a sturdy instrument type dial with two digits and vernier readout. The control shaft has a 1 to 1 ratio. Counter is direct reading to 99 revolutions, while the vernier scale permits readings to one part in 100 of a single revolution. James Millen Mfg. Co., Inc., 150 Exchange St., Malden, Mass. 02148. Booth 4204.

Circle 279 on Inquiry Card

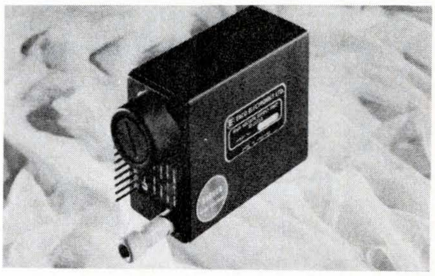
STROBOSCOPE-TACHOMETER



New SS Model 932 is for industrial inspection work where machine speeds exceed the rate the eye can follow. Large speed readout meter; four scales — 0-1000, 3000, 10,000 and 30,000 rpm. High sensitivity input (200 mV pk-pk). Power Instruments, Inc., 7532 N. Lawndale Ave., Skokie, Ill. 60076.

Circle 280 on Inquiry Card

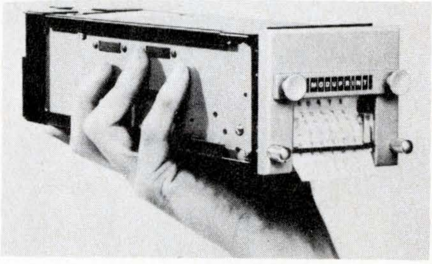
HV MODULES



These modules provide high voltages for crt displays including storage tube and projection systems. Units are available with outputs from 1 kV to 30 kV. They are resin encapsulated which gives rugged construction and prevents voltage breakdown. Units can tolerate brief overloads and flashovers. Ekco Electronics Ltd., Southend-on-Sea, Essex, England. Booths 4614-15.

Circle 281 on Inquiry Card

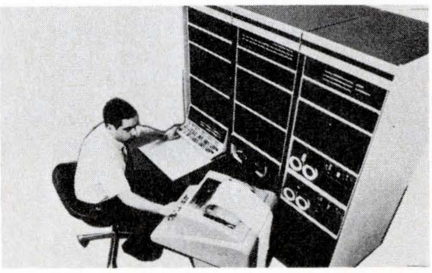
DATA PRINTER



Miniature unit prints 6 col of data, 10 or 12 char/col at up to 3½ lines/s asynchronously, on 2½ in. wide fanfold paper. Interface board, in TTL logic, is mounted inside the printer. Instrument will accept BCD, Excess 3 or Excess 3 gray codes as std. Presin Co., Inc., Trap Falls Rd., Shelton, Conn. 05484. Booth 1141.

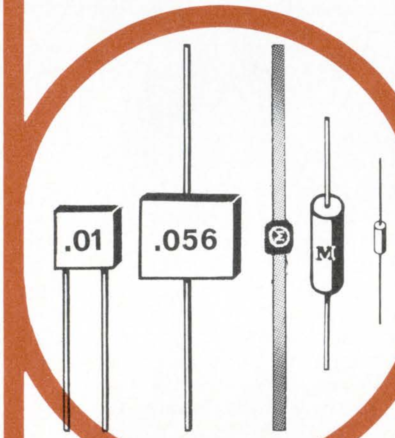
Circle 282 on Inquiry Card

MEDIUM SCALE COMPUTER



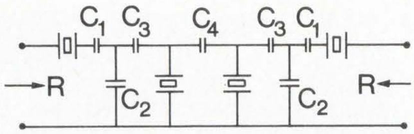
Medium scale PDP-15/20 is one of four configurations in which the 18-bit computer is being offered. Some features included are 8,192 words of core memory; a KSR35 teletype; two mag tape units; a high speed paper tape reader and punch; and advanced monitor software. Digital Equipment Corp., Maynard, Mass. 01754. Booths 5620, 21, 22, 23.

Circle 283 on Inquiry Card



EE WESCON PRODUCTS

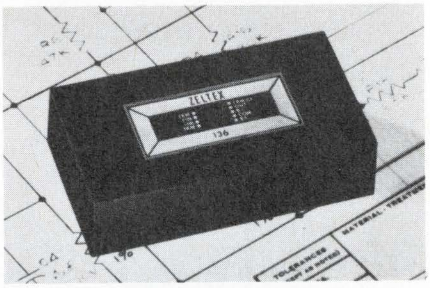
FILTERS



With this method you can build your own 455 kHz filters simply and cheaply. Heart of the concept is a std. Identical Resonator (IR). You merely use two or more of these and std. capacitors to build filters of any complexity. Clevite Corp., Piezoelectric Div.. 232 Forbes Rd.. Bedford, Ohio 44060. Booths 4522-23.

Circle 227 on Inquiry Card

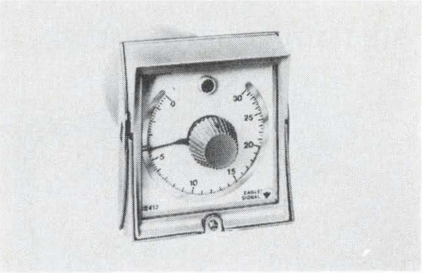
FET-INPUT OP AMP



Model 136 features short-proof circuitry, −6 dB/octave freq compensation, and a CMRR of 100 dB (min) guaranteed over a common-mode range of ±100 V min. Initial offset voltage is only 0.5 mV without ext components. Offset can be zeroed with an ext trim pot. Zeltex, Inc., 1000 Chalomar Rd., Concord, Calif. 94520. Booths 1443-1444.

Circle 228 on Inquiry Card

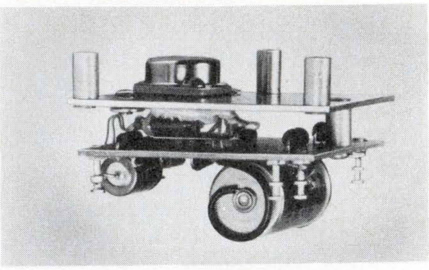
SOLID STATE TIMERS



Precision CE400 timers have a settability of ±1.0% (full scale) and repeatability of ¼ of 1% (FS) in ranges from 0 to 1.5 up to 0 - 600 s. It provides precise, adj. time delays between actuation of control circuits and operation of load circuits. Eagle Signal Div., Gulf & Western Co., 736 Federal St., Davenport, Iowa 52803. Booths 5207-08.

