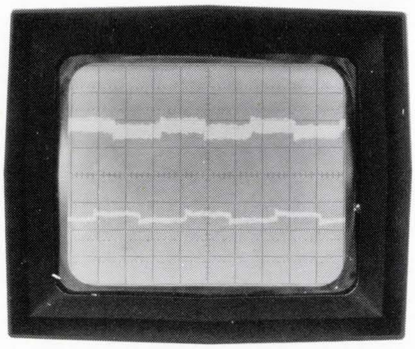
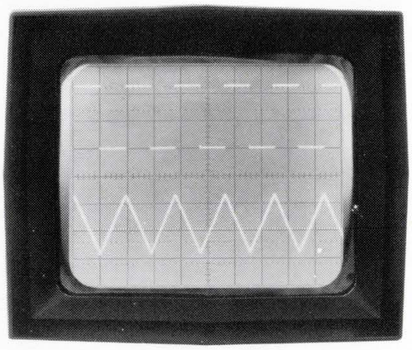
VOL. 28 NO. 7
JULY 1969

THE ELECTRONIC ENGINEER

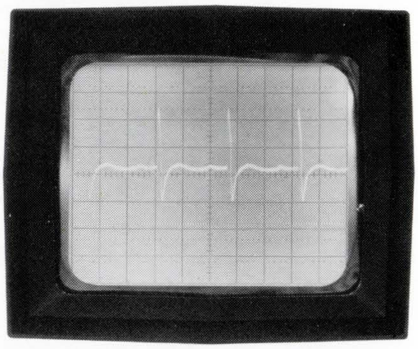
Four Reasons Why—HP's new low-cost scopes belong in your lab:



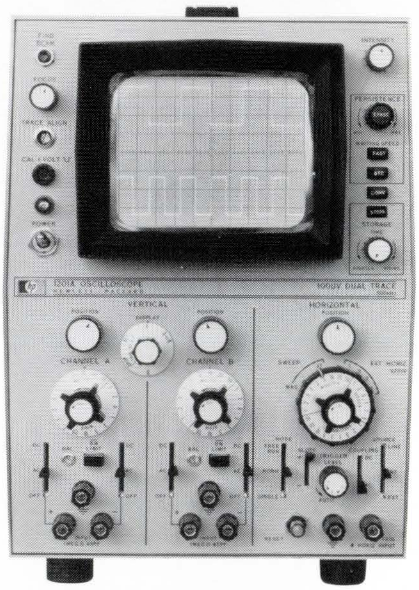
100 μV Sensitivity



Dual Trace



Flicker-Free Variable Persistence



All-Solid-State Reliability

HEWLETT hp PACKARD

OSCILLOSCOPE SYSTEMS

089/13

Get the scope you need at a price you can afford! This new low-frequency scope system has an all-new design from the inside out to give you solid-state reliability in the dc/500 kHz range. You get the better performance, greater sensitivity, low noise, and reduced drift that increases your measurement confidence and decreases your measurement time.

In the HP 1200 series, you can choose from 14 models to get single or dual trace, 100 μV/cm or 5 mV/cm sensitivity in either cabinet or rack models. You can even get an X-Y display.

Add to these, HP's exclusive variable persistence and storage—a first for low-priced, low-frequency scopes. And, only variable persistence gives you completely flicker-free displays of all your low frequency measurements—no flicker means no eye strain.

All of these new scopes have single-ended or differential input on all ranges, high common mode rejection ratio, complete triggering versatility, internal graticule, external horizontal input, dc-coupled Z-axis, beam finder—many of the features you normally find only on the high-priced, high-frequency scopes.

As a result, the 1200 series gives you the best performance of any scope in its price range.

All models are available as lightweight (under 30 pounds) cabinet or 5¼″ high rack mounts. Power consumption of only 33 to 65 watts eliminates the need for cooling fans.

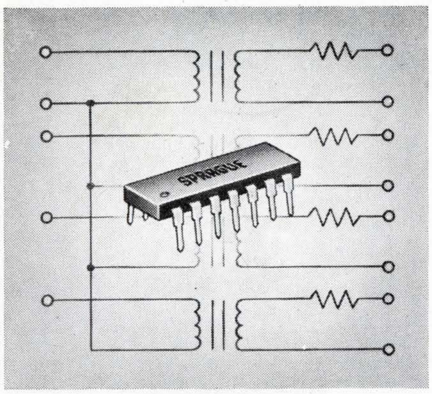
Small size and low power requirements mean an HP 1200 scope fits into your operation easier—bench or system.

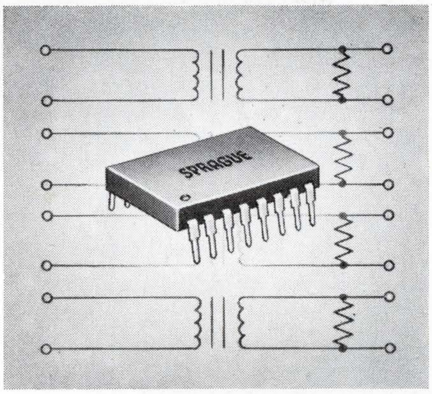
For complete information on how these new all-solid-state scopes can solve your low frequency measurement problems, contact your nearest HP Field Engineer. For additional data, see page 500 of your 1969 HP catalog. Or, write to Hewlett-Packard, Palo Alto, California 94304. Europe: 1217 Meyrin-Geneva, Switzerland.

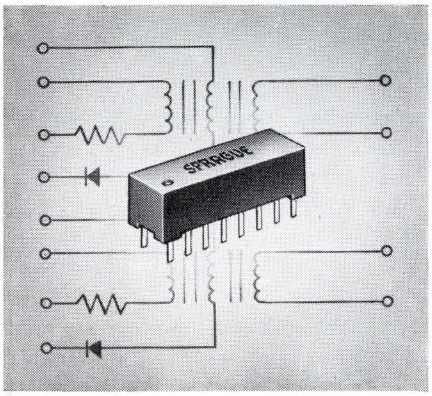
Price: HP 1200 series, \$540 to \$1800.

Circle 1 on Inquiry Card

MODULINE® Memory-drive Hybrid Circuit Modules combine miniaturized inductive elements with thick-film ceramic-based technology.







You get pulse transformers and resistors (diodes and capacitors can also be included) in a circuit tailored to your specifications.

A single module may contain up to four identical circuits. They're particularly useful in memory systems where a similar repetitive pattern exists.

Flexibility offered by modular concept simplifies specific designs.

3 package styles: standard dual in-line, jumbo dual in-line, molded case with pin leads. They're all compatible with conventional in-line circuit layout.

High component density permits substantial size and cost reduction.

For complete technical data, write for Engineering Bulletin 22210 to: Technical Literature Service, Sprague Electric Co., 233 Marshall St., North Adams, Mass. 01247.

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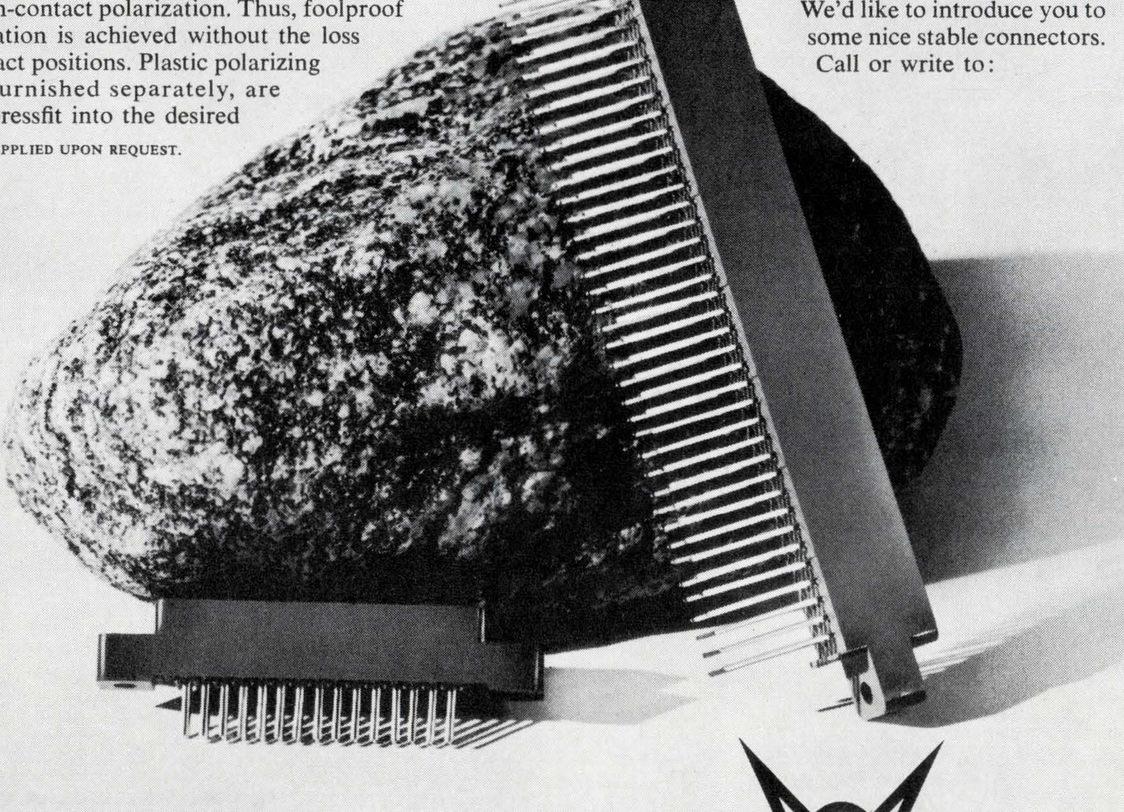
While the world of connectors is fraught with inconsistency, look to our .100 and .125 spacing printed circuit edgecard connectors for dimensional and operational stability. ■ Our connectors offer dimensional stability within each line. For instance, if you're designing a 22-contact connector into your system and you want to change to one with 36 contacts, you won't have to worry about variations in insulator height and width. Even if you switch from pierced tab to wire wrap terminals, the insulator still remains dimensionally constant, making your job much easier. ■ Our .100 (J Series) and .125 (C Series) P/C connector lines are available in double readout with from 6 to 50 contact positions. Both lines will accept a 1/16-inch P/C board. Two C Series wire wrap lines are available to accommodate both 1/16 and 3/32 inch boards. ■ Each line has molded-in slots for between-contact polarization. Thus, foolproof polarization is achieved without the loss of contact positions. Plastic polarizing keys, furnished separately, are easily pressfit into the desired positions. ■ Contact terminations available are pierced tab, dip solder, and wire wrap. Standard mounting styles are clearance hole, molded-in threaded bushing, and float bobbin. ■ Our standard green insulator is molded from diallyl phthalate per MIL-P-19833, Type GDI-30 or MIL-M-14, Type SDG. Contact material is beryllium copper per QQ-C-533. The contacts are gold plated per MIL-G-45204, Type II. ■ Perhaps the most dramatic part of our story is reliability. A study involving Viking P/C connectors that was conducted by a major avionics firm* revealed that after 167,500,000 operational part hours, the observed failure rate was a remarkable 0.00055% per 1000 hours. ■ We'd like to introduce you to some nice stable connectors. Call or write to:

*NAME SUPPLIED UPON REQUEST.



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EE

The Electronic Engineer

July 1969 Vol. 28 No. 7

COVER

As electronic instrumentation moves into operating rooms, intensive care units, and recovery wards, the patient now finds two or three electronic instruments hanging on him, when at one time he wouldn't have seen any. How safe are these instruments? Does anybody mind that one instrument may close a current loop for another, through the patient's vital organs? Read a fascinating discussion on these and other problems related to safety in electronic instrumentation for medicine, in the article starting on page 35.

Circle 6 on Inquiry Card

EE

The Electronic Engineer

Vol. 28 No. 7 July 1969

Chilton BPA

Executive and Editorial Offices:
One Decker Square, Bala-Cynwyd, Pa. 19004
Tel. (215) SH 8-2000
Address Mail to: 56th & Chestnut Sts.
Philadelphia, Pa. 19139

Western Office: Stephen A. Thompson
1543 W. Olympic Blvd., Los Angeles, Calif. 90015
Tel. (213) DU 7-1271

New York Office: Robert Patton
100 E. 42nd St., New York, N.Y. 10017
Tel. (212) OX 7-3400

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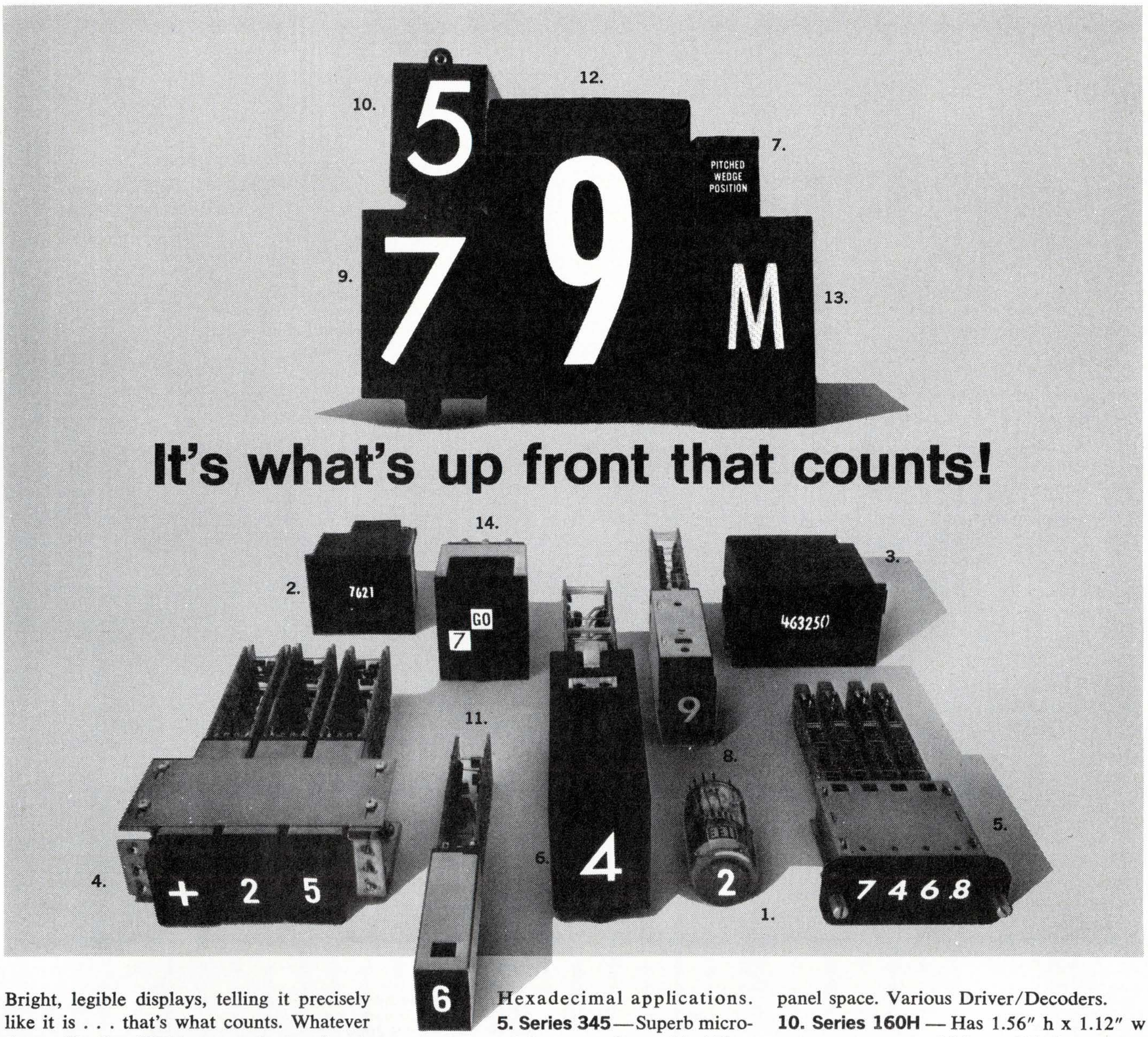

Bright, legible displays, telling it precisely like it is . . . that's what counts. Whatever the application, IEE has a readout and mating driver/decoder geared to deliver unsurpassed displays, up front . . . *where the action is.*

1. nimo™, single-decade — Single plane, 10 gun CRT. Displays numbers, letters and words with unsurpassed brightness and clarity. Driver/Decoder with BCD input.

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3. nimo™, 6-decade display — Ideal for instrument use, read bright and clear at 75 F.L. — low, $2.90/decade. Highly compatible electronic interface cards.

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6. Series 10H — World's most popular rear-projection readout. Projects any numeral, character, message, color, etc. High performance Driver/Decoder.

7. Series 120H — Miniature readout, only 1″ wide, presents ⅝″ h characters. Readability unmatched at 30′. High reliability potted Driver/Decoder for military application.

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EE EDITORIAL

Archimedes and Leonardo were members of the industrial-military complex

Few people think of these two pioneers of science as members of the much maligned industrial-military complex, but it's true. Archimedes was a consultant to Hiero II, King of Syracuse. He not only determined the specific weight of the king's crown, but also devised war machines which the Syracuseans used effectively against the besieging Roman legions. And Leonardo da Vinci was nothing less than the engineer general of the army of Pope Alexander VI during the war in Central Italy. Yet we remember both Archimedes and Leonardo today not for their military sponsorship, but for the scientific (as well as artistic) legacy they left to us.

We hear and read much today about the industrial-military complex, and how our readers are truly responsible for the applications of those of their designs that find their way onto the battlefield. If you have been exposed to the controversy, I know that there are nagging questions in your mind.

- Are you responsible for the applications of your designs?
- Should you shun a military job, in favor of a nonmilitary one, even at a lower pay?
- How can you determine when a military job is truly vital to the country, and when is it unnecessary? Worse yet, is it for you to determine such priorities?
- Even if you wanted to, could you easily change your output from military applications to civilian ones? Could you effect, by yourself, the technological conversion from swords to plowshares?

Last month, the Massachusetts Institute of Technology — one of the largest institutions of learning and research in electronics—addressed itself to these questions. A panel composed of faculty, alumni, and students examined in detail the role of the two special laboratories of M.I.T.—the Lincoln Lab and the Instrumentation Lab.

While it made no effort to hide its admiration for the remarkable work both laboratories have done in the last two decades, the panel tackled the issues forcefully and questioned the relationship between an institution of learning such as M.I.T. and those two special laboratories—whose combined budget is much larger than that of the school. For example, the panel pronounced itself against classified work being carried out at the laboratories, since such work detracts from the school's primary mission of making knowledge available to its students and to society. On the other hand, the panel agreed that the labs can engage in defense-oriented research, as long as the final product of such research is not an actual weapon.*

Whether or not you choose to work on a military project is a matter for your conscience to decide. But we find that many engineers would prefer to work on nonmilitary projects, if they could only find them. And the reality of our times is that, for every dollar that civilian agencies such as the Departments of Health, Education and Welfare (HEW), Housing and Urban Development (HUD) and Transportation (DoT) spend in electronics, the Department of Defense (DoD) spends twenty-five.

Actually, the fallout of that money invested for defense may benefit everybody, as was the case with Archimedes and Leonardo. The Army, for example, points with pride to the development of the ambulance, and to the fight that Doctors

Walter Reed and Carlos Finlay carried out against yellow fever, as military-sponsored projects that resulted in unquestionable benefits for the whole population. And what about more recent and more electronic developments such as radar, telemetry, and two-way radio? What about the modern Archimedes and Leonardos, such as Dr. Charles Stark Draper of M.I.T., who started his work on inertial navigation systems by developing an antiaircraft gunsight for the Navy in World War II; or Eckert and Mauchly, who developed the first digital computer to calculate ballistic tables?

Defense, and national challenges in general, have been throughout history the prime movers of research and development. Now that general welfare may take its place as a national challenge, we may see it attracting research dollars. When this happens, the civilian population may benefit directly from electronic developments, rather than from the fallout of military R&D. To get engineers to be more conscious of civil research, the more vocal members of the M.I.T. panel proposed the creation of an interdisciplinary "Department of Conversion Science" at the school.

Although not new, the idea of conversion from military to civilian projects is good. Industry, however, cannot convert just by wishing to do so. Conversion must take place at both ends, at the producing end and at the user's end. It's not enough for industry to convert; those who need the talent of the electronic industry must also be equipped to understand its products. HEW, HUD, and DoT must understand the way our industry operates, as the DoD understands it now. Which means that many electronic engineers must first become involved in political and community affairs, to get to the key decision posts where they can influence those departments.

This is why I have noticed with delight that some very talented engineers, who got a taste of public office during their tenure at NASA, are now populating the aforementioned departments. These people think like engineers, can understand engineering, and are truly prepared to encourage our industry to turn their best talent onto worthwhile civilian projects.

And this is exactly the motivation our engineers need.

Alberto Socolovsky
Editor

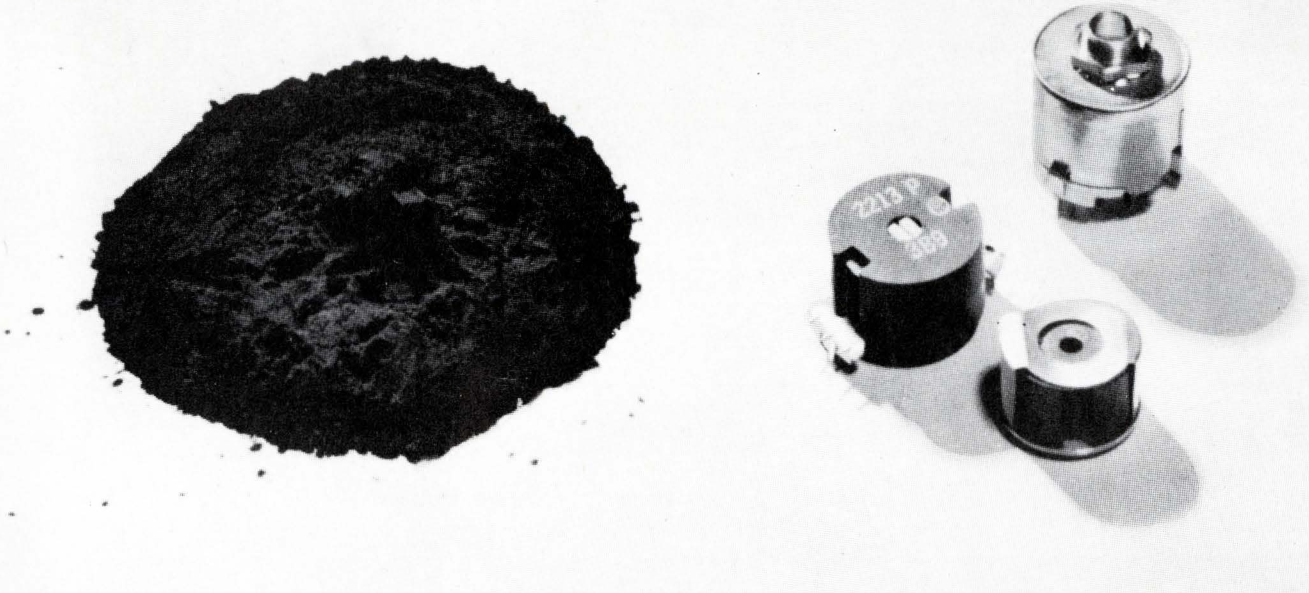
*Since several universities are reexamining the role of their special laboratories engaged in defense-oriented research, we may well see in the future a change of status for these labs, or the creation of new ones. At a symposium organized by the National Security Industrial Association, Mr. William B. Carey of Arthur D. Little Inc. (former Assistant Director of the Budget) predicted the creation of "midway" institutions between government labs (such as the U.S. Army Electronics Lab or the Naval Research Lab) and university-connected labs such as the Lincoln Lab of M.I.T. This type of midway institution may constitute the only place where classified research could be carried out in the future.

Send it back

What do you do when you buy an instrument, and then find it does not meet the advertised specs? "Send it back," Ed Swenson of Electro Scientific Industries told a meeting of the Boston Section of the Precision Measurements Association, a users group.

"Not so fast," said a user, who related a bitter experience in which he had vainly tried to return an instrument that didn't meet advertised specs. The manufacturer refused to accept it, pointing to the fine print at the bottom of the spec sheet reading "Prices and specifications subject to change without notice." In other words, the manufacturer claimed that he had changed the specs, and the user had to keep the instrument.

Any time you buy an instrument on the strength of a spec that claims to be a fraction of a percent better than the competition, get a signed list of specifications from the manufacturer or, better yet, ask your Purchasing Department to issue a purchase order with the list of specs, with a duplicate for the manufacturer to acknowledge. And beware of instruments that don't pass this simple test.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DM8001N (SN7401N)	Quad 2-Input, NAND gate (Open Collector)
DM8003N (SN7403N)	Quad 2-Input, NAND gate (Open Collector)
DM8010N (SN7410N)	Triple 3-Input, NAND gate
DM8020N (SN7420N)	Dual 4-Input, NAND gate
DM8030N (SN7430N)	Eight-Input, NAND gate
DM8040N (SN7440N)	Dual 4-Input, Buffer
DM8050N (SN7450N)	Expandable Dual 2-Wide, 2-Input AND-OR-INVERT gate
DM8051N (SN7451N)	Dual 2-Wide, 2-Input AND-OR-INVERT gate
DM8053N (SN7453N)	Expandable 4-Wide, 2-Input AND-OR-INVERT gate
DM8054N (SN7454N)	Four-Wide, 2-Input AND-OR-INVERT gate
DM8060N (SN7460N)	Dual 4-Input expander
DM8086N (SN7486N)	Quad Exclusive-OR-gate
Flip Flops	
DM8501N (SN7473N)	Dual J-K MASTER-SLAVE flip flop
DM8500N (SN7476N)	Dual J-K MASTER-SLAVE flip flop
DM8510N (SN7474N)	Dual D flip flop
Counters	
DM8530N (SN7490N)	Decade Counter
DM8532N (SN7492N)	Divide-by-twelve counter
DM8533N (SN7493N)	Four-bit binary counter
DM8560N (SN74192N)	Up-down decade counter
DM8563N (SN74193N)	Up-down binary counter
DM8520N	Modulo-n divider
Decoders	
DM8840N (SN7441N)	BCD to decimal nixie driver
DM8842N (SN7442N)	BCD to decimal decoder
Shift Registers	
DM8570N	Eight-bit serial-in parallel-out shift register
DM8590N	Eight-bit parallel-in serial-out shift register
Miscellaneous	
DM8200N	Four-bit comparator
DM8210N	Eight channel digital switch
DM8220N	Parity generator/checker
DM8820N	Dual line receiver
DM8830N	Dual line driver
DM8800H	Dual TTL to MOS translator
DM8550N (SN7475N)	Quad latch

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EE UP TO DATE

Future for color CRTs looks bright

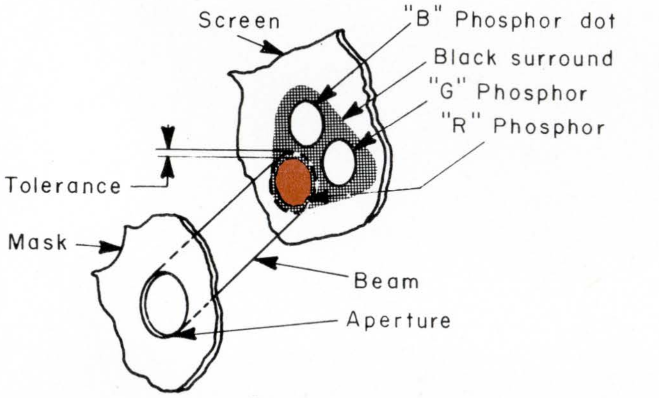
Two major color cathode-ray tube manufacturers made similar announcements at the Chicago Spring Conference on TV and Broadcast Receivers on June 9-10. These companies, RCA and Zenith, announced that their newest color tubes were as much as 2.4 times more brilliant than existing tubes.

In the Chroma-Color tube manufactured by the Rauland Division of Zenith Radio Corp., phosphor dots are of reduced diameter when compared with those in a conventional shadow-masked tube. Moreover, in this new tube there are spaces between the dots, whereas in the shadow-masked tube the dots are substantially in tangential contact with one another.

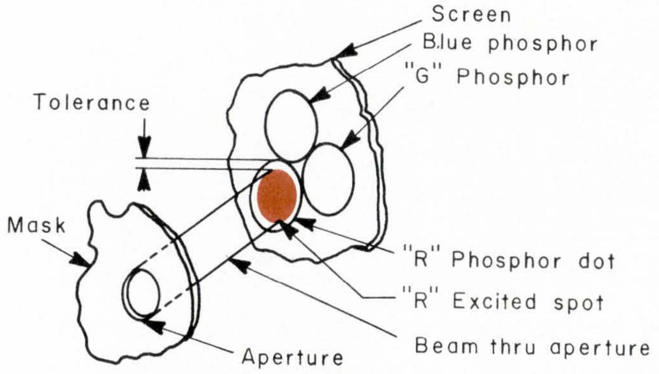
The new tube has a light absorbing black pigment deposited to fill the spaces between the phosphor dots. This gives the system the generic title of "black surround." There is also a reversal in the relationship of beam diameter to phosphor dot diameter. The conventional shadow-masked color tube uses a beam diameter smaller than the phosphor dot diameter, with their difference in size providing a guard band or tolerance which protects against color tinting to assure a white field purity. In the Chroma-Color tube, the beam diameter exceeds the smaller phosphor dot diameter slightly. Our guess is that gun alignment accuracy is not as critical in the new tube as it is in the old (see sketch).

About half or more of the available screen area in the new Chroma-Color tube is covered with a black non-reflective material which attenuates the effect of ambient light, but has no effect on light coming from the screen in response to electron excitation of its phosphor deposits. This gives an increase in tube contrast.

RCA's Hi-Lite Matrix color TV tube is similar in concept to the Zenith tube. Along with the "black matrix" system on its new tube, RCA also claims development of a new high-resolution, precision-aligned electron gun with advanced electron optics to provide sharper focus over the entire brightness range. RCA will introduce this new 23 in. diagonal tube at a price of $110 each to set manufacturers in the next few months.

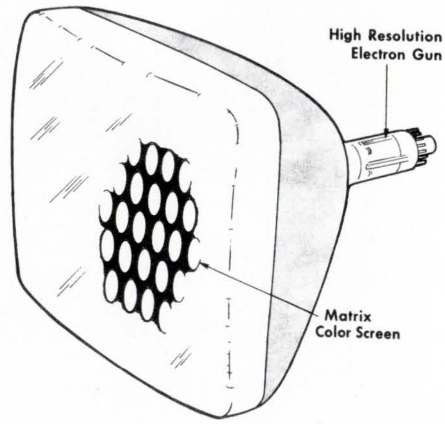


Chroma color



Conventional tube

The two sketches illustrate the conventional tubes phosphor dot size in relation to its beam, and the new Chroma-Color tube. Note that the Chroma-Color tubes phosphor dot is smaller, insuring color even with slight gun mis-alignment. The black surround acts as a guard band between dots.



RCA's new Hi-Lite Matrix tube uses a black area around the phosphor dots in a manner similar to Zenith's mentioned above.

NEW PRODUCT NO. 77

μA715 HIGH-SPEED OP AMP

The new Fairchild μA715 is the fastest linear IC op amp available today.

For applications where power bandwidth, acquisition time or slew rate is the prime consideration, the μA715 stands alone. It's ideal for applications such as wide-band amplifiers, high-speed integrators, precision comparators, sample-and-holds and video or deflection amplifiers. You can start raising the performance of your data acquisition, control, communications or display systems today.

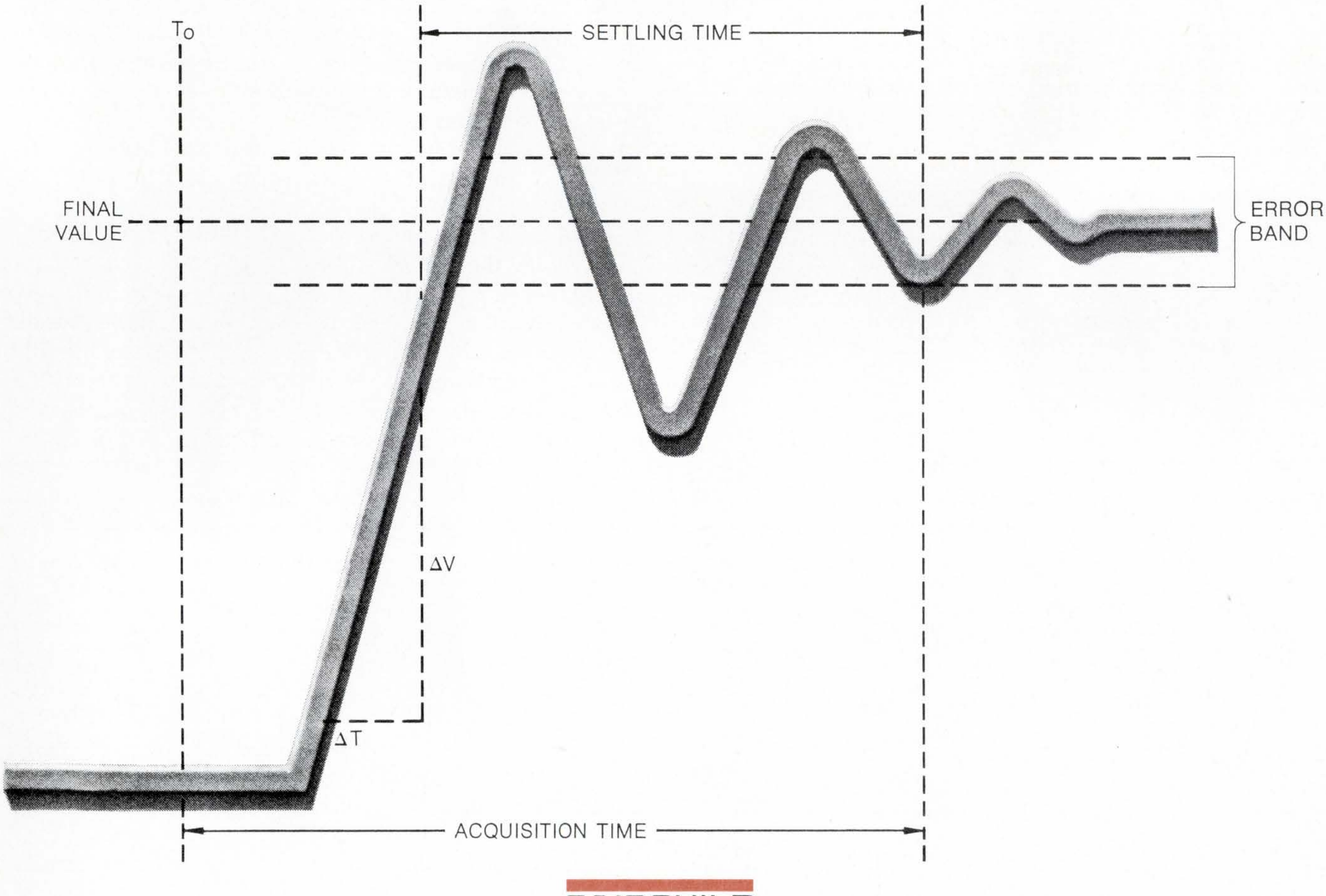
The μA715 is a 3-stage amplifier, with a Darlington cascode input for optimized ac and dc performance, a differential second stage and a class AB output for low distortion. Bandwidth is 60MHz, open loop gain is 92dB, input offset current is only 80nA and both input and output are short-circuit protected.

And, even though op amps are available with slew rates higher than the μA715's 60V/μs ($A_v = 100$), it's *still* the fastest op amp available. The curve shown represents the typical response of any op amp to a step input at time T_o. First, there's a short delay, then the output starts rising to its final value at a rate determined by the slew rate ($\Delta V/\Delta T$). But, in most op amps made, there is first an overshoot, then ringing. The final output value is not achieved until the end of the settling time, when the excursions no longer exceed the bounds of the error band. The total time to achieve the final value (acquisition time) is the sum of the first delay, the rise time and the settling time. In most other op amps, the settling time is measured in microseconds. In the μA715, the settling time is just 300ns. Combine this with a maximum initial rise time plus delay of 350ns (for a 10V swing) and you've got a total acquisition time of just 650ns. And the fastest op amp made.

You can get it now in quantity from your Fairchild distributor.

To order the μA715, ask for:

Part No.	Package	Temperature Range	Price
U5F7715312	TO-5	−55°C to +125°C	$48.00
U5F7715393	TO-5	0°C to + 70°C	15.00



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Only a representative listing is shown here of the thousands of different types and sizes of fuses and holders available from BUSS.

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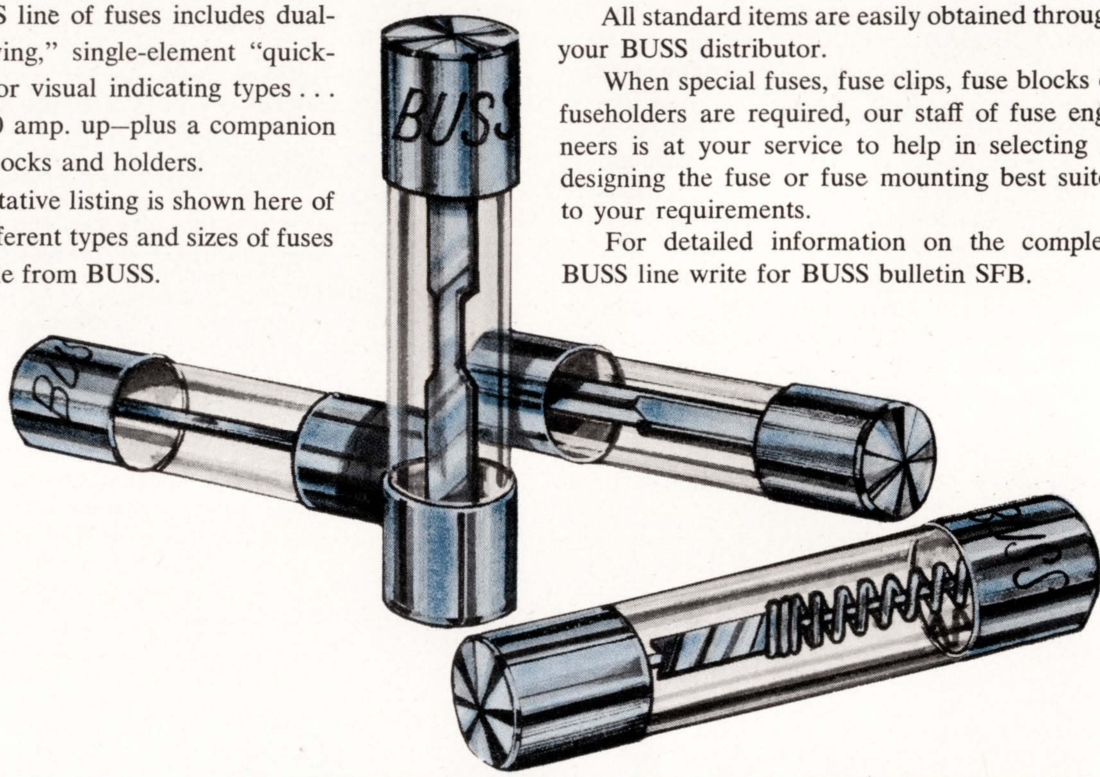
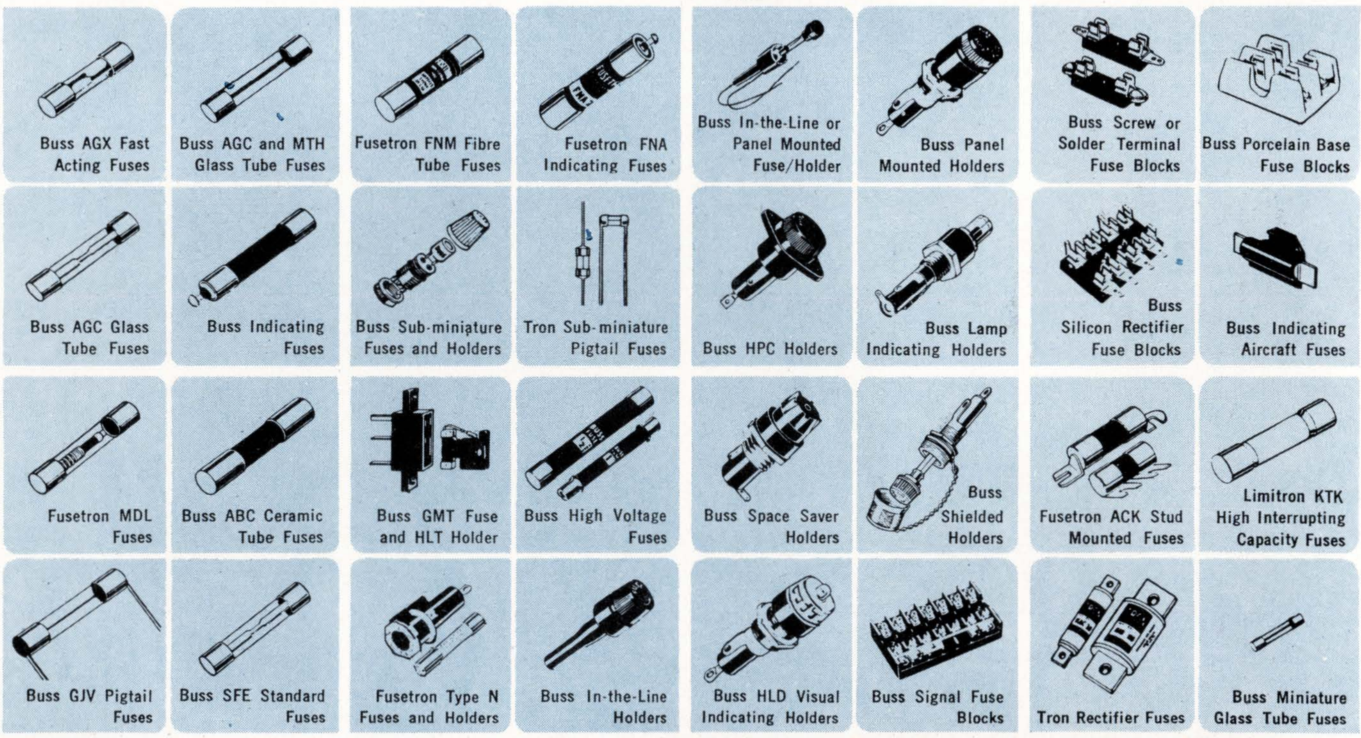
When special fuses, fuse clips, fuse blocks or fuseholders are required, our staff of fuse engineers is at your service to help in selecting or designing the fuse or fuse mounting best suited to your requirements.

For detailed information on the complete BUSS line write for BUSS bulletin SFB.





BUSSMANN MFG. DIVISION, *McGraw-Edison Co.*, ST. LOUIS, MO. 63107

Electron beam welder works in open air

Electron beam welders have been around for a while, but they have had to work in a vacuum. Now Westinghouse has a unit going into production that does not need a vacuum environment. It can weld in open air.

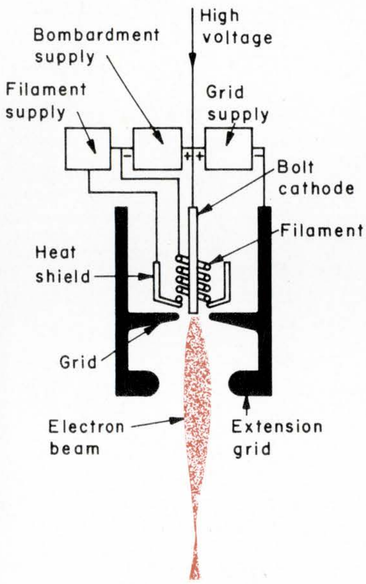
Model EB1512NVA, the new nonvacuum system, is a production unit with a movable welding head—a capability of special importance for welding large structures. Head mobility is possible because of a compact, lightweight power supply which is coupled directly to the welding head, eliminating trouble-some high-voltage cable. Also, sulphur hexafluoride (SF_6) is used as the insulating medium for the power supply instead of oil, as in conventional EB power supplies, because of its light weight.

The movable portion of the system weighs 295 lb and has a motion range of 10 ft in a horizontal or vertical plane.

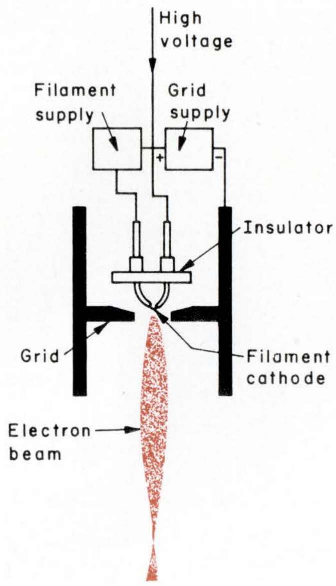
The welder has an indirectly heated rod-shaped emitter which has at least four times the average life of the fragile filament wire emitters in current use. Thermionic emission is induced indirectly from 0.06-in dia tungsten rod by means of an auxiliary filament which encircles the rod.

The main high-voltage power supply has the following ratings: Output voltage, 150 kVdc; output current, 80 mA; output power, 12 kW.

Nonvacuum electron beam welders are preferred for certain applications because they can reduce or eliminate filler material, increase welding speeds, eliminate joint preparation, or improve mechanical properties. Moreover, they eliminate the expensive, time-consuming, and, in certain cases, impossible task of placing the workpiece inside a vacuum chamber.



Bolt Cathode



Conventional Filament Cathode

Electron beam welders have usually required a vacuum to make welds. A new production model can operate in a normal atmosphere, and the cathode has four times the life of most units that do operate in a vacuum. The new welder also has a moveable welding head, giving added flexibility.

New MIL Specs

We encourage any agency issuing new military specifications or amendments to send us a copy of the specifications so that our readers will be up to date.

Spec.	Brief description
MIL-T-81714	General specification for terminal junction systems. Both feedthru and feedback types of modules are covered.
NAVAIR 01-1A-514	Technical Manual. Design of electric systems for Naval aircraft and missiles has just been updated with the addition of chapter 11.
MIL-R-27777	General specification for relays, telegraph, passive, solid state, now has an amendment 1, issued 10 Apr. 69.