Circle 229 on Inquiry Card

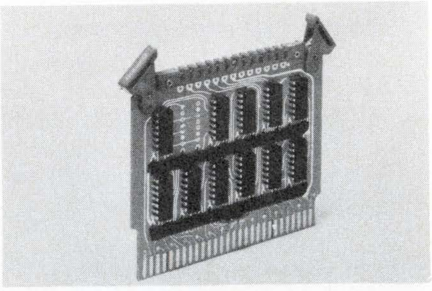
SPOT REGULATORS



Compact dc assemblies will accept either ac or dc input. Spot regulators may be used to provide low cost isolation within a system or as a precision voltage source. SR type has a ±1% line reg., while the SRA's is typically 0.01% or 1 mV. Spar Electronics, Inc., 7969 Engineer Rd., San Diego, Calif. 92111.

Circle 230 on Inquiry Card

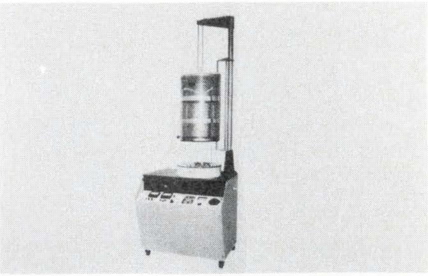
LOGIC CARDS



High Noise Environment Logic (HNEL) cards are for industrial uses requiring high inherent electrical noise immunity. Initial 15 cards of D-4400 series cover almost all system designs. They are mechanically compatible with current EECoLogIC 2 cards. Electronic Engineering Co. of Calif., 1441 E. Chestnut Ave., Santa Ana, Calif. Booths 3814-17.

Circle 231 on Inquiry Card

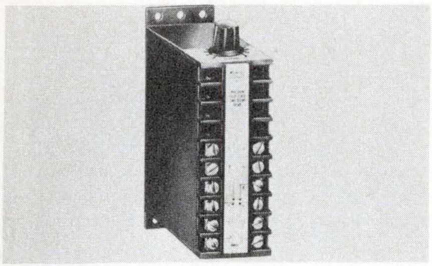
HIGH VACUUM EVAPORATOR



VE-770 thin film evaporator pumps down to $< 3 \times 10^{-7}$ torr in 15 min and $< 1.5 \times 10^{-7}$ torr in 1 hr. (with 18 x 30 in. bell jar). It has a high speed (2000 liter/s) 7¾ in. diffusion pump, and an integrally housed liquid nitrogen trap and water baffle. Veeco Instruments Inc., Terminal Dr., Plainview, L.I., N.Y. 11803. Booths 3010-12.

Circle 232 on Inquiry Card

TIME DELAY RELAY



Class 212M relay uses precise components for close tol. operation with 1% repeatability typical. It uses hybrid circuitry, combining SS circuitry for timing function with an electromechanical relay for 10 A output switching. It is adj. to 500 s. Magnecraft® Electric Co., 5575 N. Lynch Ave., Chicago, Ill. 60630.

Circle 233 on Inquiry Card

SI WAFERING EQUIPMENT

Model 700 "Sea-Saw" is for wafering and dicing Si and similar hard, firable materials. It dices crystals to 3 in. in dia. Wafers as thin as 0.0055 in. can be sliced with an 0.004 in. dia. wire, resulting in a total 0.0055 in. kerf loss. Geoscience Instruments Corp., 435 E. Third Ave., Mt. Vernon, N.Y. 10553. Booth 3123.

Circle 234 on Inquiry Card

ULTRASONIC CLEANER

This ultrasonic cleaner (Ultra-Clean 320D-2) features two 1¼ qt transducerized tanks capable of simultaneous ultrasonic cavitation. This doubles cleaning capacity and cuts cleaning time. Each tank may also be run separately. L & R Mfg. Co., 577 Elm St., Kearny, N.J. 07032. Booths 3304-3305.

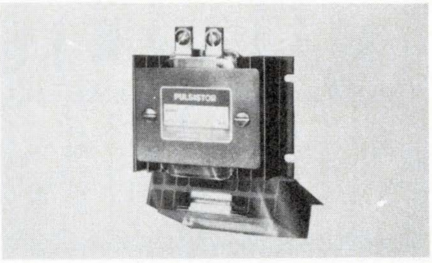
Circle 235 on Inquiry Card

CLOTH TAPE

Mystik 7700 is an acetate cloth tape that is electrically stable under high humidity and temps to 250°F. It can be used as coil wrap, for tabbing leads and for splicing. Total thickness is 8 mils; die. strength 2600 V and tensile rating 50 lbs/in. Mystik Tape, Borden Inc., 1700 Winnetka Ave., Northfield, Ill. 60093. Booths 2611-12.

Circle 236 on Inquiry Card

SS SURGE PROTECTOR



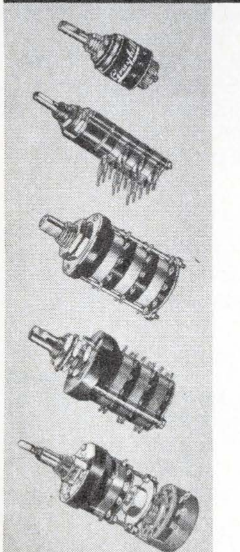
The Pulsistor, a surge protector designed to limit high wattage loads can lengthen the life of high inrush devices with steady-state dissipations up to 4 kW. It has a special thermistor integrally designed with an electronic heat sink. Victory Engineering Corp., Victory Rd., Springfield, N.J. 07081. Booth 4525.

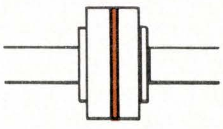
Circle 237 on Inquiry Card

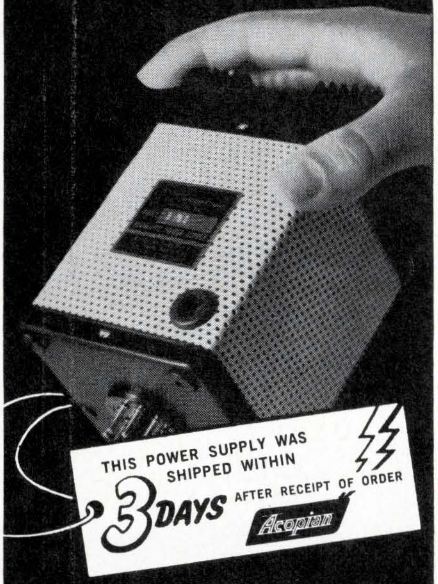
DIGITAL READOUT

Midgi-Lite Bi-Filament, Model M645 digital readout has a displayed character that is formed by an incandescent tungsten filament or light bar. Voltage controllable over a wide range of brightness, it has a 100,000 hr filament life. Pinlites Inc., 1275 Bloomfield Ave., Fairfield, N.J. 07007. Booths 4814-15.