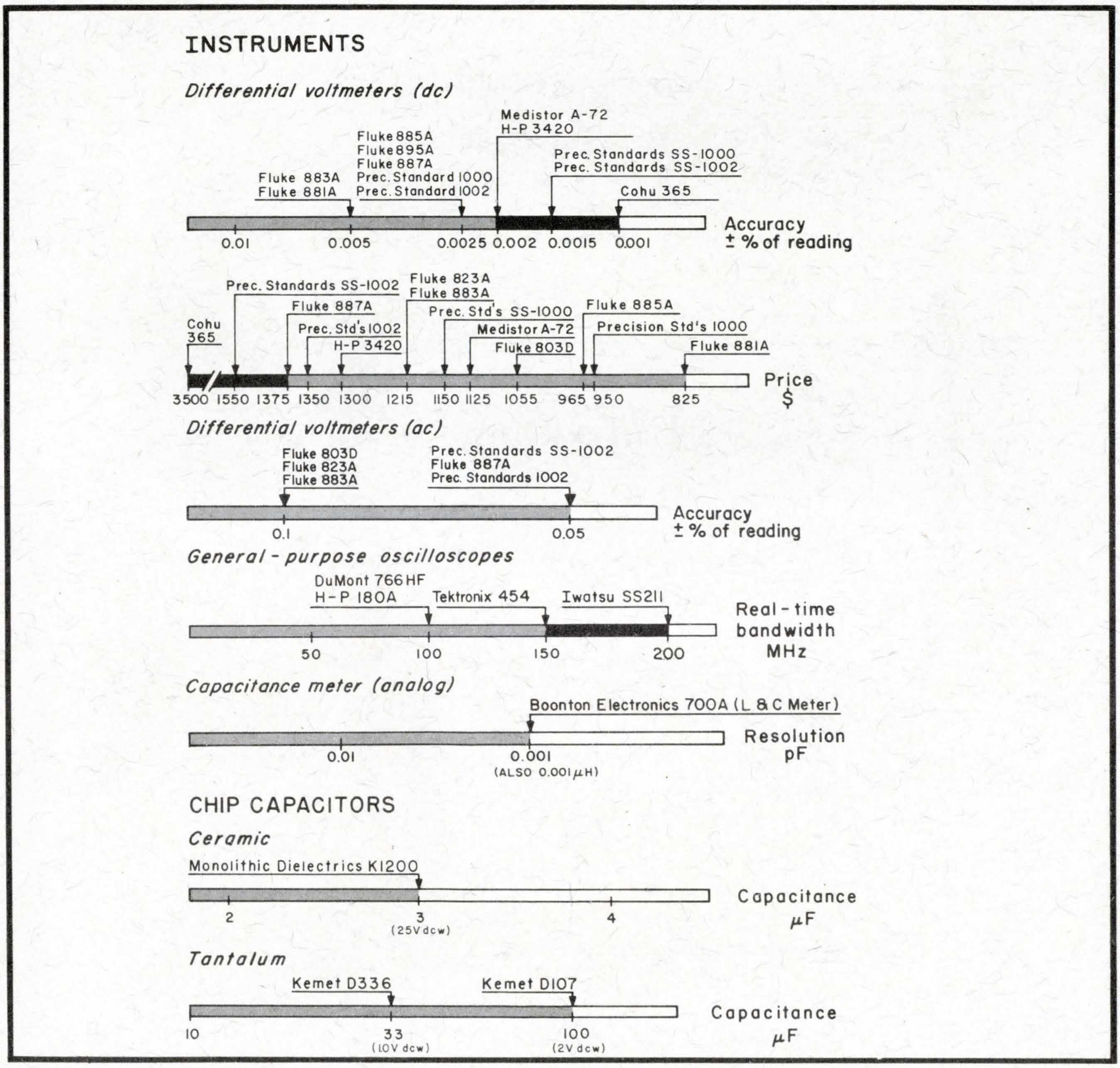
EE FOREFRONT

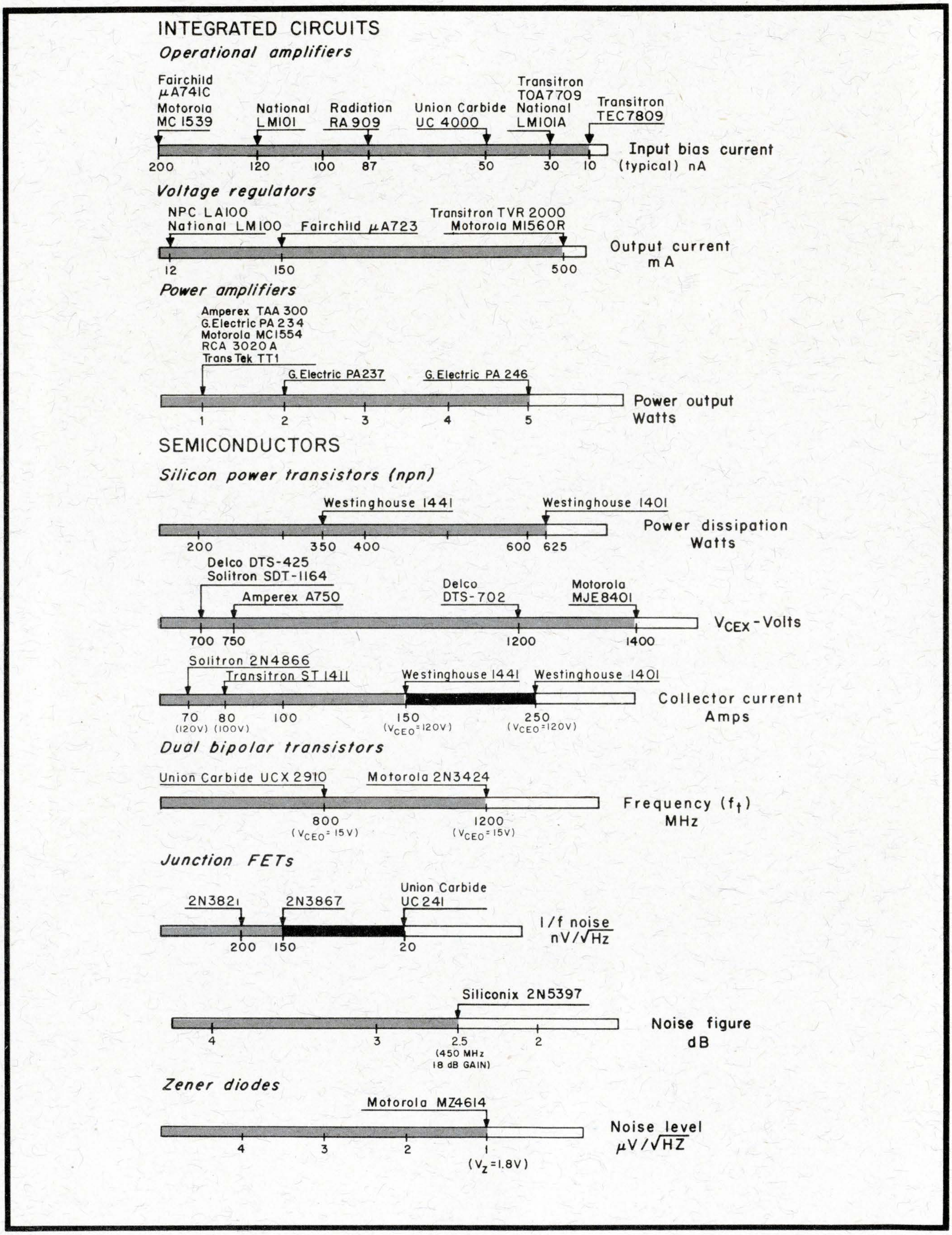
The EE Forefront is a graphical representation of the practical state of the art. You will find here the most advanced components and instruments in their class, classified by the parameter in which they excel.

A word of caution

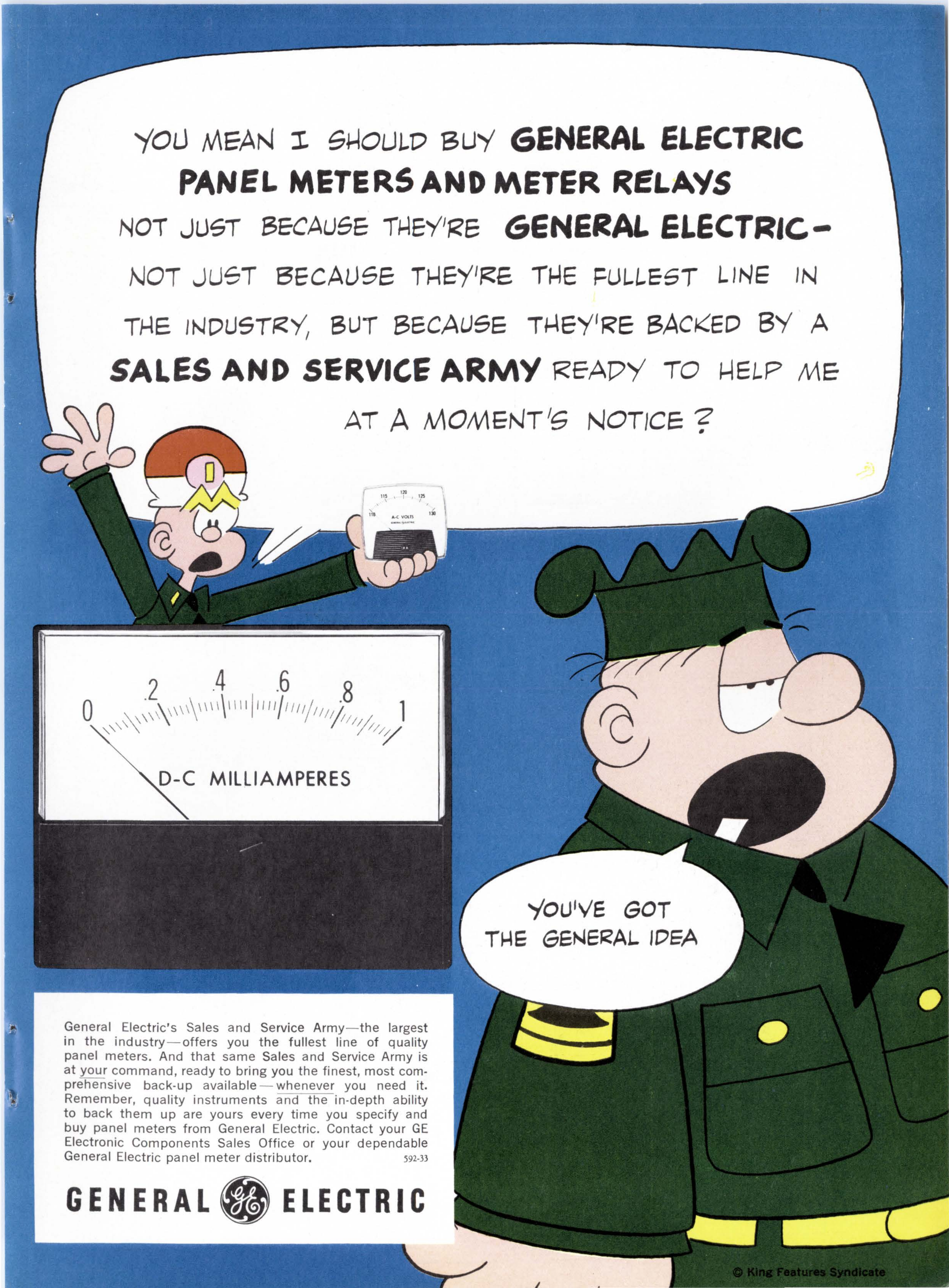
Keep in mind the tradeoffs, since any parameter can be improved at the expense of others. If there is no figure-of-merit available, we either include other significant parameters of the same products, or we provide additional bar graphs for the same products.

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





Circle 13 on Inquiry Card →


YOU MEAN I SHOULD BUY GENERAL ELECTRIC PANEL METERS AND METER RELAYS NOT JUST BECAUSE THEY'RE GENERAL ELECTRIC— NOT JUST BECAUSE THEY'RE THE FULLEST LINE IN THE INDUSTRY, BUT BECAUSE THEY'RE BACKED BY A SALES AND SERVICE ARMY READY TO HELP ME AT A MOMENT'S NOTICE?
0 .2 .4 .6 .8 1
D-C MILLIAMPERES
YOU'VE GOT THE GENERAL IDEA
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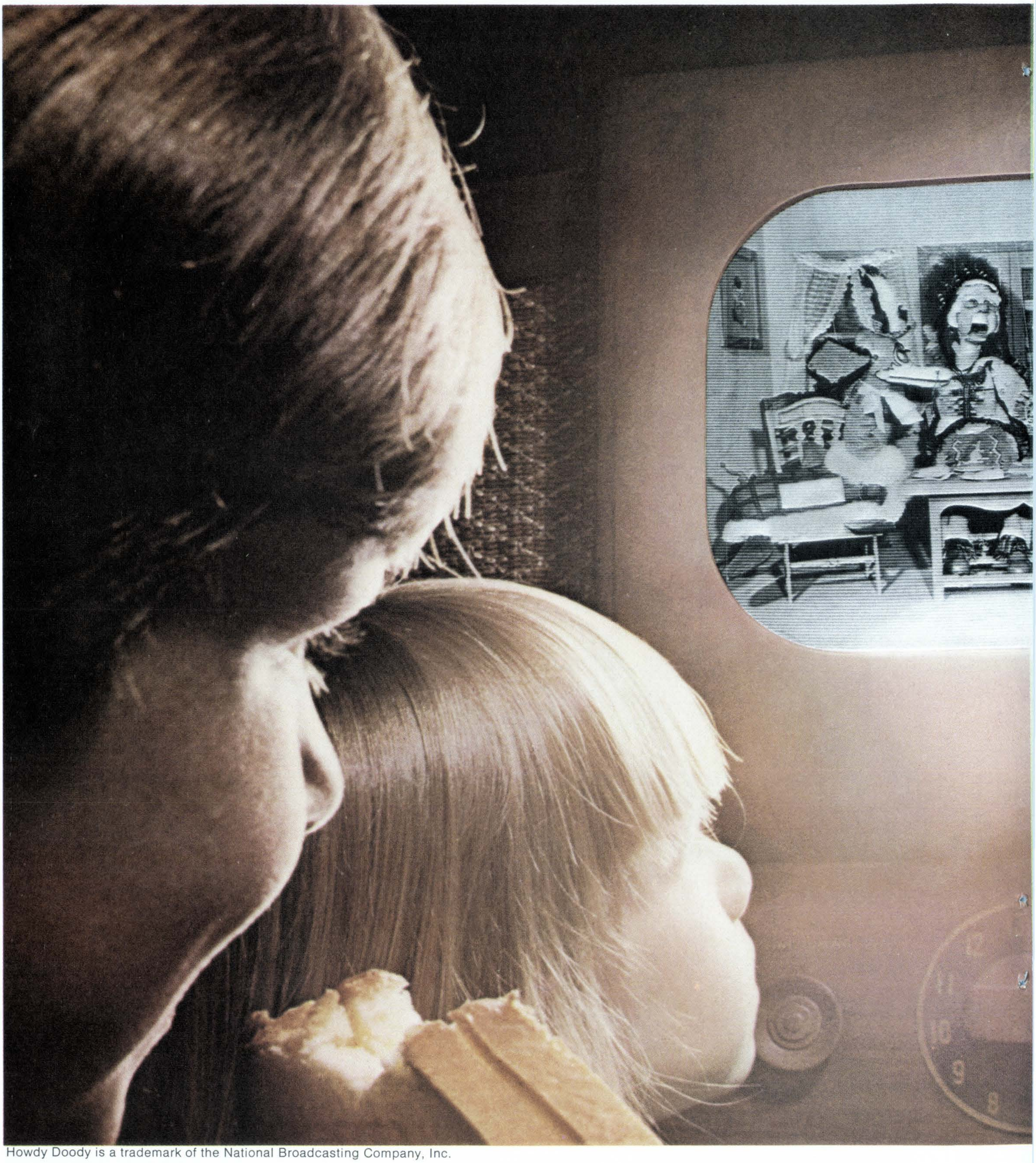
THE PLASTICS

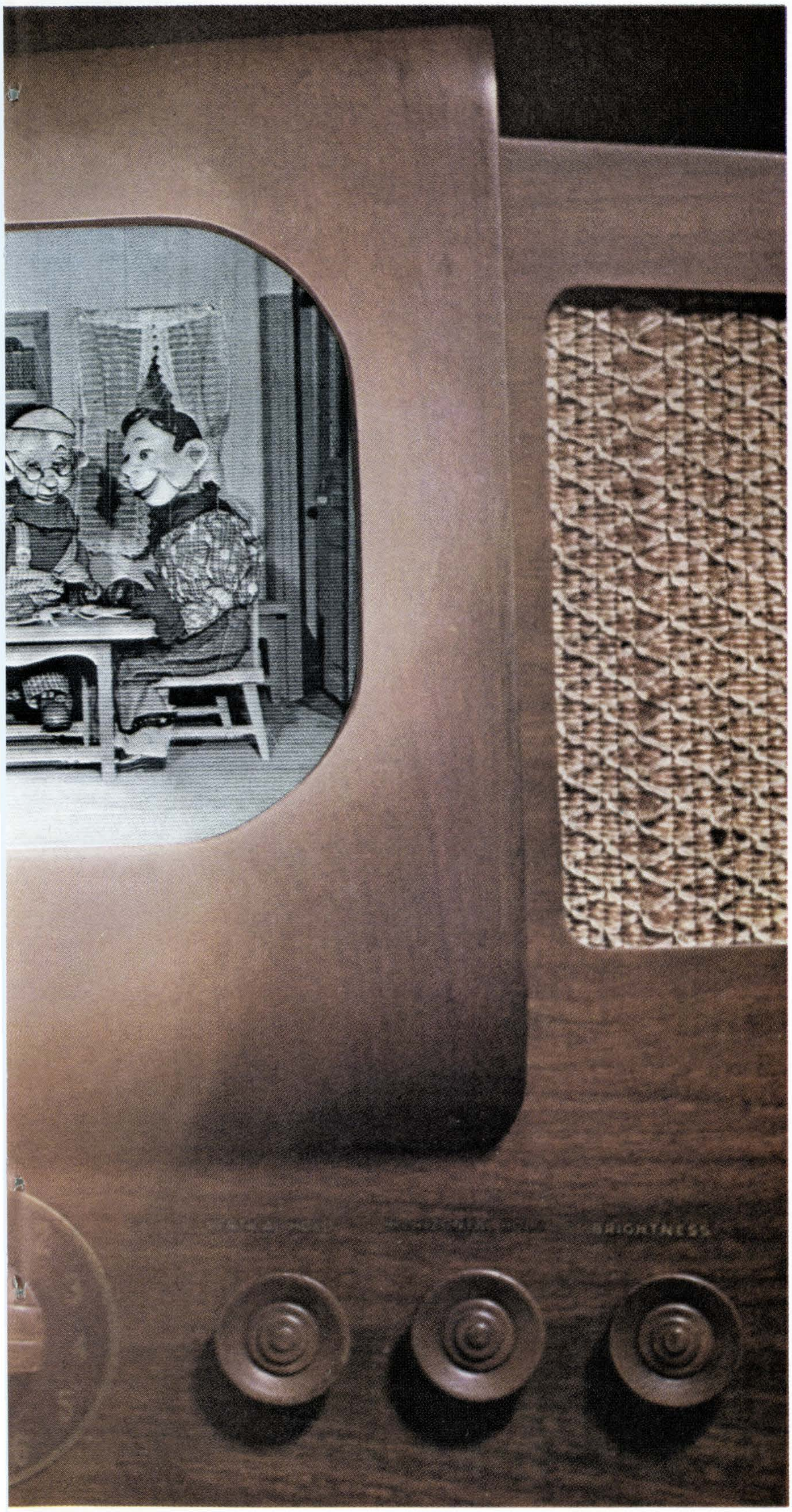
Back in the forties, one of the few uses of plastics in TV was for tube sockets. Today



Howdy Doody is a trademark of the National Broadcasting Company, Inc.

AGE + 20

there are hundreds.



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Circle 14 on Inquiry Card

Multiplexer has 32 channels

A 32-channel multiplexer with 40 analog switching devices on a single MOS (metal oxide semiconductor) chip has been developed by IBM.

The new IC has multiplexing circuits, timing logic, and two shift registers requiring an external clock and power supplies. Power requirement is reduced from 250 mW to about 120 mW.

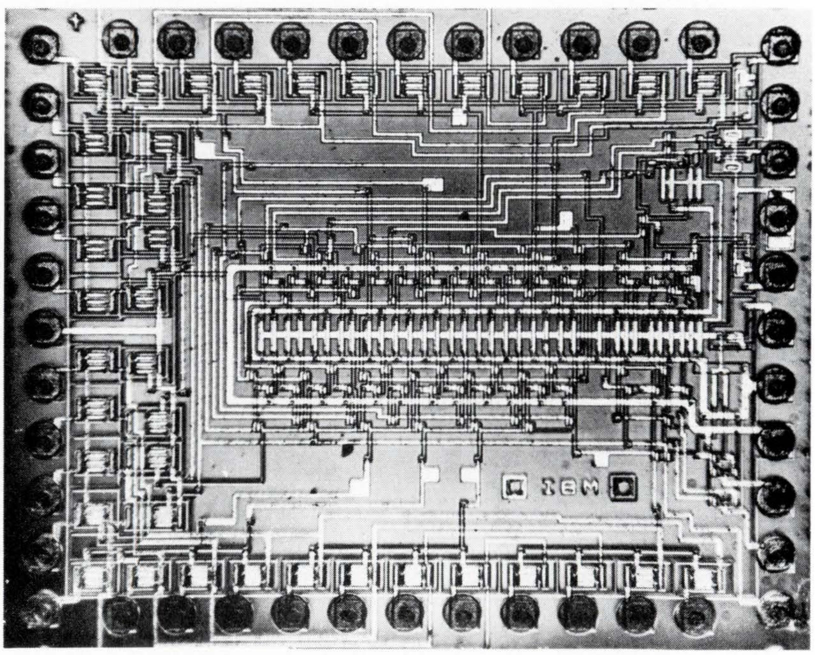
For systems larger than 32 channels, the chip can be interconnected to form a 64-channel or larger multiplexer in multiples of 32 or in a multiplexer-submultiplexer configuration.

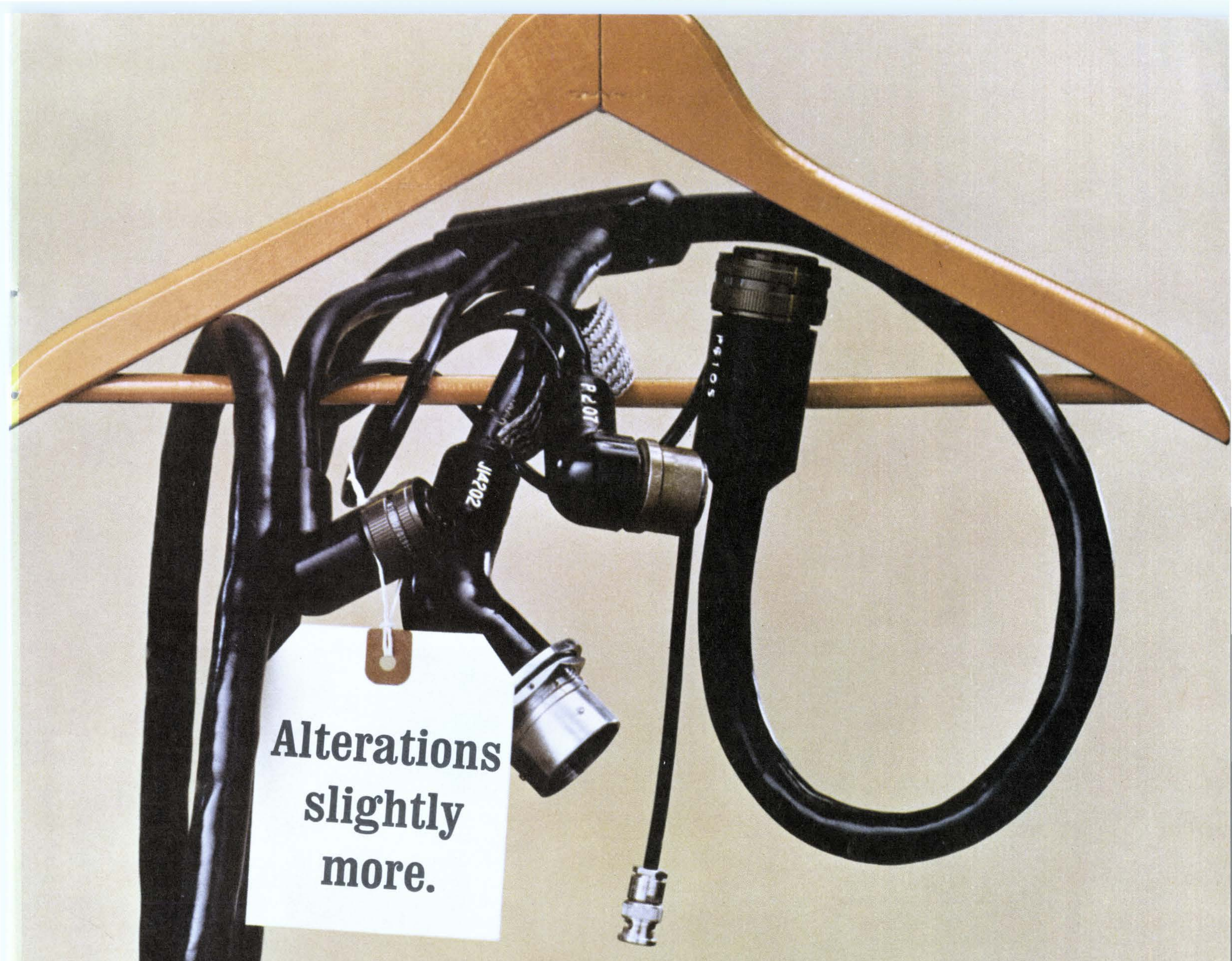
In its present form, the chip functions only as a serial multiplexer, but production masks can be modified to produce a random access multiplexer.

The analog switching devices are laid out in the shape of a "U" around the outside of the chip. Shift registers and associated logic are contained in the center. A holding register can be added to produce a random access capability if needed. Chip design is such that a random access multiplexer could be produced with a minimum of mask modification.

The IC was developed jointly by the Federal Systems Division's Space Systems Center in Huntsville, Ala., and the Components Division's East Fishkill facility.

This 32-channel serial multiplexer contains circuitry for both multiplexing and a five-stage counter. All of this circuitry is contained on the 117 x 117 mil metal oxide semiconductor chip. Forty analog switching devices, forming two matrices, are arranged in the shape of a "U" around the outside of the chip, and the shift registers and logic are in the center of the chip.




Alterations
slightly
more.
J4202

EE SPEAK UP

Subtract by complementary addition

Sir:

The statement in the article "Negative-binary Code Simplifies Logic Design" by P. C. Krueger (The Electronic Engineer, November, 1968) that ". . . both [addition and subtraction] types of logic must be built into the computer along with programs to order the right one at the right time" is patently wrong. Most computers use only an adder. Subtraction is performed in the adder by the simple process of complementing the negative operand and adding one in the least significant digit position.

The reason it works is easy to comprehend without a rigorous mathematical proof. By way of explanation, assume a one digit decimal adder which is capable of adding two numbers, either of which can assume any value of 0 through 9. The logic network comprising the operand registers and adder is basic, and the ability of the operand registers to present to the adder the nines-complement of the operand is straightforward, easy to implement, and need not be described.

It is obvious that adding ten to the sum will not affect it because there is only one digit position. The one in the tens position will simply be propogated as a carry. Therefore, if the negative operand is subtracted from ten and the remainder added to the other operand, the sum will be the desired answer and a carry will be propagated beyond the capacity of the adder, i.e., lost.

It remains now to show how the negative operand is subtracted from ten. Subtracting any number from zeroes must result in "borrows" from higher order digits. However, subtracting the number from nine will never result in a borrow and the result is the nines-complement. Adding one to the nines-complement will give the tens-complement; adding one to the 99's-complement will give the hundred's complement; and so on. Therefore, presenting the nines-complement to the adder and generating a carry into the least significant digit will be equivalent to subtracting the negative operand from ten before adding it to the other operand.

An example will show that this works.

(*continued on page* 26)

Here's your answer to shock and vibration problems

■ Allen-Bradley Type R adjustable fixed resistors are unexcelled for holding precise settings through extreme conditions of shock and vibration. This unusual ruggedness is the result of a manufacturing process—perfected and used only by Allen-Bradley—which hot molds the resistance and collector elements, terminals, and insulating material into an almost indestructible component. Thus, the controls can be mounted by their own rugged terminals *without* additional support.

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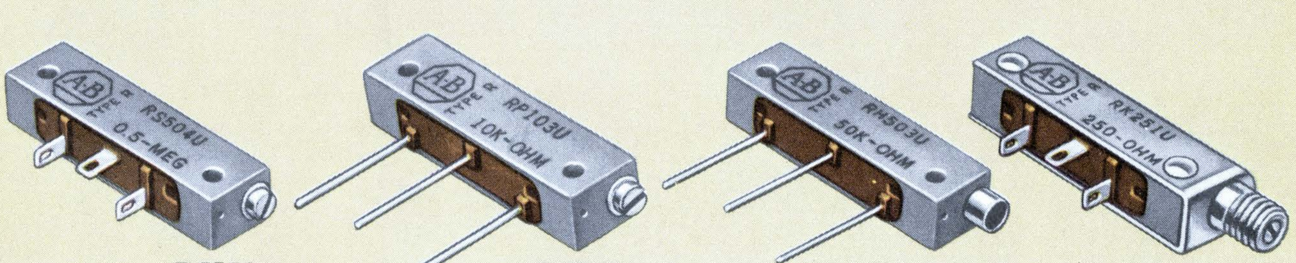
Allen-Bradley Type R controls are suitable for use from −55°C to +125°C and are rated ¼ watt at 70°C, 300 volts max. RMS. Available as standard in total resistance values from 100 ohms to 2.5 megohms with tolerances of ±10% or ±20%. As special, can be furnished down to 50 ohms. Technical Bulletin B5205 contains complete specifications. Please send for your copy today: Allen-Bradley Co., 1201 South Second Street, Milwaukee, Wis. 53204. Export Office: 1293 Broad Street, Bloomfield, New Jersey, U.S.A. 07003. In Canada: Allen-Bradley Canada, Ltd.

Allen-Bradley Type R Adjustable Fixed Resistors—Shown actual size



TYPE RS TYPE RP TYPE RH TYPE RK

ALLEN-BRADLEY
QUALITY ELECTRONIC COMPONENTS

266E-2

EE SPEAK UP

(*continued from page* 24)

```
  8  positive operand
 −5  negative operand
 03  difference

  1  carry
  8  positive operand
  4  nines complement of neg. operand
 13  sum
  3  difference (when carry is disregarded)
```

To extend the number of digits, more adder and register positions are added and the carries between the digits are propagated in the usual manner. For example:

```
                  1
  586           586
 −348           651
  238          1238
```

Extension to any desired number of digits is obvious. When an over-flow position is provided at the high order end of the adder output, the operands are modified by tacking on non-significant zeroes, e.g.,

```
                                  1
  6839                        06839
              06839     =
             −04334
 −4334                        95665
 02505  overflow             102505
        position
```

The ability to sense the final carry provides a means to make the operation of the adder more flexible. It simplifies the use of a computer if the arithmetic unit will give algebraically correct results without the user having to regard the relative magnitudes of the operands. If the subtrahend is greater than the minuend, then it is desirable to have computer subtract the positive number from the negative number and tag it with a minus sign. Determining the relative magnitudes of the operands is bothersome, especially where the machine is organized to retrieve and operate on only portions of operands at one time.

The solution is to assume first that the negative number is smaller and perform the subtraction process as described above. If a carry is propagated beyond the most significant position, the result is correct. If a carry is not propagated at the end, the result obtained is subtracted from zeroes. This is the same as taking the nines complement of each digit and adding one to the least significant position. The sign is also changed to a minus.

This is illustrated below.

```
                1
 −586         413        1
  348         348      000
                       237
 −238        0762
                      −238
```

The operations of algebraic addition and subtraction are equivalent if viewed in terms of the signs of the operands, remembering to change the sign of the subtrahend. Tabulated below is the summary of the possible combinations of operands and operand signs (S=SAME SIGN: D=DIFFERENT SIGN).

Addition

addend signs (first register)

augend signs (second register)

	+	−
+	S	D
−	D	S

Subtraction

minuend signs (first register)

subtrahend signs (second register)

	+	−
+	D	S
−	S	D

The arithmetic unit logic rules can be derived from the above and are summarized:

(1) when S, tag result with sign of first register and add register contents;

(2) when D, tag result with plus and add register contents, complementing the negative operand and generating an initial carry,

(a) if final carry is propagated, the result is correct,

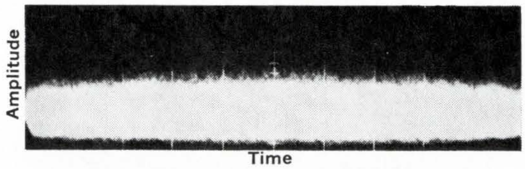
(b) if final carry is not propagated, add complement of result to zero, generating an initial carry.

Subtracting by adding the complement was used for centuries by merchants and mathematicians. Next time you want to compute the change from a large bill, use this method. What change do you get from a $10.00 bill when making a $3.76 purchase? $6.24, obviously.

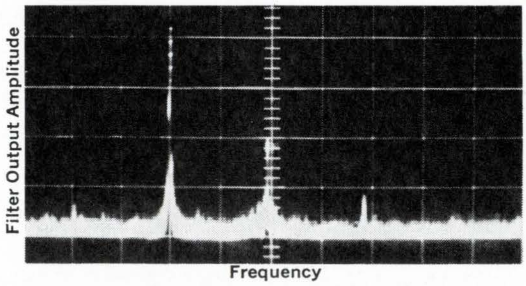
Carl M. Wright
Cinnaminson, N. J.

(*continued on page* 28)

Radar signal processing engineers:



NOISE EMBEDDED SIGNAL



DETECTED SIGNAL OUTPUT

Our expansion can be your opportunity.

Today at Hughes, we're developing digital radar signal processors for a variety of important airborne applications.

An engineering model of one of these processors has been developed for real-time operation. It uses the Cooley Tukey, or fast Fourier transform algorithm, to form a bank of 512 narrowband doppler filters, together with their associated detectors and threshold circuits.

The scope photographs show a processor input signal 12 db below wideband input noise, and the resulting processor output signal 15 db above rms noise in one digital filter output.

Several programs are now starting to carry this technique and others further toward operational radar systems.

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AEROSPACE DIVISIONS

EE SPEAK UP

(*continued from page* 26)

The author replies: I merely described a type of logic which has certain advantages in performing certain mathematical functions. Using Mr. Wright's example of $6.24 change, this change could be made in several ways too: $6.00, 4 nickels and 4 pennies or 1 five, 1 dollar, 2 dimes and 4 pennies—depending what you have and what you need.

P. C. Krueger
Wharton, N.J.

Who's responsible?

Sir:

The two articles in April EE, "EE Opinion" are timely and interesting. I tend to agree with Mr. Ficchi more than I do with Mr. Sears. Mr. Sears applies to the old tried and true attitude of be responsible for what you do, an unnatural and impossible extension of obligation beyond reason.

Mr. Sears' article appears to me to tell engineers they are forever responsible for the uses of their inventive genius. This I cannot accept. For example, did the inventors of the first automobiles mean for them to be used for burglar get-away cars too? I doubt it. He therefore appears to blame an engineer for all the different uses "someone else" will apply to his device. Even God doesn't judge a person on those terms.

His statement that engineers are not educated because they haven't taken courses in college that non-engineers take, is also not acceptable. Most engineers choose carefully their curriculum, just as carefully as some non-engineers choose theirs. In fact, you won't find any engineering students involved in political demonstrations that do no more than destroy, they are too busy working toward a goal they have already chosen. (This sort of logic could be bent around to imply non-engineers are not educated without courses that engineers take, and those people will be just as sensitive about that as I am about his claim I'm not educated.)

A fully responsible design engineer will have to keep his device to himself, not sharing it with others, if we are to accept Mr. Sears' attitude. Let's be responsible for what we do, but don't blame engineers for other uses of their devices.

James A. Strickland
Sr. Engr. Writer
Sampling Instr. Group
Manuals Dept.
Tektronix, Inc.
Beaverton, Oregon

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The result is trimmer performance neither wirewounds nor cermets can match. Only Film-Met™ offers both infinite resolution and a low temperature coefficient of 100 ppm/°C. (50 ppm/°C is available on request.) Film-Met trimmers have excellent high frequency and pulse characteristics and low contact resistance variation. Their low thermal and current noise features are comparable to metal film fixed resistors.

The new Amphenol Film-Met trimmer line isn't designed to replace wirewounds and cermets in every application. What Film-Met performance does is eliminate circuit design compromise. By adding these trimmers to our line of cermets and wirewounds, we can now match your performance needs perfectly.

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*U.S. Patent No. 3,353,134; also foreign patents.

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25
20
15
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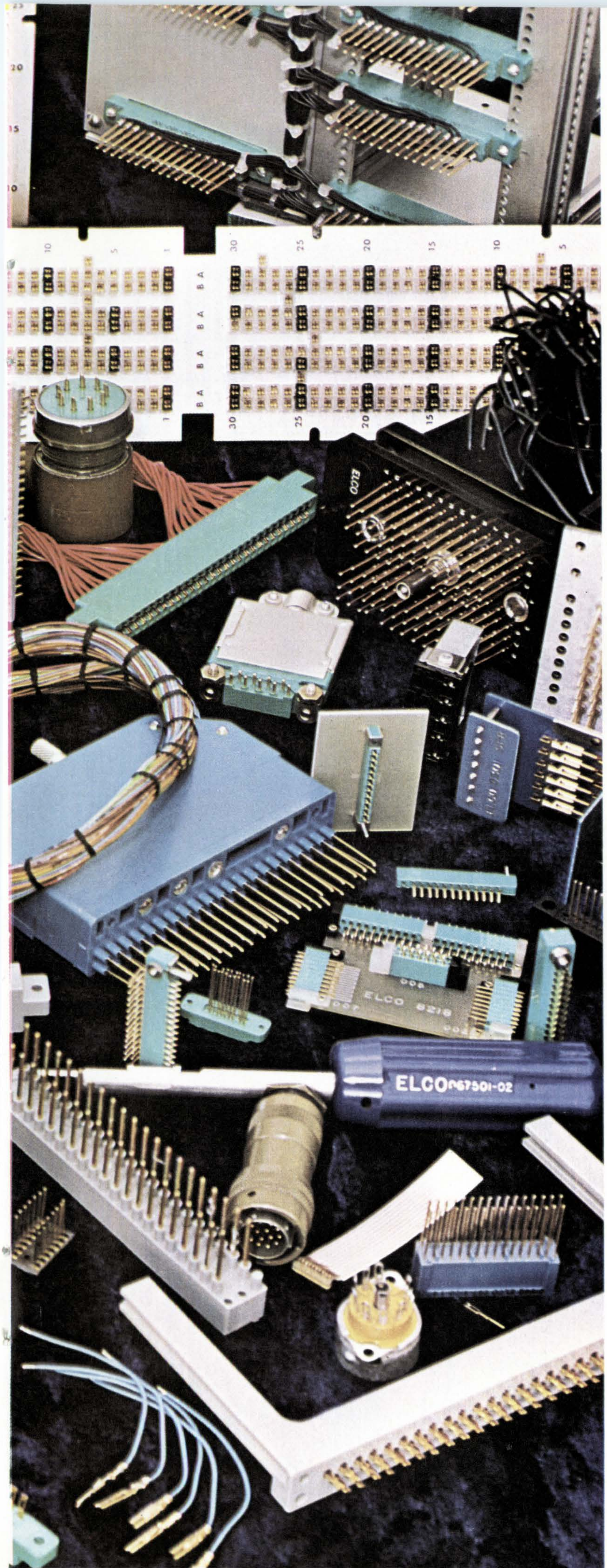

Several hundred thousand unfair advantages.

There you are, busting your back trying to beat another company to market with a new, improved electronic Thing.

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ELCO Connectors

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JULY

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

July 20-25: Eng'g in Medicine & Biology and Int'l Fed. for Medical & Biological Eng'g Conf., Palmer House, Chicago, Ill. Addtl. Info.—Box 1969, Evanston, Ill. 60204.

July 28-Aug. 1: '69 Research Conf. on Instrumentation Science, Hobart and William Smith College, Geneva, N. Y. Addtl. Info.—Thomas E. Tremellen, Mgr., Education & Research Services, Instrument Society of America, 530 William Penn Pl., Pittsburgh, Pa. 15219.

AUGUST

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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.

SEPTEMBER

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

'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

April 6-8, 1970: Third Communications Satellite Systems Conf., Los Angeles, Calif. Submit 1000-word abstracts in triplicate before **Sept. 25, 1969** to Nathaniel E. Feldman, The RAND Corp., 1700 Main St., Santa Monica, Calif. 90406.

May 19-21, 1970: Conf. on Signal Processing Methods for Radio-telephony, London, England. Submit a 250-word synopsis by **Aug. 25, 1969** to IEE Conf. Dept., Savoy Place, London, W. C. 2, England.

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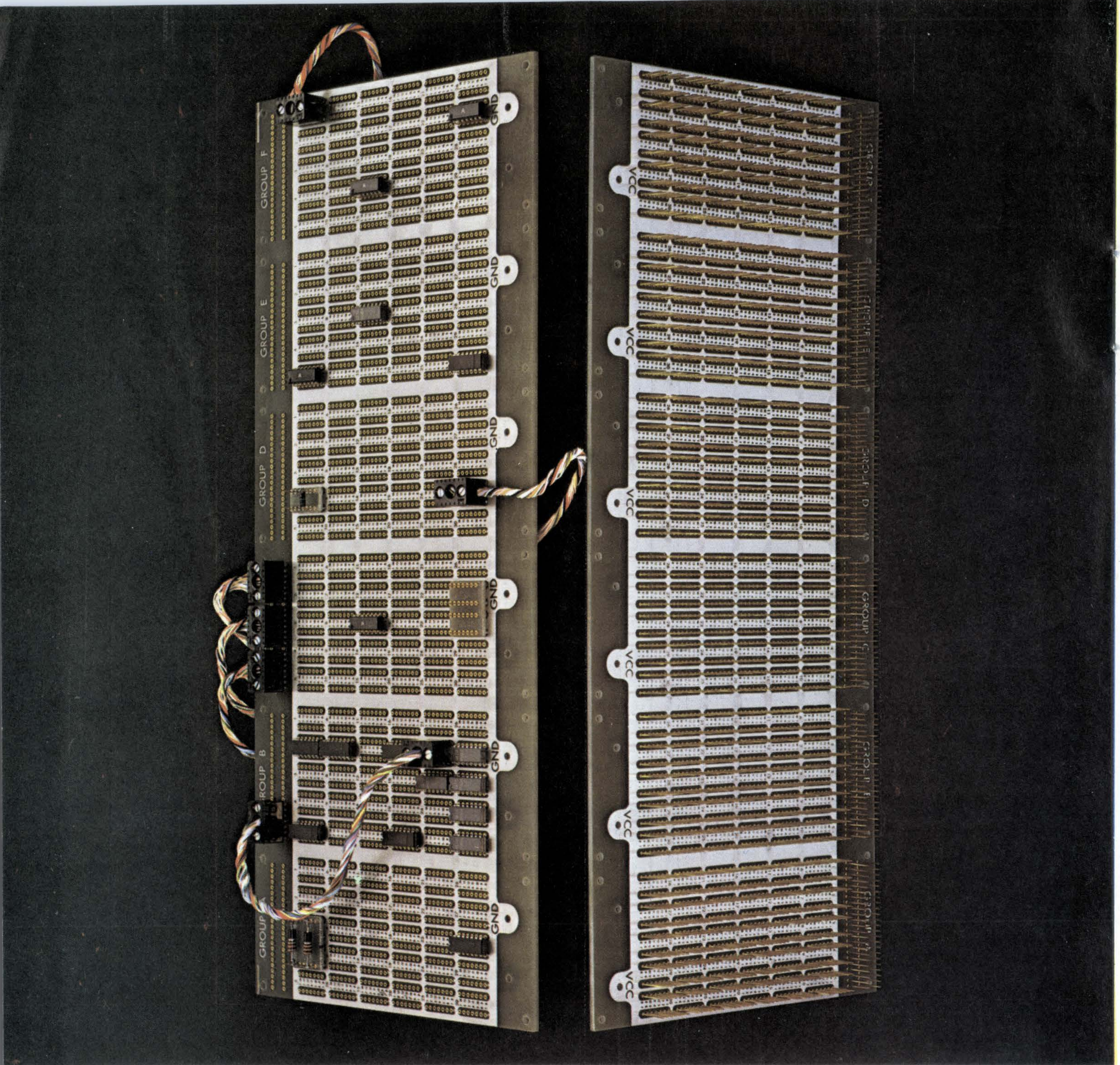

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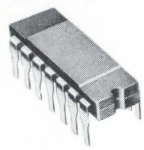

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Circle 24 on Inquiry Card

EE CAREERS

Would you put that probe on your sick grandmother?

Who should regulate safety in electronic instrumentation for medicine? The government? The UL? Whoever does it, only you can implement it.

By Roger Kenneth Field, Contributing Editor

It's a rainy night in the middle of March, and a few dozen men—some perhaps driven there by conscience, others by curiosity—assemble at The New York Academy of Sciences to hear an unsettling account of defects in medical instrumentation—defects believed responsible for roughly 1200 deaths annually in hospitals in the United States.

The speaker is Seymour Ben-Zvi, an engineer who for two years has been Director of Scientific and Medical Instrumentation at the State University's Downstate Medical Center in Brooklyn, New York. The audience consists of doctors, representatives of medical instrument manufacturers, several engineers who, like the speaker, are working for hospitals and medical centers, and several members of the press.

At the appointed hour the meeting's chairman, Dr. M. Jack Frumin, introduces the speaker, and announces "a slight change" in his topic. From "safety standards in medical instrumentation," he says, "the author has very appropriately changed it to "the **lack** of safety standards in medical instrumentation." (Members of the audience chuckle nervously.)

Seymour Ben-Zvi steps up and places his notes on the stand. He is of small physical stature, neatly dressed, dark-rimmed eyeglasses, extremely polite, a quiet man.

Mr. Ben-Zvi tells the audience that during the last two years he and his colleagues at the Downstate Medical Center have checked several thousand pieces of incoming medical instrumentation for defects. The equipment, he explains, is considered acceptable if it meets

Mr. Seymour Ben-Zvi, *"Forty percent of the medical instrumentation I have checked is defective."*

two simple requirements: First, the unit must meet the specifications set by the company that made it; second, it must not be hazardous to the patient or to those who use it.

In spite of the modest nature of these requirements, nearly 40% of all incoming instrumentation is defective—a startling rejection rate, and a frightening one when you consider that very few hospitals check incoming instrumentation at all!

The defects of rejects

The defects, Mr. Ben-Zvi explains, are not trivial; they can seriously mislead the physician in his diagnosis, or can directly injure or kill the patient—or even the physician himself. Mr. Ben-Zvi gives some examples of such defects, which he insists were chosen more or less at random and not to shock the audience:

In a centrifuge, the manufacturer placed what he thought was an insulator—a black, cardboard-like material—between the "on-off" switch and the metal housing of the unit. Proper testing, Mr. Ben-Zvi believes, would have revealed to the manufacturer that the so-called insulator was a truly good conductor of electricity.

Not all the defects uncovered by Mr. Ben-Zvi's group are quite so obvious. He cites, for example, the case of the nasty sigmoidoscope—a long hollow tube with a concealed light bulb that the physicians use to peer up the patient's rectum and into his colon. The unit's six-volt bulb is isolated from the 115-volt line by a transformer. The patient is usually propped up on a metal examining table. Quite possibly he is connected to other instruments, which, in turn, are grounded. "All that is now needed," says Mr. Ben-Zvi, "is a short between primary and secondary windings in the transformer: lethal levels of current could flow through the patient. This may be one way to remove hemorroids, but I'm certain there are far better, safer ways to do it." (Chuckling.)