Circle 238 on Inquiry Card

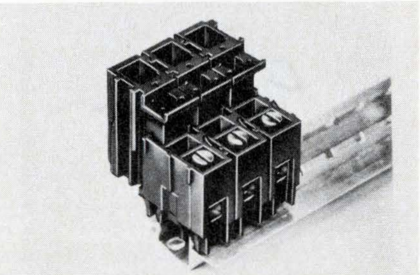






EE WESCON PRODUCTS

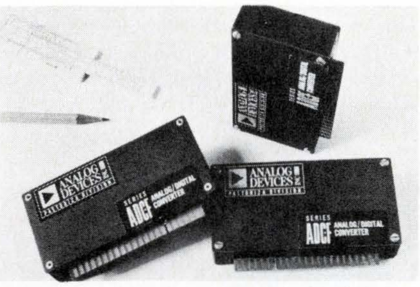
TERMINAL BLOCKS



Modular "Vice-lock" blocks are for installing either stranded or solid wire without terminals. They have a stainless steel split collar and pressure saddle and are vibration resistant yet expand and contract with no changes in the diameter of the conductors. The Thomas & Betts Co., 36 Butler St., Elizabeth, N.J. 07207. Booths 3817-18.

Circle 239 on Inquiry Card

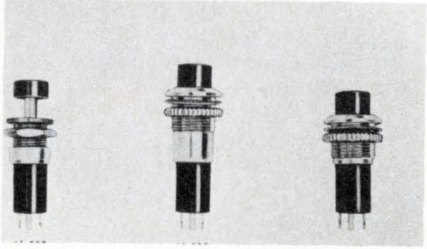
A/D CONVERTER



Model ADC-F combines successive approximation methods and single card modularity to achieve complete 10-bit conversions within 1 μs. It needs only 100 ns for each level or bit of comparison. Differential linearity is within ±½ LSB, and relative accuracy is 0.05% for 10 bit unit, 0.2% for an 8 bit version. Analog Devices, Inc., Pastoriza Div., 221 Fifth St., Cambridge, Mass. 02142. Booths 1706-7.

Circle 240 on Inquiry Card

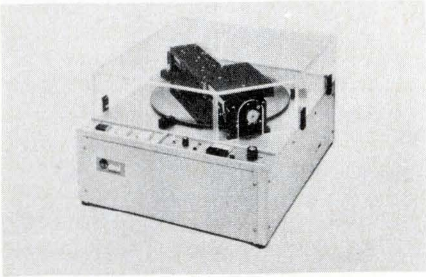
PUSHBUTTON SWITCHES



These Series 46 alternate action push-on, push-off switches have SPDT circuitry. Alternate action mechanism will lock down or release from the down position for more than 250,000 cycles of operation. Grayhill, Inc., 561 Hillgrove Ave., LaGrange, Ill. 60525. Booths 3922-23.

Circle 241 on Inquiry Card

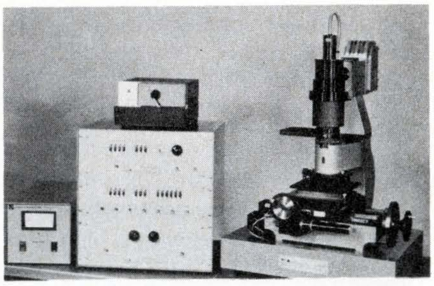
DISC RECORDER



IDR 100 instrumentation recorder uses a 12 in. disc rotating at 1800 rpm to record analog signals from 400 Hz to 2 MHz. Primarily for recording and analyzing transient signals, it has a spiral 0.004 in. track with 0.001 in. guardband and 20 s of cont. record/playback. Data Memory, Inc., 1255 Terra Bella Ave., Mt. View, Calif. 94040. Booths 5306-07.

Circle 242 on Inquiry Card

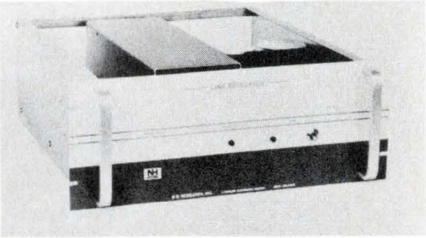
PHOTOREPEATER



Instrument produces a photomask for a 250 mil chip at 10X reduction on either high resolution photographic plates, or on photoresist-coated plates for chrome mask manufacture. The photomask array obtained with Type 1795 Single-Barrel Dual-Purpose Photorepeater is over a 4 in.^{2} area. Positional precision is 0.00001 in. David W. Mann Co., Div. GCA Corp., 174 Middlesex Tpk., Burlington, Mass. 01804. Booth 3315.

Circle 243 on Inquiry Card

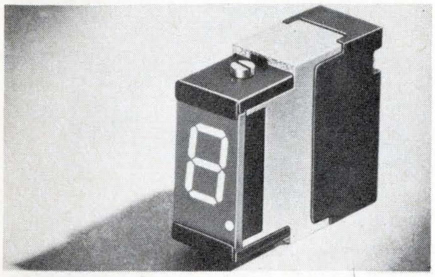
LINE REGULATOR



Model 3131 1000 VA line regulator has a 3 wire, fully isolated output configuration. The output voltage is 115 V rms nominal, adj. 110 to 120 V rms. Operating freq is 60 Hz ±3 Hz. Price is $995. NH Research, Inc., 1510 S. Lyon St., Santa Ana, Calif. 92705. Booth 1015.

Circle 244 on Inquiry Card

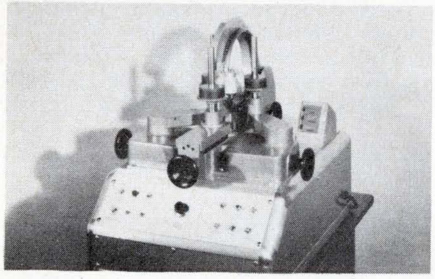
MINIATURE READOUTS



MSM single plane mosaic style readouts display 0 through 9 numerals and some alphabetic indications by illuminating a combination of lamps through a diode matrix or encoding switch. Interlocked segments provide a bright wide-viewing angle of about 150°. Alco Electronic Products, Inc., Box 1348, Lawrence, Mass. 01842. Booth 5120.

Circle 245 on Inquiry Card

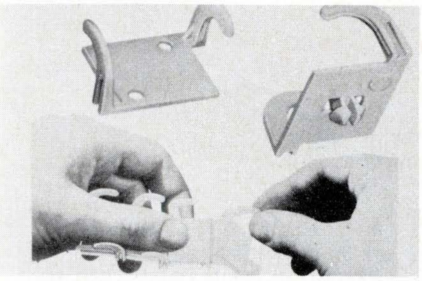
TOROID WINDING MACHINE



Open shuttle principle makes it possible to wind several toroids from a single load. The loading cycle, which on normal machines may require more time than the winding itself, is spread over several cores. Thus, it is practical to machine wind coils having relatively few turns. Coil Winding Equipment Co., Railroad Plaza, Oyster Bay, N.Y. 11771. Booths 3001 & 3101.

Circle 246 on Inquiry Card

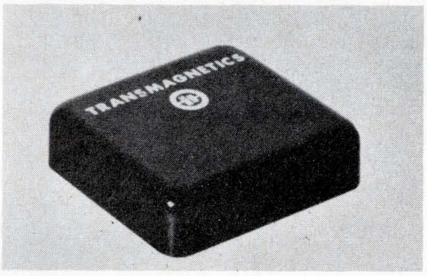
CABLE HOLDER



This new way to hold cable eliminates binding so common with the usual type of clamp. "Cable Keeper" is particularly useful for coax where binding causes a change in impedance. It holds cable securely, yet cable can be easily inserted or removed when one end is free. Weckesser Co., Inc., 4444 W. Irving Park Rd., Chicago, Ill. 60641. Booth 3917.

Circle 247 on Inquiry Card

CONVERTER



This SS converter can replace gear train servos in many applications. Model 1637 converts a three wire synchro input to a linear dc output proportional to the synchro angle. It is 2.6 in.^{3} and sells for under $100 in quantities of 1000 or more. Transmagnetics, Inc., 134-25 Northern Blvd., Flushing, N. Y. 11354. Booth 4180.

Circle 248 on Inquiry Card

SEARCH WEST

Search West is a communications program established to keep professional talent throughout the United States apprised of opportunities with our San Francisco Bay area clients. We have been retained by young, prolific firms to locate communications, video and digital circuit engineers, project leaders and managers. If you want to contribute to state-of-the-art development in the electronic and computer fields, please reply in strictest confidence. We are employer retained.

RJP & Associates
505 W. Olive, Suite 165
Sunnyvale, Calif. 94086

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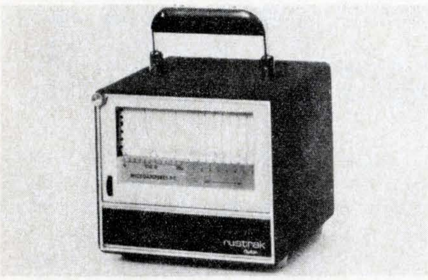
CHART RECORDER



New "300 Series" two-wide strip chart recorder provides greater flexibility in monitoring current, voltage, temp, pressure and many other parameters that often require two or more std recorders. Gulton, Rustrak Instrument Div., Municipal Airport, Manchester, N.H. 03103. Booths 1436-37.

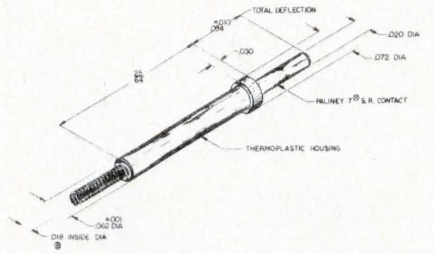
Circle 249 on Inquiry Card

PUSHBUTTON SWITCH

Time-saving bi-directional miniature 10-position switch Series MPB/AS-27000 is for space-saving applications requiring high reliability and long life (over 1 million operations). Push one button to add, push the other button to subtract. Chicago Dynamic Industries, Inc., Precision Products Div., 1725 Diversey Blvd., Chicago, Ill. 60614. Booth 5025.

Circle 250 on Inquiry Card

MINIATURE PROBE



New plunger type electrical contact includes only three parts and one solder joint. It may be used as a miniature probe, a make-and-break contact, a sliding contact, and a reliable light pressure probe for testing ICs. The J. M. Ney Co., Maplewood Ave., Bloomfield, Conn. 06002. Booth 4414.

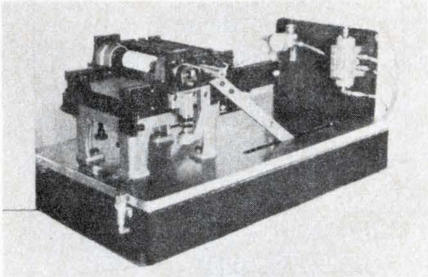
Circle 251 on Inquiry Card

SCREWDRIVER SET

PS-89 set contains 8 midget Allen hex type screwdrivers in sizes from 0.028 to ⅛ in. "Piggyback" torque amplifier handle can be slipped over the midget tool handles to provide a larger gripping surface, extended reach, and increased driving power. Excelite Inc., Orchard Park, N.Y. 14127. Booth 3002.

Circle 252 on Inquiry Card

MARKING MACHINE



Model R4/AC is for printing or serializing small flat or slightly irregular components. A dry offset printer is operated by an air cylinder with adj speeds. Inexpensive type or photoengravings are used. Eastern Marking Machines, 30 Alabama Ave., Island Park, L.I., N.Y. 11558. Booth 3319.

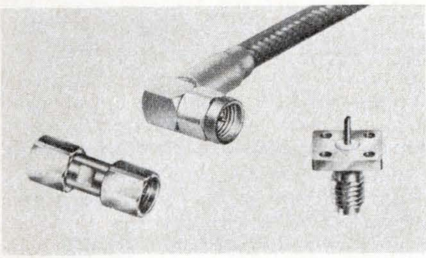
Circle 253 on Inquiry Card

SPUTTERING SYSTEM

Sputter etching, rf bias sputtering, plasmatomic sputtering and multiple film deposition are combined in the new 8630 series modules and systems. The new series was developed to meet the needs of IC semiconductor manufacturers. Materials Research Corp., Scientific Instruments Div., Orangeburg, N.Y. 10962. Booths 2409-10.