Failures such as a primary-to-secondary short in a transformer are not nearly as uncommon as one would like to think. For example, Mr. Ben-Zvi examined a shipment of ten defibrillators,* and found that in all ten, the critical vacuum relays that turn the high voltage on had not been properly degassed. Consequently, the defibrillators discharged the high-voltage pulses even when their triggering buttons were not pressed. "The hazardous condition (of the defibrillators) could have been fatal to both the physician and the patient," says Mr. Ben-Zvi, "especially the patient, if the physician had been doing cardioversion, a procedure where the energy must be delivered to the heart at a fixed point in time during the cardiac cycle.

"All defibrillator manufacturers claim they check all machines completely before they are shipped. Nevertheless, when units arrive at the hospital—whether it's from moisture accumulation in the vacuum relay, insufficient degassing, or a crack in the glass envelope of the relay due to improper handling—a hazard exists far more often than the manufacturers are aware. . . .

"One manufacturer said that his company stood behind every unit it made; that if a unit is found defective they would be happy to replace it. But how will they replace a dead patient, or physician, or nurse who was killed because of that machine?"

* * *

Seymour Ben-Zvi's speech is certainly an eye-opener. More amazing still, however, are the questions and answers that follow it.

Question (*The Electronic Engineer*): You've showed us some rather striking examples of safety hazards—for example, ten defibrillators that did not work properly—and I wonder if you can name their manufacturer—as well as the manufacturers of other faulty equipment.

Answer: I don't think this is the proper time or place for it.

Q: Why?

A: There are certain problems involved in naming this . . . I'd have to first clear it with our university. I'm not an independent agent; we're not doing this as an independent group. We're part of the State University.

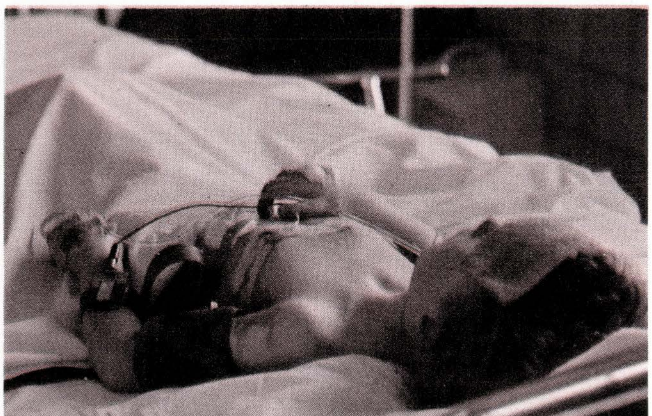
Q: One of the principal problems involved in tracking down these difficulties is that doctors are unwilling to mention names of equipment manufacturers, or to specify which equipment is at fault. And for those of us with the press it is very difficult to get after these people when you can't mention their names.

A: I agree, and we hope to correct this. There are many groups that are interested in finding out the names of the companies and I am working with these people, and we're going to try to do something about it. At the present time I can't give you any information along those lines.

Q: Is there any pressure brought to bear on you from your superiors?

A: Let me say this. We have been fairly successful in negotiating with the manufacturers to correct many of the problems in design, strictly because we haven't announced to the public the particular manufacturer's name. They certainly don't like this kind of publicity and . . . er . . . in just discussing this on a confidential basis they have been always openminded: They have listened to our complaints, they've evaluated our suggestions and, if they've found them valid, they have modified their equipment. As an example, one of the companies that makes the sigmoidoscope has redesigned its unit. This now has a three-prong plug, and a double-shielded transformer, which the earlier models did not have.

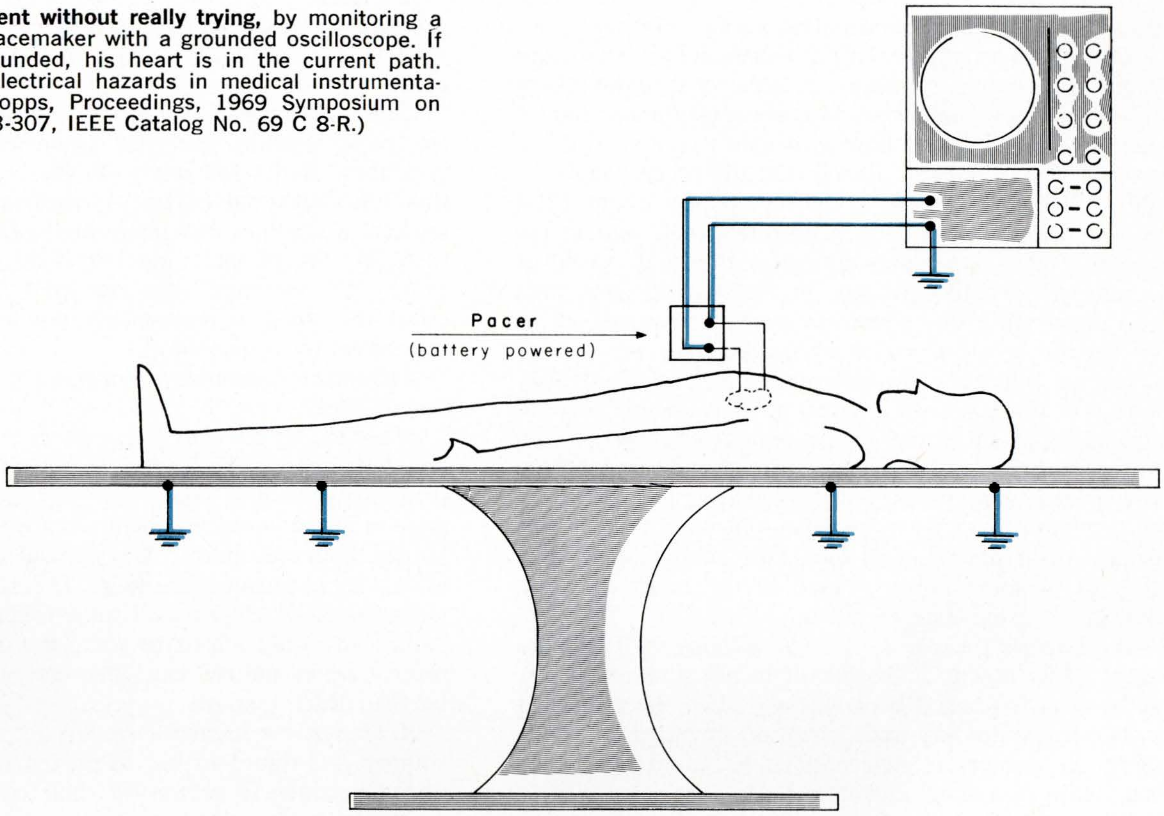
Q: Would it be possible to have the manufacturer's personnel check out each piece of new equipment at



". . . the physician is an unsophisticated purchaser of sophisticated equipment . . ."

* Used to restore coordination to the heart's natural pacemaker. At the push of a button, a high voltage vacuum relay closes and the defibrillator jolts the heart of a patient with a 7500-volt pulse that interferes with the uncoordinated muscle activity, and allows the normal beating to take over again.

How to kill a patient without really trying, by monitoring a battery-powered pacemaker with a grounded oscilloscope. If the patient is grounded, his heart is in the current path. (Adapted from "Electrical hazards in medical instrumentation," by J. A. Hopps, Proceedings, 1969 Symposium on Reliability, pp. 303-307, IEEE Catalog No. 69 C 8-R.)



the hospital to insure that it works in accordance with advertised specifications.

A. We have tried that and we have been successful. It took one company a year to get their equipment working. (The audience laughs.) Nevertheless, I find that most of the manufacturer's sales representatives, even though they're quite capable and know how to use the equipment, are not equipped to make the kinds of tests required.

Q: What about equipment recall? What happens to all the equipment in the field that is not modified?

A: When we brought the defibrillator failure to the attention of the manufacturer, he immediately advised all hospitals and people who had purchased this particular model to conduct certain basic tests that would expose this defect. In this way they are doing what the auto companies . . . recalling the instrumentation.

The chairman interjects: I think it's fair to state that, although one company may be responsible for one defect, all of them (the instruments) have defects at one time or another. But this is a generalized problem and there's not much point to singling out one particular company. All of them have problems.

Q: I'm not looking for one company. I'm looking for lists of companies.

A (*Mr. Ben-Zvi*): There are many. I would almost be willing to say that a major portion of the instrumentation—as we've indicated in our case, 40% —is defective. And this comes across the board—both mechanical as well as electronic. So that one can see that this is true with almost every company.

Q: Do you routinely do anything in your hospital to alter any of this equipment as it comes in? Like, for example, do you routinely cut off two-prong plugs and install three-prong plugs?

A: The University has a basic policy that requires that all equipment should have three-prong plugs.

Another member of the audience questions the speaker on the status of legislation that would set safety standards.

Q: What are your comments on current bills pending before Congress? Who would you propose should do the regulating?

A: Some people have started to take action, including Ralph Nader, who has taken up the banner. They are trying to get some legislation. Last year they weren't very successful—the bills didn't pass. What will happen in the future I can't really say, but I read a very cute statement that someone said: "As soon as the first congressman's wife gets killed we'll have a bill tomorrow." And I agree.

Chairman Frumin: We (the chairmen) selected this topic precisely to create the atmosphere that might ultimately result in legislation being passed. Members of the press come . . . with a lot of manufacturers . . . and this is the kind of understanding the public has to have to press for legislation.

An audience member points out that this country is trailing Canada in the legislation of medical safety standards for electronic instrumentation:

I'm in industry, and we've been involved with the Canadian standards. If the American manufacturers followed these standards, they would be well on their way to safer instruments. For example, every instrument that goes to Canada has to be high-potted—a thousand volts between any ac line and the case. You can't sell a two-line-cord instrument in Canada. You can't even have it "mechanically" connected to ground —it must be first mechanically secured, and then soldered. The Canadian standards are a good place for the American manufacturers to start.

Q (*Another member of the audience*): The engineers have taught physicians a great deal about safety . . . um. I am Director of a coronary-care unit and I dare say that learning how to isolate pacemakers from ground was a valuable lesson. On the other hand . . . ah . . . when one reads in the newspapers about 1200 people being electrocuted in hospitals each year in the United States—and then taking an informal survey of coronary-care-unit directors in the metropolitan area and discovering that none has ever noted a patient in his care to be electrocuted within the past two years—I suspect that one can interpret your remarks to say that 40, 30, 10, even 5% of patients in the hospital right now are in serious risk of being electrocuted. And this doesn't jive with my experience. I want to get from you a realistic appraisal of, first, what is the real extent of the lethal hazards to patients—in what area is this hazard most severe—and then (for you) to give us a clue as to some things missed in the report of what happened at the time of death.

A: This isn't a case of a single parameter. There are many. This is why it is difficult to get a report of exactly what happened because very often the patient is in bad shape anyway and there's no investigation made of the equipment to determine if he could have been the victim of a small current.

Chairman Frumin: Often a patient dies during an operation where anesthesia is being used along with electrical apparatus. And there you never know (the cause of death) because there's surgery, anesthesia, and electrical apparatus. That's why the 1200 figure is a gratuitous one . . . it's a guestimate.

A gentleman stands up to assert that he believes the clean-up should begin in the medical sector, rather than in industry: I'm sitting on both sides of the fence being a part of the section here (The New York Academy of Sciences) and being in industry. I share Mr. Ben-Zvi's concern. For the last twenty years I have been in a position of passing a lot of equipment into hospitals. And I had to learn, the hard way, that from the most reputable and most august institutions of commerce the equipment sent out is not reliable enough to put into the hands of a layman. We had to learn in industry, at our own expense, that we have to take every piece of equipment and make a physical and electrical check—at our own risk and for our own survival.

Going back and looking into the industrial enterprises, you find that the personnel used in the final check-out procedure have nowhere near the status, the income, or the reliability that the job really demands. Usually somebody very low on the industrial scale of income and responsibility is given the task to "check it out and ship it." And the management, the chief engineers, and all the other officers intentionally fluff off this important and vital task. As a result, many very expensive, well-conceived, and excellently designed pieces of equipment are slovenly put together, with no one at the tail end to catch this. A very inefficient and dangerous practice. I think it behooves the medical profession, much more than us in industry, to start a hue and cry, and say, "Put on the best possible people that you can find in your industrial enterprise to make sure that the quality of your product is high enough so that it can go into the hands of a technical layman—which the physician happens to be."

Q *(The Electronic Engineer):* In many products, like toasters or washing machines, Underwriters Laboratory tests these things for safety. Is there any requirement that UL check out or test or ascertain the safety of medical electronics and instrumentation?

A: At the present time UL does not have a program . . . does not have any kind of tests that will cover the types of instruments that you come across in medical instrumentation.

An audience member interjects: That's not so. That's not so, Ben.

Mr. Ben-Zvi goes on: They do certain types of testing, but they do not cover, across the board, all the types that will give you a safe instrument. Of course, there is an additional problem: It's not required in the United States to have UL approval to sell either to a state or to various hospitals. The amount of time it takes to get UL approval is quite long and many companies just can't afford to wait. I'm sure a manufacturer's representative can give us more information on that. Bill?

A man in the audience stands up: Yes. One of the companies I represent has taken the trouble, the time, and the money to submit all their commercial instrumentation to UL. And none of the equipment is put out for sale until they have gotten complete UL approval.

Q *(The Electronic Engineer):* How long does that take?

The same man: Sometimes a year; sometimes a little longer.

Once again, Mr. Ben-Zvi continues: But this does not in any way test the piece of equipment. I think if you look into this, they check the line cord, they check the components, but they don't check the entire instrument as a functioning unit, such as a defibrillator. They may check only certain parts of it, but just because the instrument has UL approval there is no guarantee that it's safe, and many people are deceived by this. I even heard one physician say to me, "Well, that instrument was approved by UL. Look at the line cord; there's a little yellow tag on it." But that was just the line cord that was UL approved. The rest of the instrument certainly was not.

Q *(The Electronic Engineer):* You mean that manufacturers can buy line cords that are approved by UL and put them on instruments?

A: Of course. You can buy line cords and put them on anything you want. Go down to Canal Street (New York's radio row) and get all you want. (Several members of the audience chuckle).

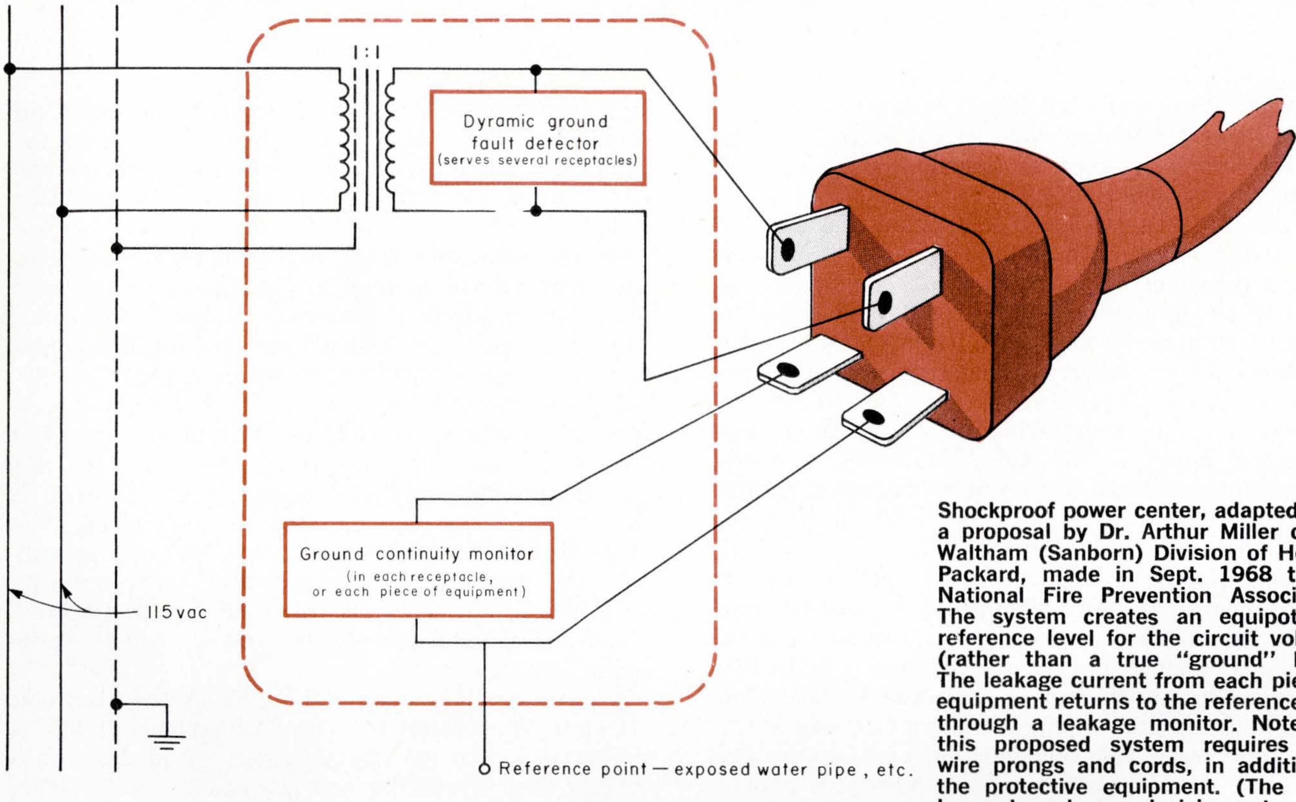
The gentleman who had previously described himself as director of a coronary-care unit poses another question:

Q: On the defibrillator. Did those you tested still use a vacuum relay for high-voltage switching?

A: Most manufacturers today still use the vacuum relay for high-voltage switching.

Q: What safer method is there?

A member of the audience volunteers an answer: I think that one of the biggest faults of defibrillators is that glass-enclosed relay, because you can have



Shockproof power center, adapted from a proposal by Dr. Arthur Miller of the Waltham (Sanborn) Division of Hewlett Packard, made in Sept. 1968 to the National Fire Prevention Association. The system creates an equipotential reference level for the circuit voltages (rather than a true "ground" level). The leakage current from each piece of equipment returns to the reference level through a leakage monitor. Note that this proposed system requires four-wire prongs and cords, in addition to the protective equipment. (The NFPA has not made any decision yet on this system, nor is there any equipment built that complies with it.)

ionization within the relay itself—and this is definitely a hazard. But there are semiconductors today that can switch high voltages more reliably than can a glass-enclosed vacuum relay.

Another member of the audience: There are new protective devices now coming on the market that will indicate leakage going outside the instrument—such as through the patient. For example, Cambridge Instruments has just come out with an instrument* that can shut off the power if there is more than a set amount of leakage. Also, Federal Electric offers a unit for installation into operating rooms (which can be similarly tripped by small currents).

Mr. Ben-Zvi: Are there any more questions?

The manufacturer's representative who had addressed the group earlier requested the floor:

Yes. I'd like to make a plea for positive action, since many of the people here are professional. I think we have a parallel in the aircraft industry. In the early days of flying the pilot checked out his own plane. Later he got mechanics, and eventually these mechanics had to be certified. Maybe the various members of the profession will see to it that the many medical-electronic engineers and technicians now graduating from school are qualified for their services and have a sufficient sense of responsibility to see that the quality of the equipment they handle—the quality of the equipment they allow to get on the patient for diagnostic use—is of sufficiently high standards. I think that industry will eventually—at some price, but eventually—follow suit. I think what we need is a drive for registration of qualified personnel, and standards that are enforced, so that at least the manufacturers live up to the specifications they themselves print on their own literature.

* * *

With this impassioned statement the meeting at The New York Academy of Sciences ended. However, the question-and-answer session continued deep inside each of the participants long after the lights at the Academy were extinguished and the big doors locked for the night.

We are dealing here with a complex problem that presents a beholder with many facets.

- First, should a machine kill a patient, the doctor that used it and the hospital that provided it are open to malpractice suits. Consequently, neither doctors nor hospitals crawl over each other to report a lethal diagnostic test. And, since a cause of death can only be surmised—but not proven—the statistic of 1200 deaths annually can be opened to doubt.
- There is much haggling and little medical agreement on the amount of leakage current the human body can withstand. Or on the amount that is lethal. Actual values, of course, depend upon such indeterminables as the exact path of the current, the hardiness of the patient, the moisture of his skin, and whether or not the current is introduced below the skin, which is normally a good insulator.

For example, it was generally believed that the human was able to tolerate at least 100 mA, provided the skin remained intact and unpunctured by the electrode delivering the current. Recent tests, however, indicate that a human hand cannot let go of a rod that delivers only 20 mA, which seems to be enough current to interfere with the motor neurons and immobilize the fingers. And once the skin is punctured, as little as 20 μA delivered to the heart appears able

*EDITOR'S NOTE: This gentleman refers to the Camsafe®, a leakage indicator for power lines, made by Cambridge Instruments for its Versascribe® electrocardiograph. It trips with leakage currents of 10 μA.

to trigger ventricular fibrillation.

Safe limits for leakage now appear to be 5 μA for currents introduced inside the human body, and 1 mA for currents outside it.

• As Mr. Ben-Zvi points out, many medical colleges in the past have placed little emphasis on developing and strengthening the physics background—an unfortunate situation in medical education that has not changed significantly. Consequently, a chronic barrier has developed in information and understanding between doctors and engineering.

• As electronic instrumentation moves into operating rooms, intensive care units, and recovery wards, the patient now finds two or three electronic gadgets hanging on him, when at one time he would have seen one or none.

Thus the stage is set for a weird kind of anti-synergism: One instrument can provide an unintentional path to ground for a lethal leakage current from another instrument. Or the use of a cauterizing probe may require seating the patient on a grounded metal plate coated with conductive jelly while a monitoring instrument, which was designed under the assumption that the patient would be electrically floating, kills him by trickling a handful of microamperes through his brain or heart to ground.

• There is no standard and no convention to suggest to the designer what part of the circuit the patient should be. "Some manufacturers of monitoring equipment say that the patient should be grounded only through the monitoring equipment, while instrumentation delivering energy to the patient should be floating," says Mr. Ben-Zvi. "Electrosurgical instrumentation manufacturers, however, don't fully agree."

• The logical person to demand automatic protection devices—which would detect higher-than-normal leakage currents and turn off power or sound an alarm—is the physician. But he doesn't so far seem to understand what can and should be incorporated into circuit designs for medical instrumentation. He is an unsophisticated purchaser of sophisticated equipment, far more qualified to evaluate tongue depressors than electroencephalograms.

• The presence of an Underwriters Laboratory tag of approval, in the context of medical instrumentation, is at best almost meaningless and at worst misleading. UL is a private organization originally formed by an association of fire underwriters for the purpose of reducing electrical fires caused by inferior plugs, cords, and household devices. As such, it is mainly concerned with the building connected to the power cord of an instrument—not with the patient connected to the probe.

But UL may yet come to develop meaningful standards for medical instrumentation, if a proposal by one of UL's engineers—G. E. Schall, Jr.—is taken seriously. In a recent memo, addressed to the organization's Electrical Council and to many manufacturers and users, Schall recommended a code covering medical instrumentation, setting acceptable leakage limits for equipment connected internally or externally to the patient (separate limits for each type of connection) and safety devices that would warn the physician should those limits be exceeded. In addition, Schall suggests a plug convention in which an appropriate number of prongs would be required depending on whether the equipment was intended for use in the home, the recovery ward, the intensive care unit, or the operation theatre.*

• The economics of the marketplace do not encourage companies to develop the quality control needed for proper production of flawless medical instruments. The total amount of money spent on medical equipment in this country, \$0.3 billion, is a pittance compared with the \$55 billion spent for other medical services and products, or with the \$25 billion spent for electronics. And there are over 1000 firms dividing up the medical equipment market, half of which is X-ray equipment and hearing aids—products that don't require very much in the way of dazzling technological expertise anyway. Medical instrumentation is, in a sense, the economic stepchild of both industries, which are booming much more than is medical equipment.