Circle 254 on Inquiry Card

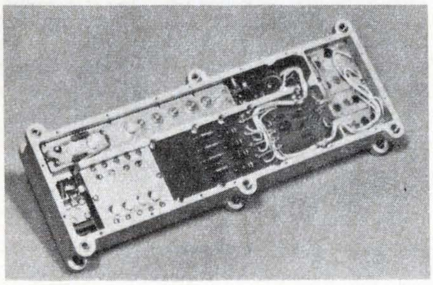
RF CONNECTORS



New SRM units include: straight and rt-angle plugs and jacks for 0.141 in. semi-rigid and flexible coax cables; bulkhead panel and rt-angle jack receptacles; and cable units in clamp, crimp and solder-type designs. They are for use from dc to 18 GHz. Sealectro Corp., Mamaroneck, N.Y. Booths 4416-18.

Circle 255 on Inquiry Card

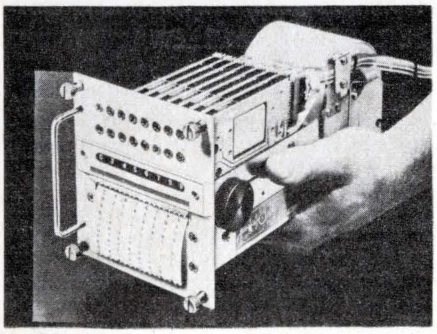
SOLID STATE SOURCES



These SS multi-channel crystal controlled sources, with discrete output freqs at any point in the range from 800 MHz to 9600 MHz, feature tight freq stab and low noise operation. They use fund. crystal oscillators that operate in the 50 to 100 MHz region. Hughes Electron Dynamics Div., 3100 W. Lomita Blvd., Torrance, Calif. 90509.

Circle 256 on Inquiry Card

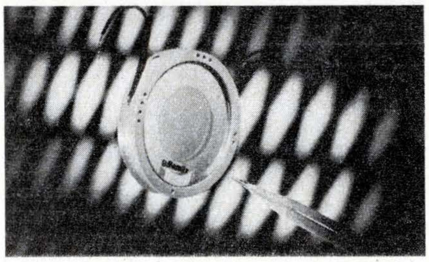
COUNTER PRINTER



Model CP Counter/Printer is available in almost limitless combinations of alphabetical and numerical characters. Complete printer requires only ext. electrical commands of position or count, print and reset. It has no messy and troublesome ink ribbon system. ITT General Controls, 6842 Van Nuys Blvd. Van Nuys, Calif. 91405. Booth 3810.

Circle 257 on Inquiry Card

IMAGE INTENSIFIER



Model BX-749 is a thin image amplifier that may be used alone or to extend the performance of existing systems. Usable sensitivity ranges from the near UV to the near IR with very effective response to GaAs lasers and light emitting diodes. Bendix Electro-Optics Div., 1975 Green Rd., Ann Arbor, Mich. 48107.

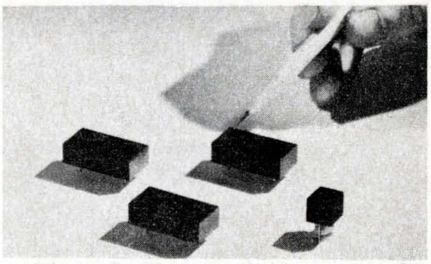
Circle 258 on Inquiry Card

FM TX AND RX LINE

Mini-Link all-SS receivers and transmitters provide a basic microwave relay link capability for TV, wideband telemetry and multi-channel telephony. The "MLT/MLR" series is available at freqs from 0.7 to 8.4 GHz with Tx output powers up to 4 W. RHG Electronics Laboratory, Inc., 94 Milbar Blvd., Farmingdale, N.Y. 11735. Booth 5403.

Circle 259 on Inquiry Card

CRYSTAL FILTERS



These 7-pole monolithic crystal filters, models 6457 MA, 6457 MB, 6458 MA, and 6458 MB, range from 0.080 in^3 to 0.274 in^3. Center freqs are 10.7 MHz ±0.7 kHz, 10.7 MHz ±1 kHz, 21.4 MHz ±0.7 kHz and 21.4 MHz ±1 kHz. Damon Engineering, Inc., 115 Fourth Ave., Needham Heights, Mass. 02194. Booth 5206.

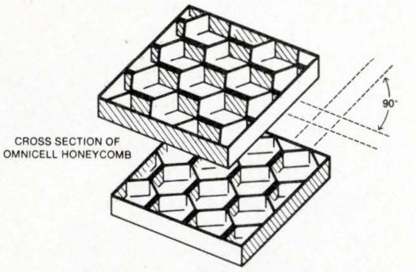
Circle 260 on Inquiry Card

ELECTRON BEAM GUN

The MXV-6 is a 6 kW heavy duty gun with a large capacity water-cooled circular hearth. Evaporant exit angle is 90° and the 37 cc hearth can hold ¼ lb of aluminum. For production use, it's still compact enough (5 x 3¾ x 4 in.) for installation in a vacuum chamber. Sloan Instruments Corp., Box 4608, Santa Barbara, Calif. 93103. Booth 2411.

Circle 261 on Inquiry Card

EMI SHIELDED PANEL



Ordinary Al honeycomb panels have one serious shortcoming; they are more conductive in the direction of the foil than perpendicular to it. In Omnicell, this problem is solved by orienting half the normal panel thickness 90° to the other half. Metex Corp., 970 New Durham Rd., Edison, N.J. 08817. Booths 5113-14.

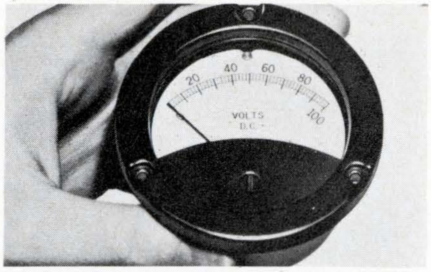
Circle 262 on Inquiry Card

WAVEDIPPING SYSTEM

Automated Rotary Dipping Apparatus (ARDA), is for solder-coating axial and non-axial component leads. It has a conveyor system to carry components around its circumference and to permit automatic lowering and raising of components, while rotating them in 90° increments. Electrovert, Inc., 86 Hartford Ave., Mt. Vernon, N.Y. 10553. Booths 3115-17.

Circle 263 on Inquiry Card

RUGGEDIZED METERS



Ruggedized meters serve where high shock and vibration levels exist. They are available for ac, dc, rf and rectifier-type ac uses. A full range of sizes, 1½, 2½, 3½ and 4½ in. provides for optimum "human engineering." Sun Electric Corp., Instrument-Tachometer Div., Harlem & Avondale Ave., Chicago, Ill. 60631.

Circle 264 on Inquiry Card

LAMINAR FLOW MODULE

Envirazone multi-purpose module is a portable, self-contained unit adaptable to many industrial and lab uses. It may be supported horiz on legs or suspended from the ceiling to serve as a downflow unit. Three models are available, all in 4 ft widths with varying heights. Envirco, Inc., Box 6098, Albuquerque, N.M. 87107.

Circle 265 on Inquiry Card

YIG FILTER

Covering the freq. range from 1 to 18 GHz, this filter has a max. BW from 20 MHz in L-band to 40 MHz in upper K_u-band while maintaining a limiting level of over +10 dBm. It is compact (2.04 in. cubed, 30 oz) and requires < 6 W of tuning power to operate at 18 GHz. Operating temp. range is 0-50°C. Watkins-Johnson, 3333 Hillview Ave., Palo Alto, Calif. 94304. Booths 2302-03.

Circle 266 on Inquiry Card

SHIELDING MATERIAL

Co-Netic M, in sheet stock form for high resolution information displays and similar uses, has high initial permeability and low remanence. Initially available in 0.020, 0.025, 0.031, 0.040, and 0.050 in. thicknesses. Magnetic Shield Div., Perfection Mica Co., 740 Thomas Dr., Bensenville, Ill. 60106. Booth 2633.

Circle 267 on Inquiry Card

TERMINAL BLOCKS

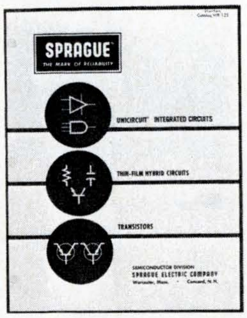
"SW" Series of track-type blocks are molded of high-strength, white polypropylene. They offer max. ckt. density of 32 poles/ft with center-to-center terminal spacing of only ⅜ in. Curtis Development & Mfg. Co. 3250 N. 33rd St., Milwaukee, Wisc. 53216. Booth 4911.

Circle 268 on Inquiry Card

EE LITERATURE

ICs, hybrids, transistors

Highlighted in this 48-page catalog are the company's Series 54/74 standard TTL logic, 54/74 complex functions, and 54H/74H high-speed TTL circuits. Also listed are special digital circuits and linear circuits. In additions to ICs, short form catalog WR-125 covers thin-film hybrid circuits and germanium and silicon transistors. All products are conveniently indexed by both application and type numbers, and package outline drawings are provided. Technical Literature Service, Sprague Electric Co., Marshall St., North Adams, Mass. 02147.



Circle 321 on Inquiry Card

Instrumentation

"The Instrumentation Users' Handbook," a 100-page brochure, contains technical and application data on such subjects as magnetic tape recording, reproducing, oscillography, signal conditioning, and magnetic heads. Glossaries, diagrams, technical articles, and product information are included in Bulletin 1329. Bell and Howell, 360 Sierra Madre Villa, Pasadena, Calif. 91109.

Circle 322 on Inquiry Card

Medium-power DTL

A 24-page catalog covers a medium-power DTL line, consisting of 57 types, three package styles, and two temperature ranges. This line includes the CD2300, CD2300D, and CD2300E series, which can serve as replacements for 830 and 930 series DTL circuits. File No. 374 contains tables of electrical characteristics, circuit diagrams, truth tables for a series of flip-flops, descriptions, and dimensional outlines. RCA Electronic Components, Commercial Engineering Dept., 415 S. 5th St., Harrison, N.J. 07029.

Circle 323 on Inquiry Card

Semiconductors

This 90-page catalog gives complete specifications on all semiconductors available from Hughes. Covered in the 1969 catalog are both monolithic circuits and discrete devices. Hughes Semiconductors, 500 Superior Ave., Newport Beach, Calif. 92663.

Circle 324 on Inquiry Card

Wire and cable

A 64-page catalog describes the materials, construction, and applications of a range of electrical wires. Also covered in Catalog GC-10 are power, control, and welding cable. ITT Wire and Cable Div., Pawtucket, R.I. 02862.

Circle 325 on Inquiry Card

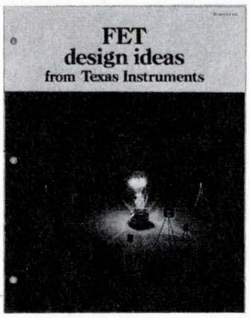
Ferrite devices

This 43-page catalog lists specs for a variety of ferrite devices, including coaxial 3-, 4-, and 5-port circulators, isolators, high-power circulators, pulse latched switches, and so forth. Also described are integratable isolators and circulators for use with microwave ICs. Western Microwave, 16845 Hicks Rd., Los Gatos, Calif. 95030.

Circle 326 on Inquiry Card

Field-effect transistors

Titled "FET Design Ideas," Bulletin CB-101 is intended for designers who use field-effect transistors in their circuits. The 12-pager describes how to bias FETs and provides circuit diagrams that illustrate 20 FET applications. Included too are short-form data on TI's standard FETs and a listing of FET application notes currently available. Texas Instruments Incorporated, Inquiry Answering Service, MS 308, Box 5012, Dallas, Tex. 75222.



Circle 327 on Inquiry Card

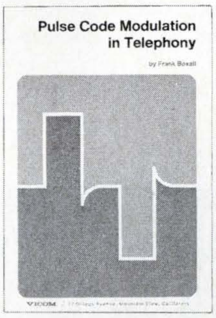
MOS circuits

This 12-page guide provides a listing of standard MOS circuits, including shift registers, memories, multiplex arrays, logic circuits, and "P" channel transistors. Military and industrial applications are listed along with operating parameters, functions, and packaging information. American Micro-Systems, Inc., 3800 Homestead Rd., Santa Clara, Calif. 95051.

Circle 328 on Inquiry Card

Pulse code modulation

"Pulse Code Modulation in Telephony," a 72-page handbook, covers PCM concepts, techniques, and hardware. The first section reviews the mode of operation and discusses the advantages of PCM. Sections II and III describe PCM line and terminal equipment in terms of hardware and engineering concepts. Vicom, 77 Ortega Ave., Mountain View, Calif. 94040.



Circle 329 on Inquiry Card

Continuous support systems

A 122-page reference manual contains 11 indexed and cross-referenced sections on cable and tubing support systems. Reprints of NEC and NEMA standards, diagrams, charts, and maps are among the useful data given. P-W Industries, 11500B Roosevelt Blvd., Philadelphia, Pa. 19115.