• Finally, the design philosophy of the electronic engineer who creates new medical equipment has to evolve to match the characteristics of medical duty. "They rolled a beautiful new instrument into my office the other day," says a Boston surgeon, "and I knew it wouldn't last three days in the clinic. Those people are out there trying to save lives, and when they need a piece of equipment, they grab it; when they're through, they toss it on the side. They just don't have time for the niceties of testing and calibrating instruments just prior to use—that's not how hospital people work. Many of them are fairly unskilled, and all of them are under a lot of pressure."

Rx for medical instrumentation

Clearly, the designer will have to start adding into the design equations two new variables—the patient and the hospital environment—as well as all the normal parameters of good ordinary industrial design. This means the designer must isolate from line currents or, better yet, use batteries wherever possible. This also means he must include protective circuitry and devices, which indicate excessive leakages or poor ground contact and automatically turn the equipment off. This means he must anticipate the effect of otherwise innocuous monitors on the patient who is, in effect, part of a larger circuit. This means the engineer, in his role as a moral man, should demand legislation requiring such circuits and signals, as well as three-prong plugs and high-potted cases. And most of all, this means that those who make medical instruments must absolutely insist on zero-defects and 100% quality control at the factory, since most malfunctions are directly traceable to poor design, slovenly assembly, or lack of quality control.

*EDITOR'S NOTE: Since many of the references to UL contained in the preceding pages of this article represent personal impressions, rather than accurate reports, **The Electronic Engineer** magazine has invited the UL to present its case, in a forthcoming issue.

INFORMATION RETRIEVAL
Careers, Medical electronics

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EE WELCOME

This column welcomes new companies or new divisions in the electronics industry.

LSI tester sans computer. Educational Computer Corp., located halfway between Philadelphia and Atlantic City in Sicklerville, N. J., has two main product lines. As the company's name implies, one of these is an electronic instructional machine for vocational-technical training.

Of more interest to electronic engineers, however, is the firm's array tester. Built for those designers who make short runs of different circuits, the unit does not need a computer, and can test almost any array or IC—be it LSI, MSI, or MOS. Among its features are: a word generator capable of 40 words, each 100 bits long, and bit rates from dc to 2.5 MHz; a four-channel clock generator with adjustable frequency, sequencing, positioning, inhibiting, and leveling of clock pulses; a 16-channel comparator with adjustable bit time strobe, 1 and 0 level windows, don't care inhibits, and error overrides; and a 40-channel converter with every word adjustable for 1 and 0 levels.

The average price with typical options is about $40,000.

Despite all the glamorous publicity on the computerized tester types, Al Homann, vice president of ECC and developer of its LSI test console, feels his product has more to offer right now for many applications. "In fact," he says, "the easiest people for me to sell are those who have already gone the computer route, because they now know it's not always the answer."

He backs this statement up by noting the price differential—computer-driven testers are much more expensive (in the one-quarter to one-half-million dollar range). And if a company finds it would like a tester for every probing station, the cost for computerized types becomes prohibitive. Moreover, these testers usually take a good few weeks to program, whereas ECC's can be programmed in less than a hour.

The ECC unit was first announced Aug. 15, 1968, and by now 10 have been delivered. General Instruments alone has bought three. Some of the other customers include Philco-Ford, Blue Bell, Pa.; Autonetics, Anaheim, Calif.; and Viatron Computer Systems, Burlington, Mass. ECC sees as potential customers both manufacturers and users.

As far as competition goes, Homann states, "We have the edge and expect to keep it by marketing hardware in practical, versatile, and economical configurations."

Homann is also not a bit worried about someone's copying his tester. He expects to announce a second-generation unit shortly, and has just started the block diagrams for a third generation.

Originally named North American Electronic Systems, Educational Computer Corp. expects to merge with EDP Technology, Inc., in the near future. It will, however, retain its present name.

Circle **413** on Inquiry Card

Time-interval detectors and other test instruments. In production for about two months now, Digital Networks bills itself as "primarily an instrumentation design company for digital products." Its first product is a time-interval detector for detecting undesired contact openings in relays, connectors, and switches during shock and vibration testing. According to Richard A. Seale, president of the Pomona (Calif.) firm, "This unit offers the component manufacturer a more convenient and cheaper testing method than was previously available." The single-channel detector model sells for $420; the four-channel unit for $1160.

Digital Networks also has three products under development. One, to be available within three months, is a spinoff of the detector, and includes both pulse height discrimination and pulse width detection for vibration and shock testing of semiconductors. The single-channel version will be in the $700 to $800 range.

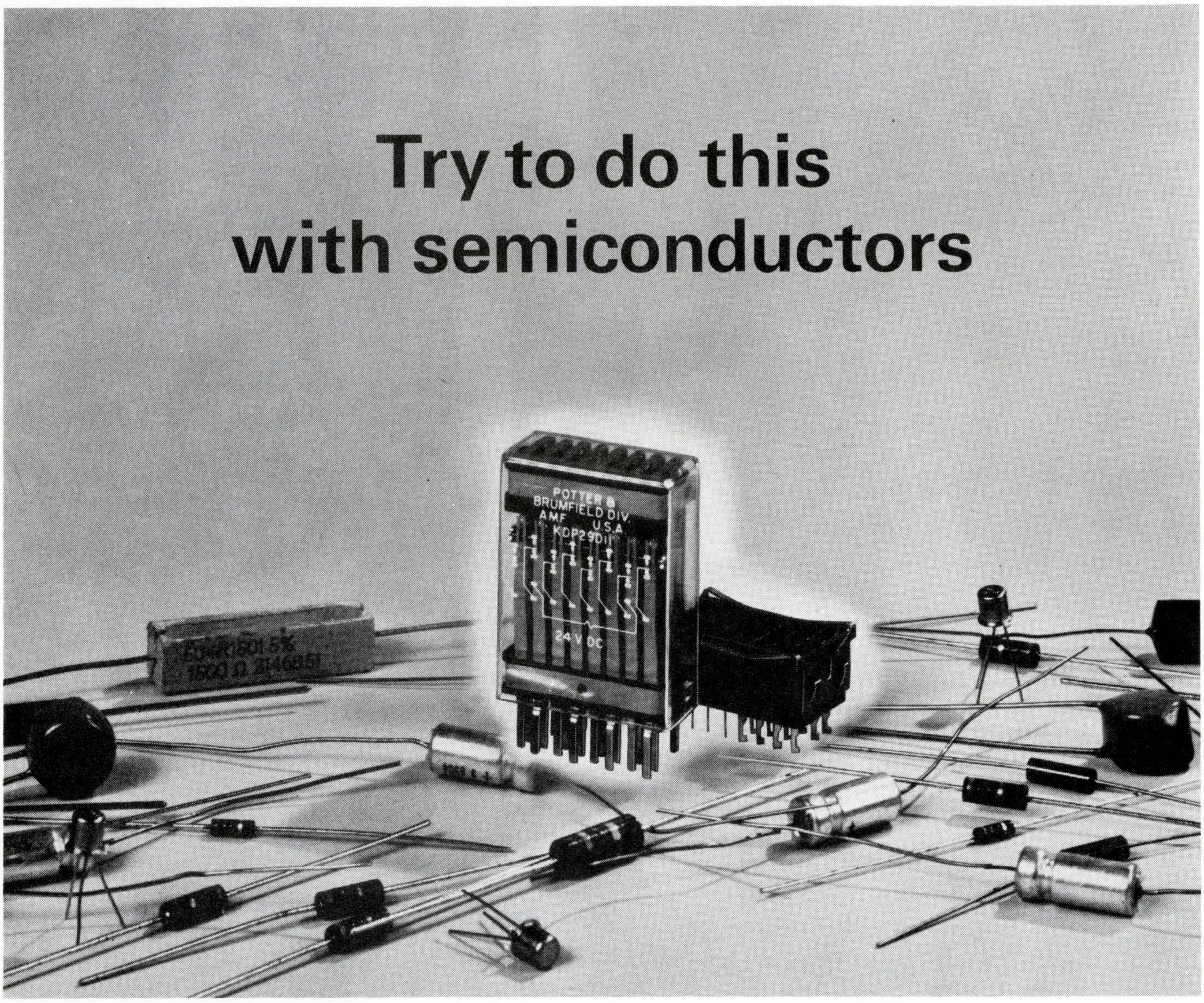
The second product being developed is a small go/no-go digital integrated circuit tester, which will be available in about six months, and the third is an instrument for frequency measurement using period averaging.

Although the new company is starting out with specialized items, it hopes to move into the standardized instrument and computer areas. "Our long-term goal," says Seale, "is to become competitive in the instrumentation field."

Right now Digital Networks is also doing custom design work in the test equipment field.

Circle **414** on Inquiry Card

Try to do this with semiconductors



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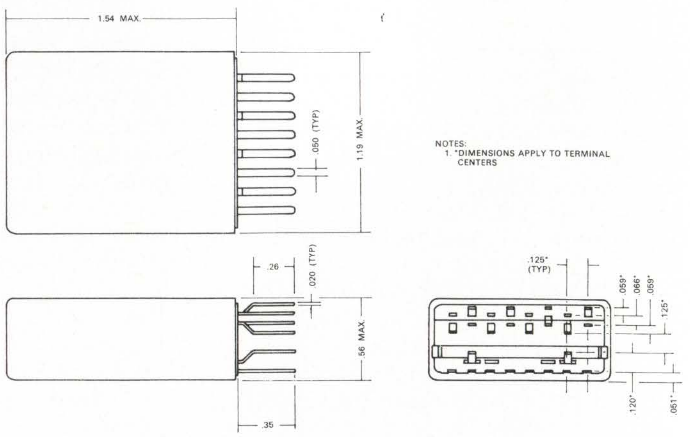

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EE PRODUCT SEMINARS

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

Fundamentals of DC Electrical Measurements: Aug. 4-8, North Wales, Pa., no charge. Quantities measured—dc voltage, voltage and current, low resistance, resistance, ratio resistance; instruments — dc potentiometers, dc Wheatstone and Kelvin bridges, Universal Ratio Set, associated equipment. Leeds & Northrup Co., Sumneytown Pike, North Wales, Pa. 19454.
Circle **401** on Inquiry Card

Instrumentation for Industrial Measurement and Control: Aug. 4-8, North Wales, Pa., no charge. Emphasis is on electric power energy conversion. Leeds & Northrup Co., Sumneytown Pike, North Wales, Pa. 19454.
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Repair and Maintenance Training Session: Aug. 4-8 and Sept. 8-12, Amsterdam, N.Y., no charge. Covers EMC-25 and EMC-10 receivers, EFC-125 programmer, SPD-125 spectrum display, various antenna models, and FSS-250 spectrum surveillance system. Dale Samuelson, V.P., Fairchild Electro-Metrics Corp., 100 Church St., Amsterdam, N.Y. 12010.
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Resistance Welding & Reflow Soldering: Aug. 5, 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.
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Hybrid Microelectronic Bonding & Packaging: Aug. 12, Monrovia, Calif., $5. Bonding fundamentals, metallurgical considerations, theory and fabrication of the semiconductor chip, bonding techniques, hybrid packaging. E. F. Koshinz, Unitek/Weldmatic Div., 1820 Myrtle Ave., Monrovia, Calif. 91016.
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RGA Spectra Interpretation: Aug. 18-20, Monrovia, Calif., $150. Emphasis is on the spectra of materials found in vacuum systems; for users of residual gas analyzers. Coordinator of Training and Technical Publications, Bell & Howell, 1500 S. Shamrock Ave., Monrovia, Calif. 91106.
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Cable Pressurization: Aug. 18-29, Sept. 8-19, Sept. 29- Oct. 10; Hickory, N.C. Session I, seven days: engineering design considerations, field preparation, installation of a continuous flow pressurization system; Session II, two days: air dryer installation and maintenance. Wallace E. Jones, Systems Equipment Div., Superior Continental Corp., Box 489, Hickory, N.C. 28601.
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Post Cleaning: Aug. 28-29, Mount Vernon, N.Y., no charge. F. J. Farrell, Electrovert, Inc., 86 Hartford Ave., Mount Vernon, N.Y. 10553.
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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.
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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.
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EE COURSES

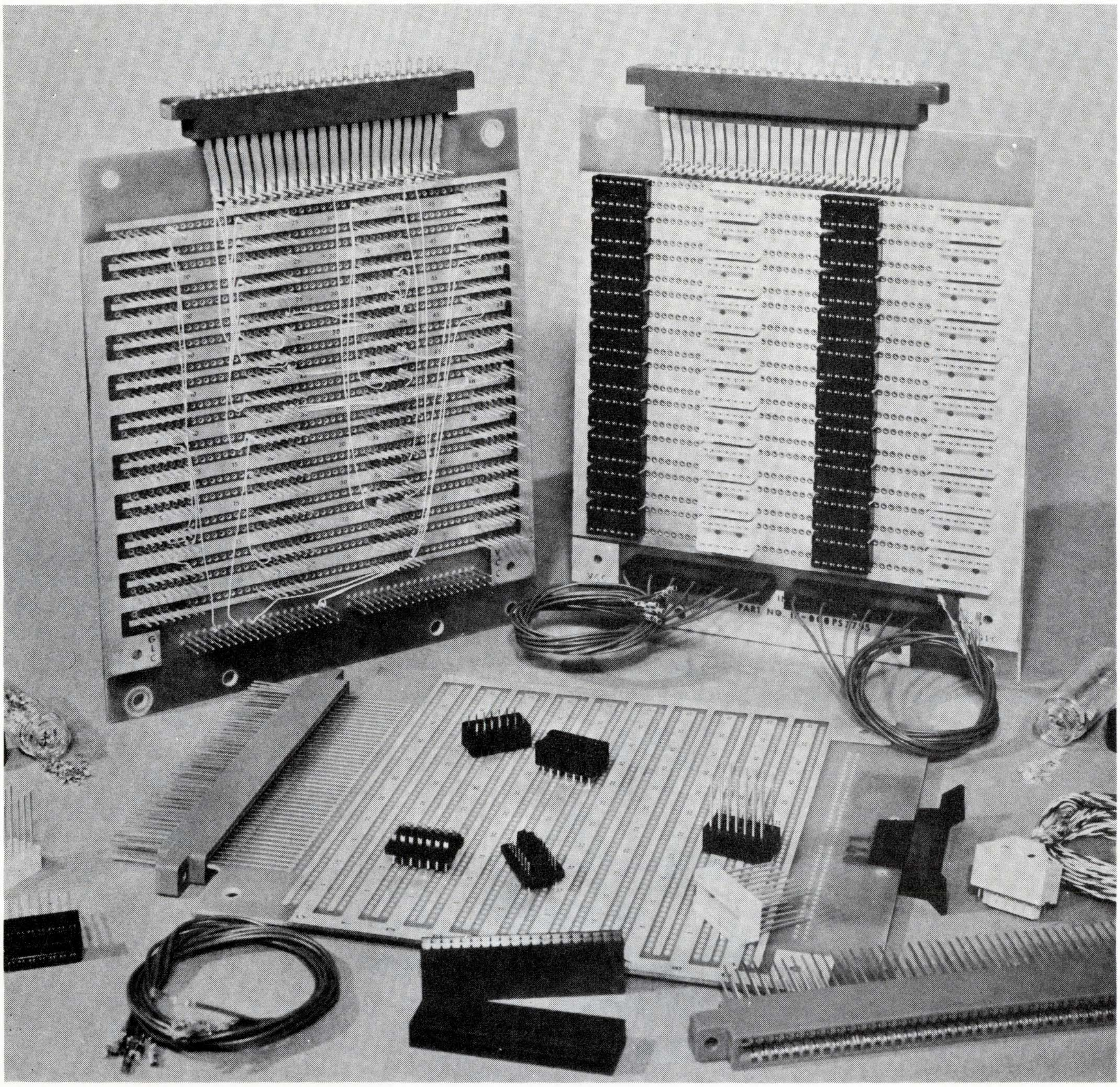
Device Aspects of Integrated Electronics: Aug. 4-8, Univ. of Colorado, $200. Semiconductor ICs, capacitors in a functional block, distributed RC networks, calculation of resistance with Schwartz-Christoffel transformation, diffused resistors in a functional block, voltage breakdown and voltage reference in functional blocks, FET structure in functional blocks, MOS transistors, etc. Dr. Donald S. Gage, Univ. of Colorado, Colorado Springs Center, Colorado Springs, Colo. 80907.

Microwave Solid-State Electronics: Aug. 4-15, Univ. of Michigan, $350. Operating principles and design techniques for microwave devices and circuits using solid-state elements, varactors, PIN diodes, detectors, mixers, avalanche-diodes, Gunn devices. Engineering Summer Conferences, Univ. of Michigan—Dept. ER, Chrysler Center, Ann Arbor, Mich. 48105.

Automated Circuit Design Workshop: Aug. 4-15, Utah State Univ., $380. Theoretical background for automated electronic circuit analysis, design, and optimization; techniques for modeling circuit components for automated analysis; application of major programs; modern nonlinear optimization techniques. Dept. of Electrical Engineering, Utah State Univ., Logan, Utah 84321.

Filter Design: Aug. 5-8, Univ. of Missouri-Columbia. Introduction to filter design, iterative and optimization methods with a digital computer, synthesis of filters with general parameters, general purpose filter design programs, crystal filter design, active filter design, digital filter design. Dr. George W. Zobrist, Dept. of Electrical Engineering, Univ. of Missouri, Columbia, Mo. 65201.

Computer-Aided Circuit Optimization: Aug. 11-15, Univ. of Missouri-Columbia. Introduction to circuit optimization, efficient circuit analysis, analysis of nonlinear circuits, modeling of solid-state devices, sensitivity analysis, computation of gradients, optimization via nonlinear programming, optimization via coefficient matching, circuit-oriented optimization techniques, applications to special circuits. Dr. George W. Zobrist, Dept. of Electrical Engineering, University of Missouri, Columbia, Mo. 65201.



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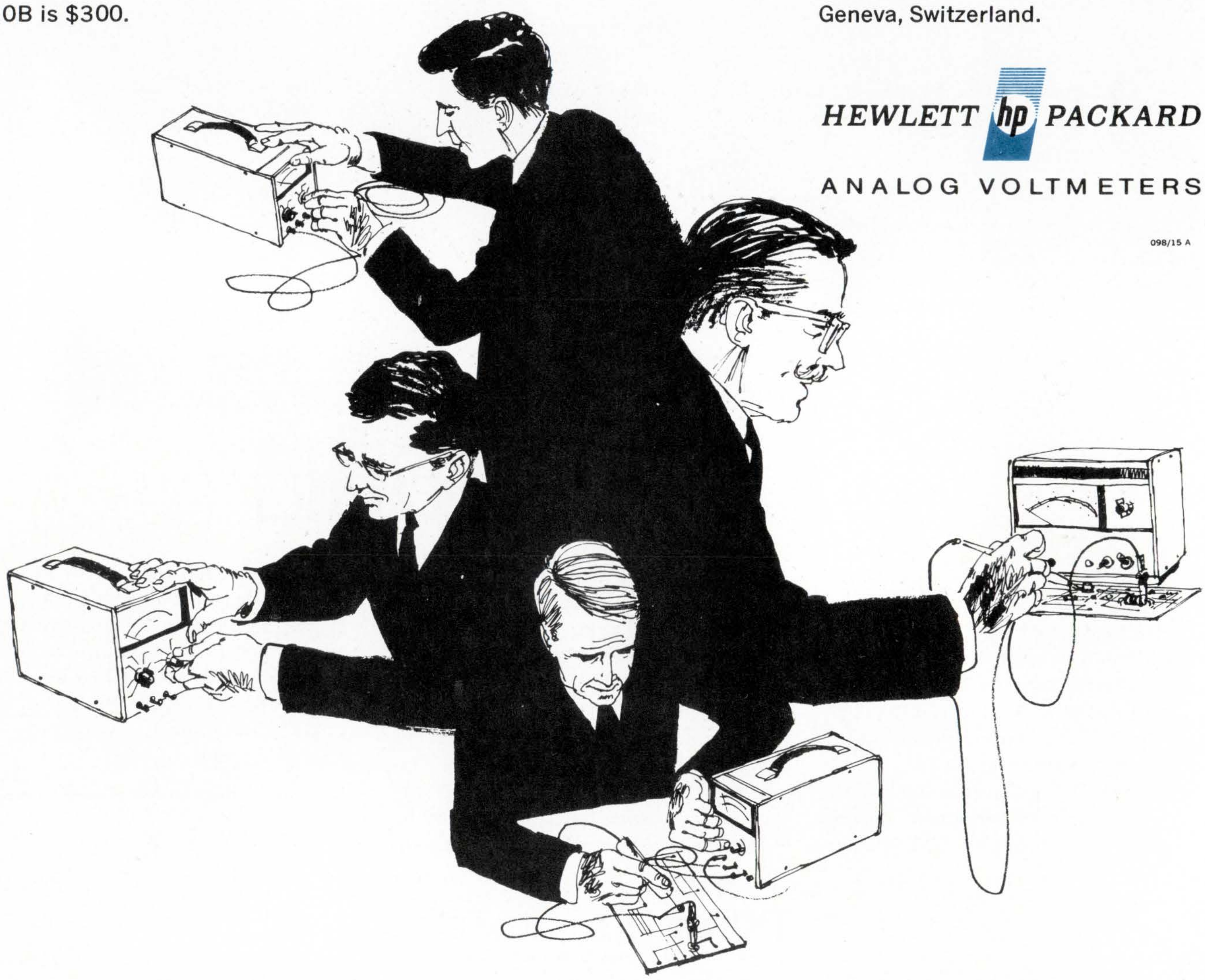


MOS memories save power

If power per logic function is a prime concern, try MOS products

By Dale Mrazek, Applications Engineer
National Semiconductor Corp.

For data storage in low power digital systems, MOS shift registers have many advantages not offered by magnetic cores. First, they require little power, and what power they do require is evenly distributed with time. Moreover, MOS memory systems can achieve a low average power per bit solution. And, by varying the normal designs you can increase power savings without degrading performance. This article discusses some of these methods for conserving power.

Since the element power of a dynamic shift register is almost a direct function of clock frequency, you can reduce the power by reducing the frequency of operation. However, there is a low frequency limit to a dynamic MOS register (its range is from 100 Hz to >1 MHz at room temperature). Figure 1 shows the power-to-frequency relationship for one element (MM406).

As I show in the box on page 50, the element will vary as a function of the number of internal storage bit locations. You can see from the analysis that power is consumed during the clock logic "1" intervals (either ϕ_1 or ϕ_2, but not both) for each of the two possible logic bit storage cases. Thus, you can minimize power at a specific frequency by designing the clock pulse for minimum widths. The power drain per bit time is then the power requirement during the clock ϕ_1 or ϕ_2 pulses. Average power becomes the clock pulse power times the ratio of clock pulse width to rep rate interval. Minimum power then requires a minimum ratio of clock PW to clock rep rate.

Let's now look at some examples that show how you can minimize power in various memory systems. All assume $+125°$ to $-55°$C. operation.