Circle 330 on Inquiry Card

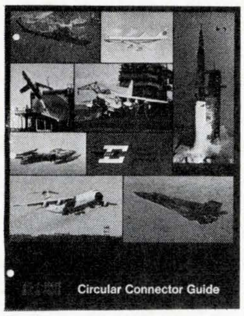
Oscillators

An 82-page catalog covers a variety of oscillators in the frequency control field. A discussion of engineering design limits and suggested applications precedes each product section. The typical performance, specs, and price for each model are given. Greenray Industries, Inc., 840 W. Church Rd., Mechanicsburg, Pa. 17055.

Circle 331 on Inquiry Card

Circular connectors

An expanded 1969 guide will provide you with data on two lines of miniature circular connectors which conform to MIL-C-26482 and MIL-C-26500. Featured in the 52-page catalog are a glossary of circular connector terms and an illustrated reference index. Included too are complete performance specs and dimensional drawings. Elco Corp., Willow Grove, Pa. 19090.



Circle 332 on Inquiry Card

Electronic instruments

This 8-page publication contains articles on the selection and use of a plug-in counter, and on the programming of frequency synthesizers. Another article discusses the true nature and behavior of the capacitor. Monsanto Electronic Instruments, 620 Passaic Ave., West Caldwell, N.J. 07006.

Circle 333 on Inquiry Card

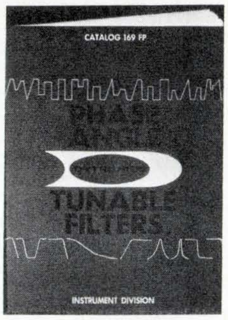
Test equipment

A line of microwave oscillators, phase-lock synchronizers, and MTI (Moving Target Indicator) radar test equipment is the subject of a 16-page catalog. Characteristics of the major series, and then detailed model specifications, are conveniently listed in chart form. Descriptive data and a price list are also included. Sage Laboratories, Inc., Instrument Div., 14 Huron Dr., Natick, Mass. 01760.

Circle 334 on Inquiry Card

Tunable filters

Catalog No. 169 FP, a 32-pager, describes phase angle devices and tunable filters. Among the products listed are phase angle standards, phase sensitive voltmeters, phase angle meters/shifters, and nine models of tunable filters. Operating characteristics, specs, and applications are given for each device. Dytronics Co., Inc., Instrument Div., 4800 Evanswood Dr., Columbus, Ohio 43229.



Circle 335 on Inquiry Card

Quick release fasteners

A 4-page catalog describes a line of quick release fasteners and components. Physical characteristics, installation details, features, and specs are included. Dzus Fastener Co. Inc., 425 Union Blvd., West Islip, N.Y.

Circle 336 on Inquiry Card

Servo and computing modules

Solid-state devices for converting and computing are listed in short-form catalog 369. The 12-pager covers synchro input and output devices, digital converters, analog computing modules, and solid-state servos. Transmagnetics, Inc., 134-25 Northern Blvd., Flushing, N.Y. 11354.

Circle 337 on Inquiry Card

Relays and controls

This 24-page catalog (C-1010) will give you condensed specs, dimensions, and prices for over 400 stock and standard relays and motor controls. Shown are 75 basic relay types, as well as timers, general-purpose contactors, and motor starters. Struthers-Dunn Inc., Pitman, N.Y. 08071.

Circle 338 on Inquiry Card

Rotary couplers

Catalog R-69 contains illustrations and specs for a variety of rotary-coupler configurations. Guidelines to follow when discussing and specifying rotary-coupler requirements are also given in the 8-page brochure. Alpha Industries, Inc., 381 Elliott St., Newton Upper Falls, Mass. 02164.

Circle 339 on Inquiry Card

Instrument knobs

A line of standard instrument and control knobs for commercial and military applications are shown in this 20-page catalog. Knobs ranging in size from ½ in. to 3 in. in diameter, dials, and assemblies are included. Kurz-Kasch, Inc., 1421 S. Broadway, Dayton, Ohio 45401.

Circle 340 on Inquiry Card

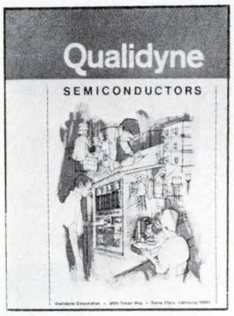
IC accessories

Catalog 91A contains drawings, specs, and ordering information for a line of IC accessories. Dual in-line sockets, circuit boards with 70-pin input-output, card files and power planes, and breadboards for in-lines are listed. Flat pack holders, card connectors, and an IC patch cord kit are also shown in the 6-page source. Cambridge Thermionic Corp., 445 Concord Ave., Cambridge, Mass.

Circle 341 on Inquiry Card

Semiconductors

Designers and component specifiers will find a variety of data on dual transistors and sense amplifiers in this "Semiconductor Fact-Pac". Specifications, including dimensional data, ratings, and characteristics, are detailed. Capabilities for custom linear circuits are also discussed. Qualidyne Corp., 3699 Tahoe Way, Santa Clara, Calif. 95051.



Circle 342 on Inquiry Card

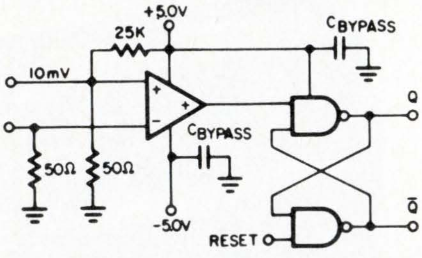
Measuring antenna errors

Application Note 110 describes a simplified method of measuring radome induced antenna boresight or beamshift errors. This method uses a network analyzer to detect phase differences in a pair of receiving antennas. The 9-page note discusses three types of antenna measuring systems—multiple beam, phase sensing, and shaped beam antennas—and gives the results of typical measurements using each of these systems. Inquiries Mgr., Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304.

Circle 343 on Inquiry Card

Linear IC applications

Circuit and system designers will be interested in this 24-page brochure, which covers a line of linear devices and their respective applications. Devices range from core memory sense amplifiers to video amplifiers, and include op amps, diff amps, high-speed comparators, and rf/i-f amps. Over 45 illustrated applications are given. Signetics Corp., 811 E. Arques Ave., Sunnyvale, Calif. 94086.



In this application, an external NAND gate is cross-coupled with the gate output of the 526 op amp to provide a bi-stable latch or storage element.

Circle 344 on Inquiry Card

Electronic calculators

This compact 16-page booklet discusses the 300 series calculators, which can perform all types of calculations from basic arithmetic to complex equations and programmed calculations. It describes features and functions of each model, and gives typical application problems and solutions for individual calculator keyboards. Wang Laboratories, Inc., 836 North St., Tewksbury, Mass. 01876.