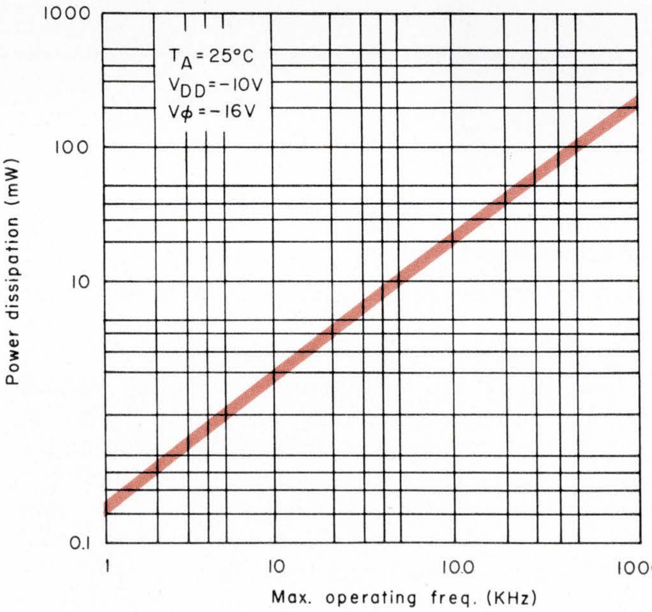
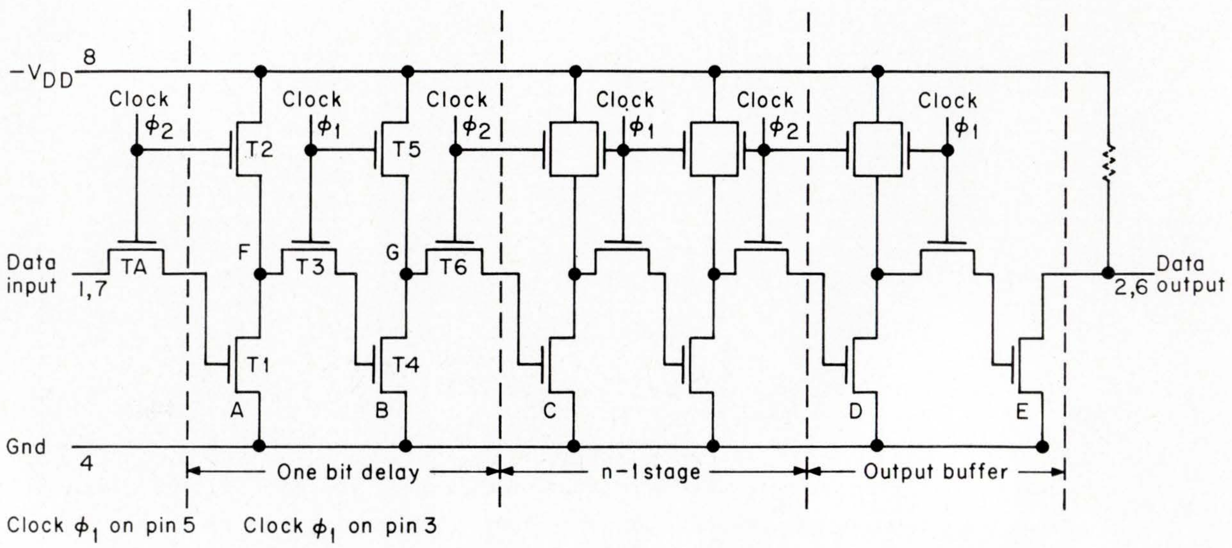


Fig. 1. Power to frequency relationship for a MM406 shift register.



Mos shift register power analysis

An MOS dynamic shift register needs power only during the clock power strokes (clock pulses). Assume a logic "1" (the most negative logic level) input data signal. Then, during the clock ϕ_2 "1" interval, current will flow from V_{DD} through T2 and T1 to ground. After ϕ_2 returns to its zero state (ground level), T2 will turn OFF, letting point F discharge to zero volts.

During the clock ϕ_1 "1" interval, T3 and T5 are clocked ON and the logic "0" at point F is transferred to point B. T4 is held OFF and point G is charged to a logic "1" by way of T5 and V_{DD}. This signal is stored at point G until the next ϕ_2 clock appears. This bit delay is repeated for all bits of delay through the register.

If the input data is a logic "0", then node F will charge to a logic "1" through T2 during the clock ϕ_2 "1" interval. The node F input, when applied to T4 during the clock ϕ_1 interval, causes current to flow from T4 to T5 to V_{DD}. The "0" state is established and can be transferred after the "1" to "0" transition of clock ϕ_1. The next ϕ_2 clock pulse starts the next transition.

Clock modulated system

If a system requires a clock of 1 MHz during the memory address interval, but needs it only 10% of the time, you can cut the clock frequency to a minimum (determined by the temperature) during the standby interval, thus reducing mean memory power. If the duty cycle is constant, there's no advantage to reducing the frequency below that needed to complete one recirculation cycle time during a standby interval. Any lower frequency would consume the same power as would the exact recirculation frequency. This is true since the memory must be reindexed by clocking to the zero bit location before the next read command. A power-time relationship is shown in Fig. 2.

Next, let's assume that a recirculating memory is bit-organized and must be indexed to the zero bit position before reading out on successive read commands.

There are two special methods for minimizing power in systems that have a known and fixed minimum duty cycle. The first assumes that the memory standby interval is $< 300\ \mu s$ at $+125°C$ or < 2 ms at $+70°C$. If this is true, then special clocking isn't needed during the standby interval for the MM400, MM402 or MM406 shift registers. Thus, you can operate the memory at the desired output rates and then inhibit the clock during the standby interval. Since in this mode no re-registration time is needed, the register power is cut to a minimum—the consumed power is directly related to the ratio of clock "1" level to clock "0" level during one total register access cycle. Figure 3 shows a clock memory system which can be used for this mode of operation.

A variation of this method extends the standby interval by a factor of two, or 600 μs at $+125°C$ and 4 ms

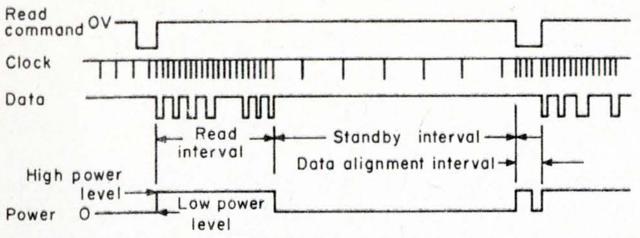


Fig. 2. Power time relationship for the clock modulated memory system.

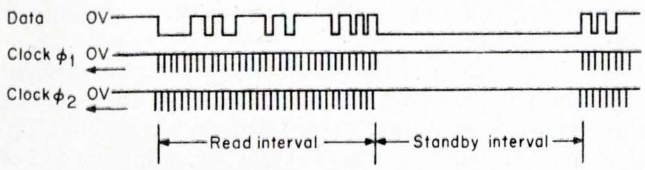


Fig. 3. Clock memory system format for the case where the memory standby interval is < 300 μs.

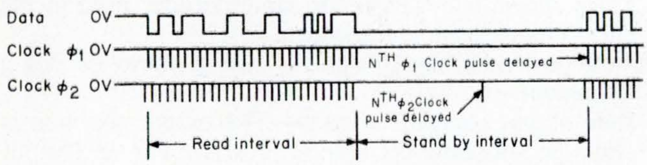


Fig. 4: Clock memory system format where the standby interval is extended by a factor of two (to 600 μs) over that of Fig. 3. This is done by extending the interval between clock ϕ_2 and ϕ_1 and also between clock ϕ_1 and ϕ_2.

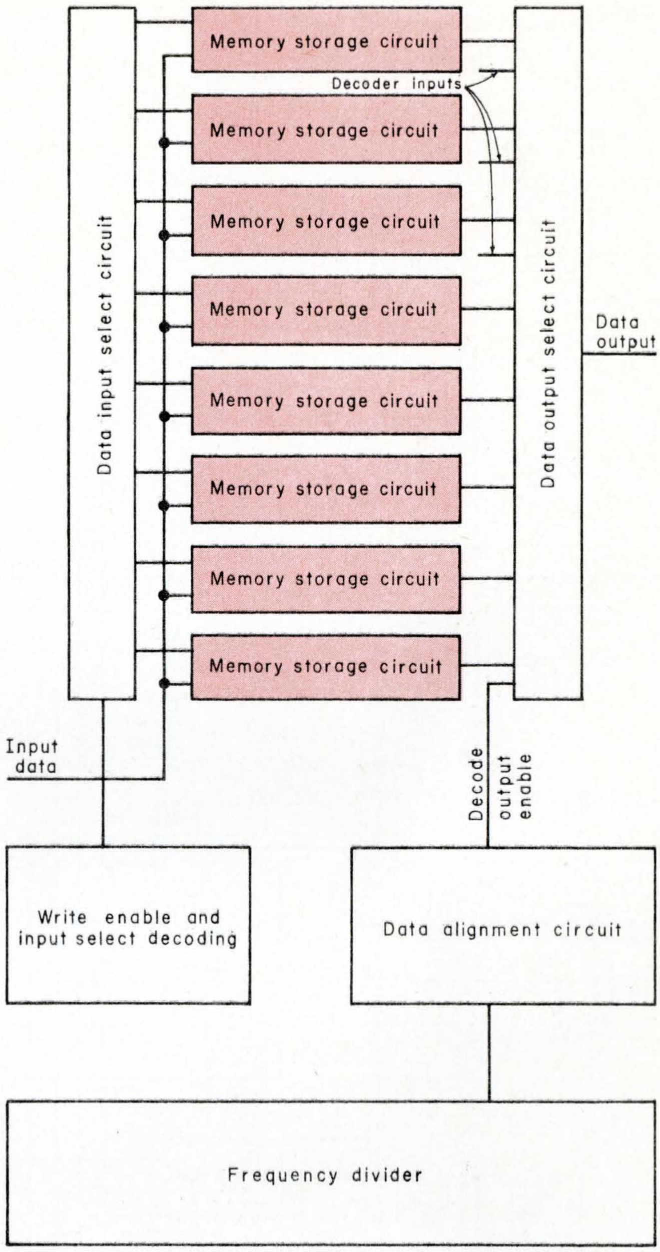


Fig. 5. Serial-parallel clock modulated memory system. This system accepts serial data from a single data line. It stores the data in one of eight parallel memory registers and recirculates it to retain storage. The output data selection is decoded from the memory register to an output data terminal.

at 70°C. The method, which has a clock format similar to that shown in Fig. 4, is based on the fact that data storage is established after each clock phase. Thus, it's possible to change the clock format by adding large delays to the interval between the clock ϕ_1 and ϕ_2, as well as between clock ϕ_2 and ϕ_1.

The above two clock methods consume only one bit-time power unit per bit of a data word for a read interval.

Serial-parallel clock modulated system

Another low power technique is shown in Fig. 5. Not all systems will lend themselves to this design or need all the characteristics described. The sections described are intended as suggestions for a variety of system designs.

Memory storage—Logically this circuit arrangement is conventional in that data is recirculated for memory retention. However, it deviates from the norm in that each register string has its own clock driver and decoder. The circuit operates the memory at a high clock rate only when the data is being read from or into a specific memory location.

All register clock drivers other than the one selected by the decoder will operate at a reduced multiple of the higher frequency clocking signals. Thus, since power is a function of clock rate, power is saved in all memory registers not chosen by the input address command.

Stored data is recirculated by using a multiplex switch element (MM482). The output of a dual 100-bit register (MM406) is connected to one data input of the multiplex switch so that output data may be fed back into the register input for storage.

Let's assume that the recirculation mode will be

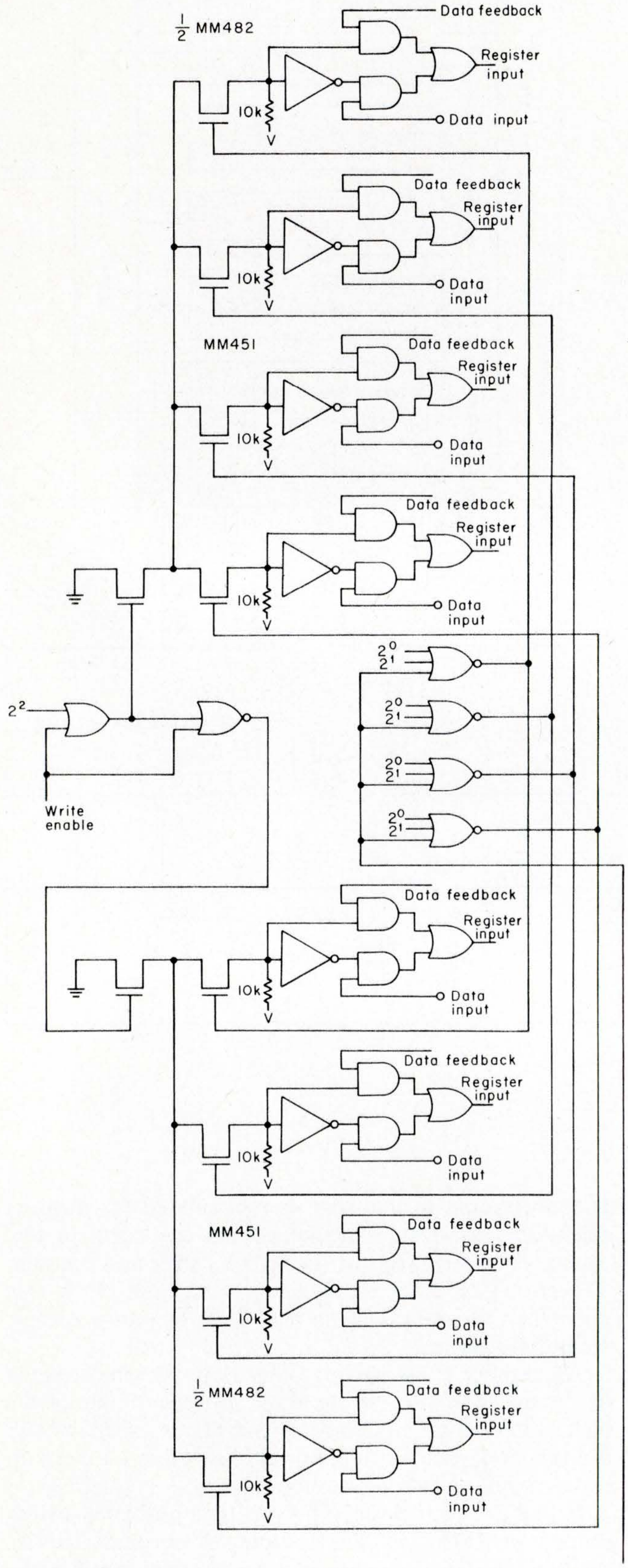


Fig. 6. Data input select circuits. When you have a Write Enable command, these circuits will select the register which will receive the data.

needed more often than will the data write mode; thus, the feedback connection is made from the register output to the multiplex or input that is enabled with a control logic "1" applied to this element (MM482). The average power used by the multiplex switch is minimized in this mode.

The memory register clock driver may vary in output design since different systems vary in their capacitance drive requirements.

Data input select circuits—This design is a one-of-eight decoder group that selects which register data will be inserted in if the Write Enable command is enable (Fig. 6). It is a modified one-of-eight decoding string of gates. The MM451 elements and decoding gates (MM482) are used logically to steer the enable control to the proper memory register—at a lower power than if normal gates were used. The one-of-four decoding group shown in Fig. 6 is the same decoder used in the data output selection diagram.

A power savings results by using these decoding techniques.

Data output selection circuits—The output selection is also a one-of-many decoder as shown in Fig. 6. Output data is logically decoded using commutator techniques and logical steering of the stored data to the output data terminal. The gates establish an output inhibit state except for the desired output data word read interval. Output inhibit-control is obtained from the data alignment control section.

Frequency divider circuit—For memory operation during the standby mode, a synchronous sub-frequency of the basic clock frequency is best. This is accomplished by counting down the desired amount with a frequency divider. The system's frequency division requirement at +125°C, is about 300; this was achieved with minimum package count by using JK binaries and a shift register element to obtain a large multiple frequency divider. Circuit output is trailing edge sensitive to the ϕ_2 clock.

Specifically, two JK binaries (MM483) and a shift register (MM400) form a twisted ring counter with a frequency division of 104. A modulo three counter connected in cascade with the twisted ring counter further reduces the basic 1 MHz clock ϕ_2 signal to a 3.2 kHz clock ϕ_2 referenced signal. The total frequency division obtained was 104 times 3 or 312. The output pulse from this counter is a pulse whose width is one high frequency interval (1 μs) and starts on the trailing edge of one clock ϕ_2. It lasts until the next trailing edge of the clock ϕ_2 and occurs once every 312 clock pulses.

Data alignment section—This circuit realigns data registers within the data storage system of registers. When one register is being addressed and operated at 1 MHz while all others are operated at 3.2 kHz, data will be stored if the higher rate register isn't re-synchronized with all others. Only one register is operated at the high clock rate because power is conserved in all unselected register strings.

To get proper register realignment you must remember the bit position at the beginning of the read interval and operate at a high clock rate until the same bit

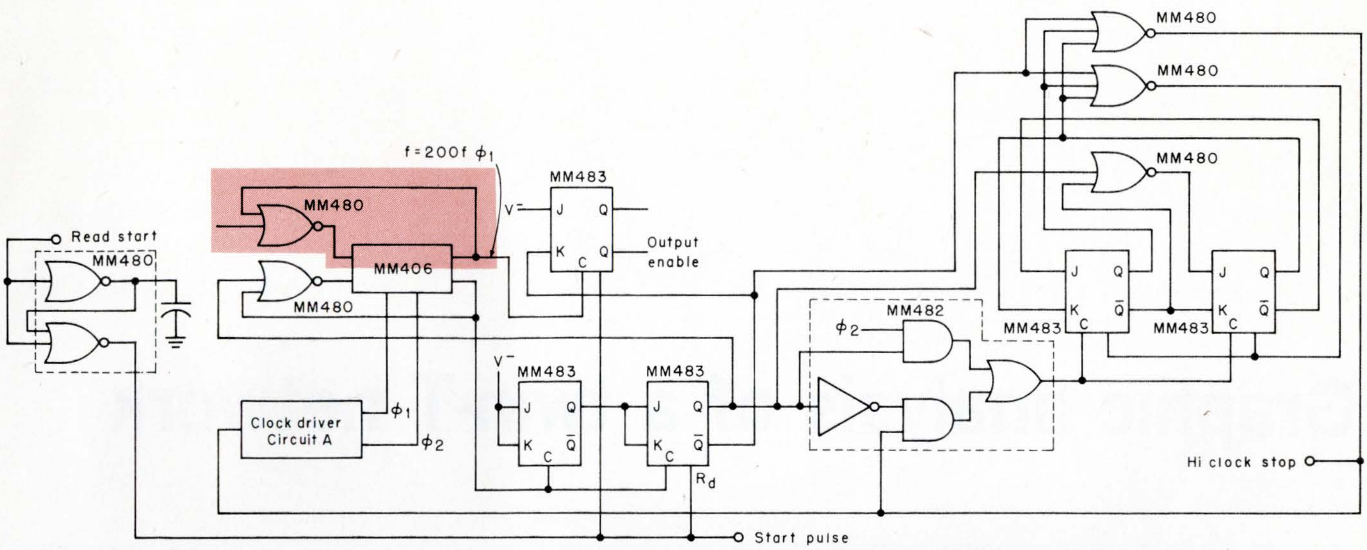


Fig. 7. Data alignment section. The shaded portion helps you get proper register alignment. The overall circuit is used to establish where the first data bit of a stored word is in relation to the start command.

position comes up again. This would require a large binary counter, a memory storage register and a comparator. A simpler way is to start at any random place in an N bit circulating loop and progress around the loop to the bit location number. If you read through the N bit data register and then return to the starting point, the total number of bit intervals covered will always equal 2N. Thus, you can start a Modulo 2N counter at the beginning of a read sequence and stop the register at the carry out of the Modulo 2N counter.

With this technique (Fig. 7-shaded portion) you just count 2N clock intervals plus any lf clock pulses which may have occurred during the randomly started address register. The lf clock pulses are counted during the 2N sequence interval and the hf clock is kept at the same number of addition intervals as there were lf clocks. At the carry out of the Modulo 2N counter, all memory registers will again be synchronized. That is, bit X of register N, bit X of register M, and so forth will all be at the same relative time position.

The Start command is the next design consideration. A start command may be asynchronous with the first data bit of a stored data word, and you must establish where this data bit may be. Figure 7 shows one method for doing this that uses a Modulo N counter. The output data is enabled when the Modulo N counter indicates the beginning of the data word and is disabled at the end of the data word.

Power analysis

A power analysis of this method can be made to determine the break-even point as compared with a straight synchronous register approach where all registers operate at the higher clock rates. Such an analysis shows that the frequency divider circuitry is not needed. The 2N counter and lf clock counter circuitry are also not needed. It is thus possible to operate some registers at normal clock rates and yet still break even powerwise. This break-even point is a memory of four registers. A memory register count any larger would result in a lower average power per bit of storage if you used the above method instead of a constant data rate clocking technique.

Summary

Several memory systems have been presented. The system requirements will establish which of these techniques or combination of techniques should be used to get the best power per bit relationship. You should keep in mind that each new memory application must be evaluated for its best solution.

INFORMATION RETRIEVAL:

Integrated circuits, Computers and peripherals, Computer design

Graphic analysis of a twin-T network

Twin-T networks are popular, especially in control systems. But the mathematics needed to calculate them are complicated. Here is a simplified method that solves the problem with simple graphics.

By John M. Shaull,
R&D Supervisor
Electronic Timing Branch, Harry Diamond Labs., Washington, D. C.

Many engineers misunderstand phase-inversion in twin-T networks where the shunt impedances are adjusted slightly lower than the true null value to achieve finite transmission. Such an adjustment is useful in oscillator and narrow band amplifier applications. To clarify the subject, this article will show you a simplified way to represent and analyze the phase sensitivity of the phase-inverting twin-T network.

Graphic analysis

There is a graphic method of analysis for the symmetrical case (see Fig. 1). At the null frequency, if the networks nodal points C-E are shorted, there are no current or voltage changes because no voltage exists between these points. (Fig. 2 is the equivalent circuit.)

The equivalent vectors for Fig. 2b form a square with the input connecting diagonal corners (dashed lines and the vectors in parentheses), as in Fig. 3. This sheds litttle insight other than to indicate two 45° angles, A′EB, and A′ED, that the branch arms make with the input. However, the bottom circuit elements in Fig. 2b are the same as those in the full T configuration, so their vectors are correct. To complete the full vector diagram, extend the input vector to V_{in} instead of $V_{in}/2$ and add the connecting lines AB and AD, thus showing the vector conditions at null.

For the complete network, the vectors for R_2 and C_2 will coincide with the vectors for C_3 and R_3 as shown at null. On either side of the null frequency the EC vector increases from zero and moves vertically up or down as the result of X_c variations, indicating a plus or minus 90° phase shift for small deviations. (Vector EC actually terminates on a circle of radius A′E.)

Phase inversion

For a 180° phase shift in the T network, as found frequently in oscillator design, the shunt impedances are slightly lowered (Fig. 3b). Assuming no load on the T network output, the angle BCD must be 90° and its vectors of equal length. As the EB and ED vectors have been shortened by reducing the related impedances and the vectors must meet at points B and D, the angles these vectors make with the input voltage will be increased from 45° each by a factor Δ. Each of these angles will approach 90° for very small shunt impedances. This forces the vector EC to be 180° out of phase with respect to the input vector.

Varying the frequency a small amount either side of the notch frequency rotates the EC vector about point E clockwise with decreasing frequency and increases its length as capacitive reactance varies. This causes a rapid phase change in the transfer characteristic with respect to frequency. This effect increases as the attenuation at notch frequency increases and the EC vector becomes shorter.

If the shunt impedances are made slightly greater than required for a true null, the output is in phase with the input at the notch frequency. If only one of the shunt elements is lowered, the phase inversion can still

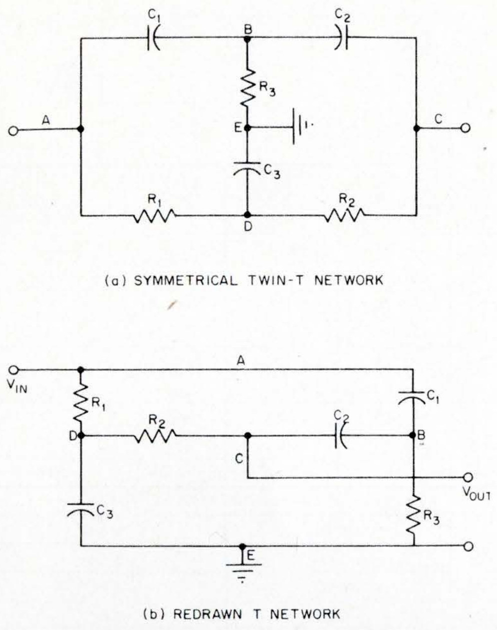


Fig. 1. In the symmetrical twin-T network (a) $R_1 = R_2 = X_{C1} = X_{C2} = 2R_3 = 2X_{C3}$ at the null frequency; (b) the same circuit as two voltage divider branches with R_2 and C_2 in series across the taps. With the component values shown, the null frequency (infinite attenuation) occurs at $\omega = 1/RC$.