Circle 345 on Inquiry Card

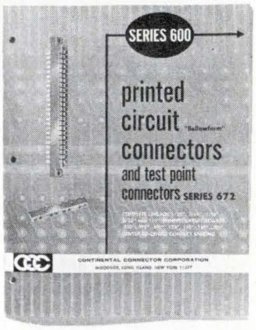
Linear IC tester

The J263 computer-operated linear circuit test system is the subject of a 12-page brochure.' Techniques used by the system to make a variety of measurements on op amps, diff amps, sense amps, and comparators are discussed. Classification and data-logging applications are also covered. Teradyne, Inc., 183 Essex St., Boston, Mass. 02111.

Circle 346 on Inquiry Card

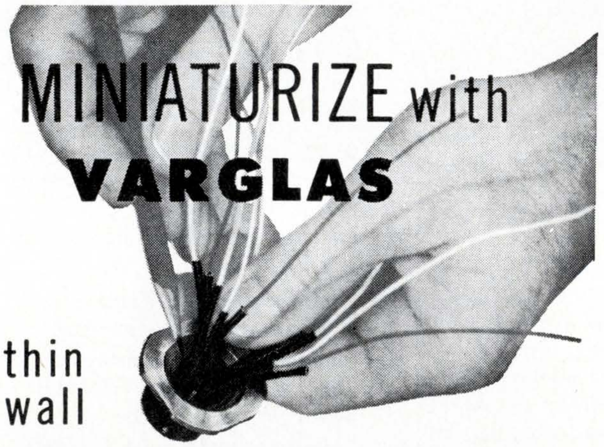
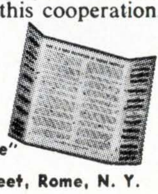
PC connectors

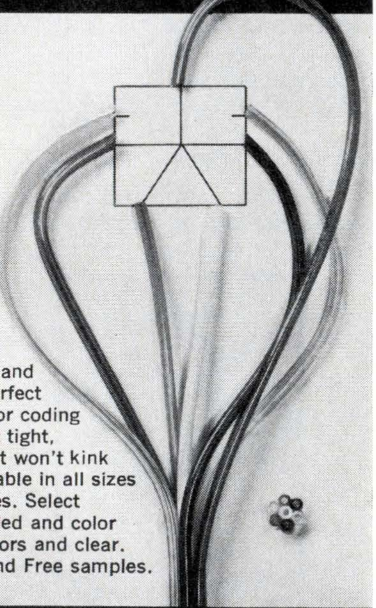
In this 80-page catalog you'll find an extensive listing of printed circuit and test point connectors. Products include microminiature, miniature, and standard types that meet or exceed applicable MIL-C-21097 specs.



Electrical and mechanical specs, along with illustrations, outline drawings, and ordering information, are provided in Catalog Form PC600672-269. Continental Connector Corp., 34-63 56th St., Woodside, N.Y. 11377.

Circle 347 on Inquiry Card



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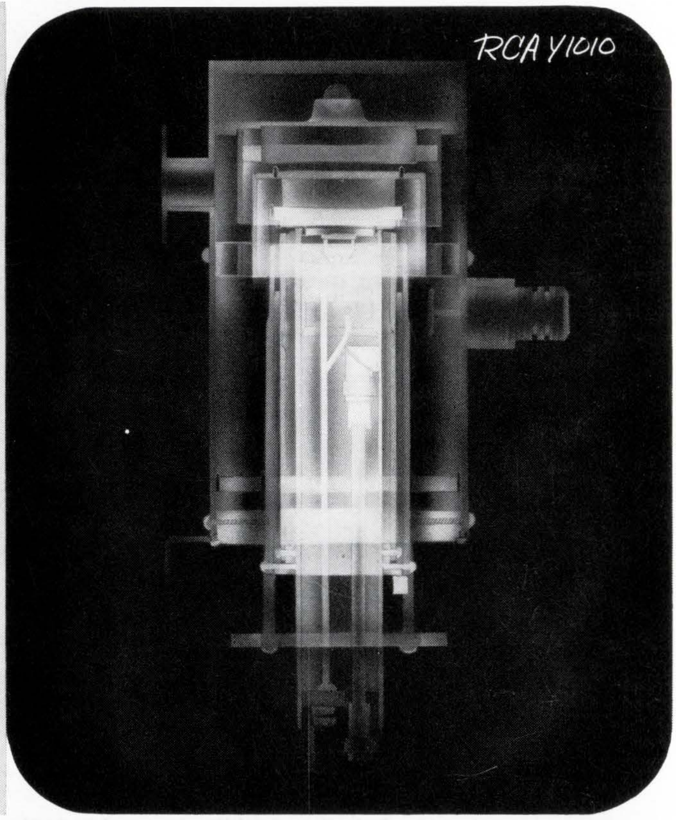
SEE US AT WESCON BOOTH 1020 AT THE ANNEX

Circle 2 on Inquiry Card

Exposed
RCA Coaxial
Cavities



Now—continuing its leadership in the development of electronic products—RCA announces a complete range of coaxial cavities to assure optimum performance from its line of CERMOLOX® Power Tubes.

Suitable for use either as complete amplifiers or as oscillators, these cavities assure specified performance with fully engineered circuitry, minimum RF losses, simplified connections, and high overall efficiency.

To fulfill your requirements, cavities are available for frequencies up to L-band and powers up to 10 kW.

The performance, reliability, and efficiency of CERMOLOX tubes have been proved. This line of cavities will augment and assure these benefits. In addition, if your requirements call for special parameters, our Application Engineers will gladly modify existing cavities or develop new ones to assure you of optimum equipment performance.

For more information on RCA coaxial cavities and RCA CERMOLOX Tubes, see your local RCA Representative. For technical data on specific types, write: RCA Electronic Components, Commercial Engineering, Section H-50 T, Harrison, N. J. 07029.

RCA Coaxial Cavities—Available Off-the-Shelf

RCA TYPE	TUBE	POWER OUTPUT (Watts)	MODE	FREQUENCY (MHz)
Y1010	8226	100	CW	1170
Y1044	8501	10,000	pulse	400
Y1050	7651	5,000	pulse	500
Y1051	8227	450	pulse	500
Y1052	8227	400	pulse	350
Y1054A	7651	5,500	pulse	150
Y1059	7214	12,500	pulse	150
Y1070	7651	6,500	pulse	200
Y1086	7651	375	pulse	200