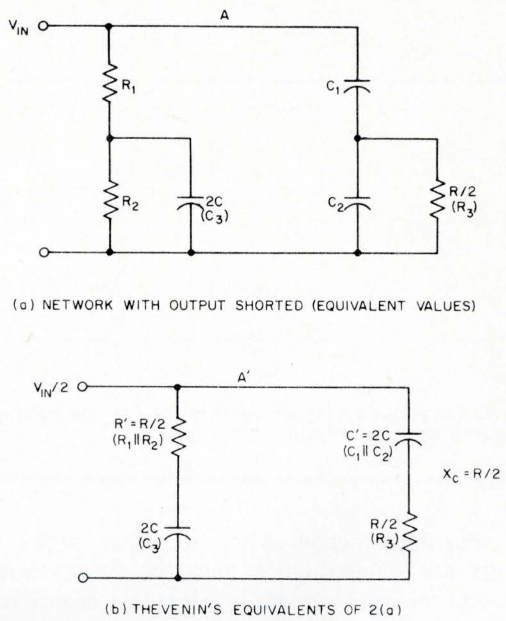


Fig. 2. With the output shorted, the circuit is the equivalent of (a). Thevenin's equivalents for the shunt arms of the two branches simplifies the situation (b). At the null frequency, the capacitive reactance of C equals R numerically; and, for 2C, $X_C = R/2$ on each branch.

be obtained, but the notch frequency is shifted slightly.

Figure 3b suggests that if vectors BE and DE are made very short (by greatly lowering the R_3 and C_3 impedances), the network transmission properties at the notch frequency will remain unchanged. This is indeed true. A network with k (the ratio of R_3/R_1 and X_{c3}/X_{c1}) lowered to about 0.02 gave attenuation and phase shift similar to a network with k of about 0.475, and oscillated at the same nominal frequency. However, this mode of operation is undesirable because it provides much less phase sensitivity than the higher k mode of operation.

If you consider the possible values of the transmission factor α in relation to the vector graphs of Fig. 3b, you'll see that a maximum value of α will be obtained between the two operating points discussed. Thus oscillation cannot be achieved by lowering the shunt impedances for an amplifier having a gain less than $1/\alpha$ max. This occurs for $\alpha = 0.0938$, corresponding to a k of 0.207.[1] Large variations in all network components can be tolerated, (e.g., $\pm 10\%$), and a true null, or a specific desired attenuation at notch frequency, achieved at the desired nominal frequency by adjusting both shunt arms of the network. Deviations from the ratios stated, however, do not lend themselves conveniently to precise graphical analysis or even simple computation.

Simplified methods have been used to compute null frequency where the left and right series elements differ by a large ratio. Such elements then require new ratios between the series and shunt arms. The maximum

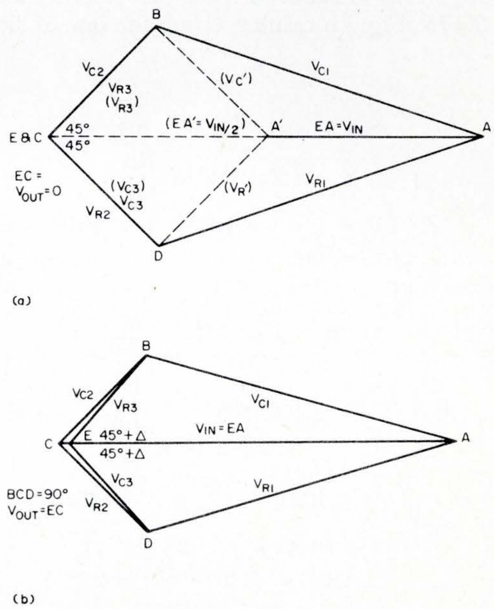


Fig. 3. (a) The voltage vectors for a null condition and Thevenin's equivalent vectors in parentheses. For a 180° phase shift and finite transmission, (b) make R_3 smaller and C_3 larger by a few percent, depending upon the attenuation desired at the notch frequency.

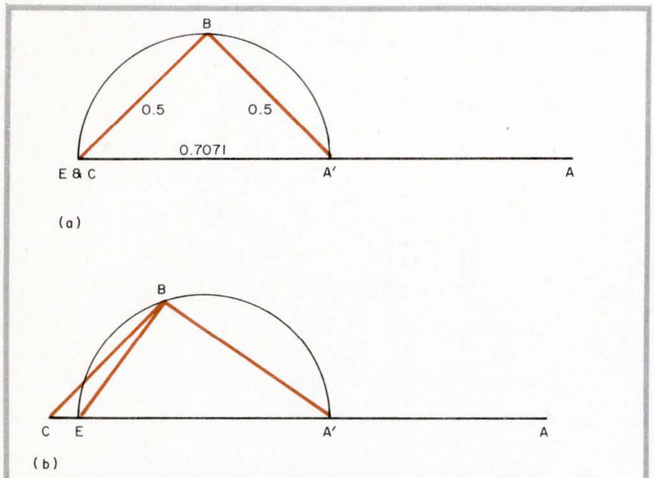
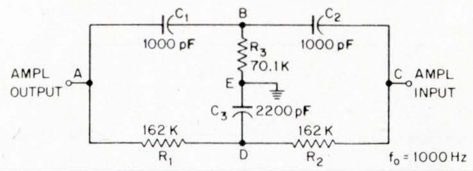


Fig. 4. Thevenin's voltage vectors for (a) the balanced case and (b) the unbalanced case.

Period and attenuation changes for capacitive and resistive loading of twin-T network elements



POINT	SHUNT = 10 pf Δα DB	Δτ μSEC	SHUNT = 16 MEGOHMS Δα DB	Δτ μSEC
AB	+0.18	+3.50	+0.72	−0.93
BC	+0.20	+3.40	+0.72	−0.92
AD	+0.76	+0.73	+0.24	−3.65
DC	+0.76	+1.16	+0.24	−3.61
BE	+0.26	−0.96	−0.25	−1.30
DE	−0.24	+1.30	+0.25	+1.05
AE	+0.003	+0.01	0.00	0.00
CE	+0.05	+0.20	+0.04	−0.17
BD	+0.32	+2.55	+0.53	−2.04
AC	+1.82	+9.60	+1.84	−9.74

FOR 1% INCREASE IN NETWORK ELEMENTS

	Δα DB	Δτ μSEC
$+\Delta C_1$	+0.18	+3.50
$+\Delta C_2$	+0.20	+3.40
$+\Delta C_3$	−0.48	+2.60
$+\Delta R_1$	−0.24	+3.65
$+\Delta R_2$	−0.24	+3.61
$+\Delta R_3$	+0.59	+3.11

phase sensitivity occurs when the filter series output elements are much higher than the input series elements. But this ratio generally offers less desirable interface impedances, and thus the symmetrical case is most often used.

Network attenuation

You can also determine the network transmission loss α graphically by assuming point C to be a virtual ground. To do this, draw the Thevenin's vectors and a semicircle through points EBA′, as shown in Fig. 4a. Then let EB = 0.5 ,which is the ratio k, of R_3/R_1 and the mirror image ratio X_{c3}/X_{c1} for the balanced case; the value of EA′ will be 0.7071. The locus of point B (and the mirror image point D) will lie on a semicircle for small changes in EB, or k.

Now, if EB is reduced from 0.5 (e.g. by 5%), to a k of 0.475, Fig. 4b results. Using the law of sines,

$$\frac{\sin A}{a} = \frac{\sin B}{b}$$

$$\mathrm{ED} = \cos \angle \mathrm{BEA'} \times \mathrm{EA'} = a$$

$$\cos \angle \mathrm{DEA'} = \frac{\mathrm{EB}}{\mathrm{EA'}}$$

$$\angle \mathrm{CBE} = (\cos^{-1} \angle \mathrm{BEA'}) - \angle \mathrm{BCE} = B$$

$$\angle \mathrm{BCE} = 45^\circ \qquad = A$$

$$\mathrm{EC} \qquad = b$$

$$\mathrm{EC} = b = \frac{a\,(\sin B)}{\sin A}$$

$$\alpha = \text{network transmission} = \frac{\mathrm{EC}}{\mathrm{EA}} = \frac{\mathrm{EC}}{2\mathrm{EA'}}$$

$$\text{For k} = 0.475$$

$$\cos \angle \mathrm{BEA'} = \frac{0.475}{0.7071} = 0.6717$$

$$\angle \mathrm{BEA'} = 47^\circ\, 12' = 47.2^\circ$$

$$\angle \mathrm{CBE} = 47.2^\circ - 45^\circ = 2.2^\circ$$

$$\sin 2.2^\circ = 0.03839$$

$$\mathrm{EC} = \frac{0.475 \times 0.03839}{0.7071} = 0.02579$$

$$\alpha = \frac{0.02579}{1.4142} = 0.01824$$

$$\text{Required gain} = \frac{1}{\alpha} = 54.8 \text{ (oscillation threshold)}$$

For α smaller than 0.02, the values of k agree within about 3% with values computed by the equation $k = (R_1/2) - 2R_1\,\alpha$, and with experimental values.[2] For larger values of a, the virtual ground equivalence does not hold and the error increases rapidly.

The value k represents the amount by which the shunt impedances are reduced for a particular attenuation with phase inversion. It should not be confused with the constant n, which is frequently used to show the ratio of R_3 and C_3 needed to obtain a complete null. In this case as X_{c3} is *lowered* R_3 must be *increased* from the nominal value and the frequency is shifted by a factor of $1/\sqrt{2n}$.

Network impedance

The $Z_{in} = Z_{out}$ for the T network at balance may also be derived graphically. The two parallel branches in the Thevenin's equivalent (Fig. 2b) are equivalent to a series impedance of $R_1/4$ and $X_{c1}/4$ or $(R_1/4)$ (1-j), across which a voltage EA′ ($E_{in}/2$) is impressed. The input voltage EA is twice EA′ and in the same phase relationship (Fig. 3a).

As both the actual network and the Thevenin's equivalents with respect to R_3 and C_3 cause the same voltages and phases to exist across R_3 and C_3, the input (and output) impedance of the network is twice the Thevenin's equivalent impedance, or $(R_1/2(1\text{-}j)$. This is equivalent to R_1 x 0.7071 at a phase angle of −45°, which agrees precisely with the vector computed value. For the unbalanced cases of interest in oscillator design ($\alpha \approx 0.02$), these impedances are still closely approximated by the above expression.

Phase sensitivity

The phase sensitivity may be related to the transmission factor of the network by the following equations:

$$Q = \frac{1}{4\alpha} \qquad (1)$$

where x = transmission factor of the network, and Q defines phase and bandwidth properties similar to those of an LC tuned circuit.[3]

The input-output phase change is expressed by:

$$\frac{d\theta}{df} = \frac{2Q}{f} \ (\theta \text{ is in radians}) \qquad (2)$$

from which the fractional phase sensitivity for a given attenuation may be obtained:

$$\frac{d\theta}{\left(\frac{df}{f}\right)} = \frac{1}{2\alpha} \qquad (3)$$

To verify this . . .

Voltages and phase relations were measured on a twin-T network in an oscillator, and as a passive device driven at the frequency of oscillation. An oscilloscope with 10 MΩ, 10-pF probes was used and the measured data agreed within a few percent with values derived from graphs such as those of Figs. 3 and 4. The oscillator frequency was 1280 Hz and the network had an attenuation of 34 dB. The ±90° points when driven were 890 and 1820 Hz. The oscillator amplifier had a gain of about 36 dB and an output phase shift of about 181° lag (1° excess phase shift). Thus, from Eq. 3, the 1280 Hz oscillator was operating about 0.07% or 0.9 Hz below the 180° phase-shift frequency of the network, as the oscillator must operate to give zero loop phase shift.

Tests performed on a 1000 Hz twin-T network determined the changes in frequency (or period) and in attenuation as the result of changes in magnitude of each of the network elements. This was done by shunting between each possible pair of nodal points successively with 10 pF and 16 MΩ. In each case the oscilloscope was used to set the drive oscillator to give a network phase shift of precisely 180°. The oscillator period and network attenuation were then measured, obtaining the values in the table. The top part of the table shows changes as each pair of nodal points is shunted and the bottom part shows equivalent changes for a 1% change in each network element. The network was driven from a 500Ω generator and the oscilloscope was provided with preamplifiers having about 100 MΩ impedance to reduce instrumentation errors. With these data, effects of temperature coefficients of the R and C elements and of stray coupling in wiring and potting materials can be evaluated and compared with the graphic predictions.

References

1. Landee, R. W., Davis, C., and Albrecht, A. P., *Electronic Designers Handbook*, New York: McGraw-Hill Book Co., 1957, pp. 16-23.

2. Hastings, A. E., "Analysis of a Resistance-Capacitance Parallel-T Network and Applications." *Proc. IRE*, Vol. 34, March 1946, pp. 126-129.

3. Hastings, *Ibid.*

INFORMATION RETRIEVAL
Passive components, Circuit design

Tables of CAD programs

Can ECAP run in any computer? How much memory does a computer need for NET-1R? These practical tables list the answers to such questions, for eleven popular CAD programs.

As computer-aided design becomes an increasingly important element of the working engineer's repertoire, staying abreast of advances in the computer sciences is becoming more and more important to him. The proliferation of computer programs does little to simplify his lot.

At least 91 programs are already cataloged and these are only a fraction of the number in actual use. Programs themselves are becoming increasingly complex. Program sophistication, measured by the number of required instruction cards, varies from 82 cards for a filter network design to over 60 thousand for automatic transient analysis.

Fortunately, the number of programs in general use is considerably smaller, because most of the special ones are not available outside the facility in which they were originated.

With the aid of the accompanying charts, you can get a good picture of the programs that are generally available. These tables list 11 digital computer programs that are operational with 16 different computers.

CIRCUS, General Network Analysis, NET-1R, and TRAC programs include fixed, built-in models for transistors. MISSAP III also has built-in models, but these can be readily altered by the user. When using a program that does not have such built-in models, you must define the equivalent circuits to include active devices.

The user of a computer program will often run into trouble when he seeks program documentation such as a user's manual or a mathematical description of the program. Documentation on the General Network Analysis, MISSAP III, Oklahoma Standard Analysis, STRAP, and TRAC programs exists, but is not available to the general user. For example, a facility may prepare a program manual for its own use, but not make it available to outside users. Although its motives in regarding such information as proprietary are quite understandable, such action tends to retard progress in the computer field.

Taking the position that progress requires the free interchange of information, several government agencies such as NASA disseminate data obtained through contracted research efforts. Also, a committee of the IEEE, CADAR (Computer Aided Design, Analysis and Reliability), has for more than two years, been actively engaged in the dissemination of information related to computer aided design to members of the Institute. Readers interested in further information on CADAR can write to: John Dumanian RCC, NASA/ERC, 575 Technology Square, Cambridge, Mass.

(See comparison tables on page 60.)

INFORMATION RETRIEVAL
Computers and Peripherals
Circuit Design

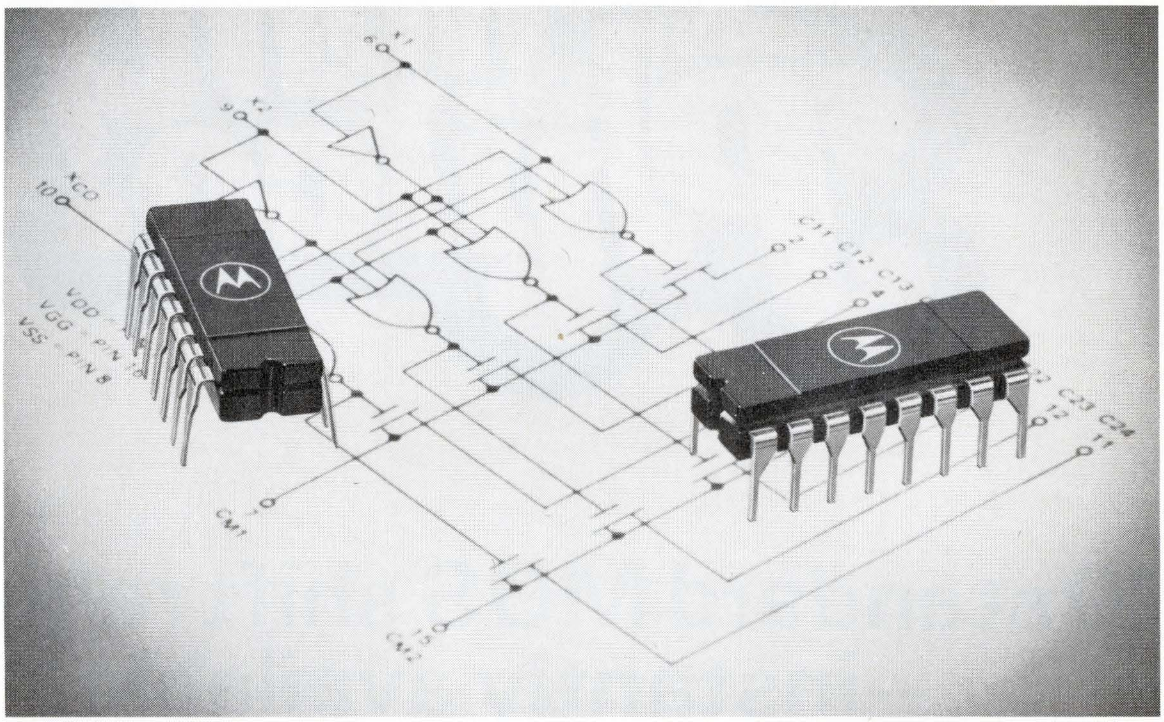
Computer Compatibility

Program	Operational on Computers	Language and size of source deck	Minimum word memory
CIRCUS	UNIVAC 1107/1108	FORTRAN IV	
	IBM 7094		
	GE 625/635		
	CDC 6600	5500 cards	32k
Gen. Network Analysis	UNIVAC 1107/1108	FORTRAN IV 3000 cards	65k
MISSAP III	CDC 3600	FORTRAN IV 2000 cards	32k
NET-1R	IBM 7094	FAP	
	IBM 7040/7044		
	MANIAC II	30,000 cards	32k
Okla. Std. Analysis	IBM 7090/7094	FORTRAN IV 2000 cards	40k
PREDICT	IBM 7090/7094	FORTRAN II PAP 10,000 cards	32k
SCEPTRE	IBM 7090/7094	FORTRAN IV	
	CDC 6600	15,000 cards	32k
STRAP	IBM 7090/7094	FORTRAN IV	32k
TAG	IBM 7090/7094	FORTRAN II 12,000 cards	32k
TRAC	IBM 7090/7094	FORTRAN II 1500 cards	32k
ECAP	IBM 360	FORTRAN IV	
	IBM 1620		
	IBM 7090/7094		
	UNIVAC 1107/1108		32k

Main Program Features

	Dc initial condition	Dc component variation	Ac analysis	Transient analysis	User's manual	Mathematical description	Plotting capability	Branches (max)	Nodes (max)
CIRCUS	X	X		X	X	X		400	200
Gen. Net. Analysis	X	X	X	X	X		X		30
MISSAP III	X	X	X	X	X		X	100	
NET-1R	X			X	X			600	100
Okla. Std. Analysis	X			X		X		60	
PREDICT				X	X	X	X	300	100
SCEPTRE	X	X		X	X	X	X	300	100
STRAP	X			X	X	X	X	300	100
TAG	X	X		X	X	X	X		100
TRAC	X	X		X	X	X	X	100	60
ECAP	X	X	X	X	X			400	100

ELECTRONIC EAVESDROPPERS



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Device	Description	Package
pL5R32C(1)	Dual 8/16-bit shift register	TO-5
pL5R40C(1)	Dual 20-bit shift register	TO-5
pL5R96C(1)	Dual 48-bit shift register	TO-5
pL5R100C(1)	Dual 50-bit shift register	TO-5
pL5R128C(2)	Dual 64-bit shift register	TO-5
pL5R128AC(3)	Dual 64-bit shift register	TO-5
pL5R250C(2)	250-bit shift register	TO-5
pL5R250AC(3)	250-bit shift register	TO-5
pL5R256C(2)	256-bit shift register	TO-5
pL5R256AC(3)	256-bit shift register	TO-5
pM1024	1024-bit read-only memory (sine look-up table)	Flat pack

(1) Clock rate 500KHz (2) Clock rate 2MHz (3) Clock rate 5MHz

the NOW people in MOS **PHILCO** Ford

Muffling noise in TTL

The bane of all electronics—noise—can be easily handled in transistor-transistor-logic systems. Here's how to recognize common TTL noise problems along with design methods to control them.

By William Heniford, Digital Applications Engineer
Texas Instruments Incorporated, Dallas, Tex.

Because of its built-in low impedance levels, transistor-transistor-logic (TTL), is less bothered by noise than other digital IC logic families despite its high speed. Simply put, it takes less noise power to develop an unwanted signal across a high impedance than across a low one.

For example, a "1" state TTL output resistance is 70 Ω; with DTL it is 6 kΩ. For a 100 ns risetime pulse and a coupling impedance between noise source and signal circuit of 30 pF: $RC_{TTL} = 2.1 \times 10^{-9}$, $RC_{DTL} = 180 \times 10^{-9}$. Total risetime, given as the RC time constant divided by the pulse risetime, is 0.021 for TTL and 1.8 for DTL. Thus, the larger the output impedance, the longer and greater amplitude the noise output pulse.

But TTL is subject to some noise problems, and its noise advantages may be lost unless you can recognize these problems and take corrective action.

Typecasting and control

Several types of noise must be dealt with in logic systems: external noise, power line noise, crosstalk, signal current noise, transmission line reflections. External noise pulses may come from many sources, but will be in the form of an electrostatic field, an electromagnetic field, or both. To effectively exclude them, sensitive circuitry must be completely shielded.

While aluminum or similar materials may stop electrostatic noise, only a ferrous metal can protect equipment against magnetic fields. It helps to connect the system to a good earth ground; but the shield system must be complete and must be grounded to the system ground. If it isn't, the shield may couple the noise into the system.

External noise may also be conducted into the system from the power lines. To prevent this, you should decouple and filter the lines as standard design procedure.

Fast logic systems are assumed to be more susceptible to externally generated noise than are slower systems, due to the former's greater bandwidth. But, in fact, a slow logic system is less susceptible to noise than a faster one only if it is slow compared to the noise signals. One of the fastest of the noise generators is the silicon controlled rectifier, which produces risetimes of about 1 μs. Edges as fast as this are slow when compared to even the slowest types of IC logic elements (about 0.5 μs propagation delay).

Grounds for decoupling

With internal noise, it is the actual transition time that determines the amplitude/frequency spectrum of the generated signal at the higher harmonics. Total propagation delay is important in determining the break point of the curve of ac noise margin versus noise pulse width (PW)—and thus the minimum noise PW to which the device can respond. In any IC logic family, this minimum PW is much less than that of common industrial electrical noise.

When you're concerned with internally generated-noise—on which propagation delay has no bearing—rise and fall times become important. It is the dV/dt of the transient that couples through small values of capacitance or mutual inductance.

Application of the Fourier Integral to TTL series waveforms shows frequency components of significant amplitude exceeding 100 MHz. When you're designing a system that uses these devices, be sure to take this frequency (rf) into account—even though the rep rates may be only a few hertz. Other factors to consider are transient currents generated by capacitance charging, changes in levels of direct currents, line driving, and so forth. (See panel below.)

In theory, line termination isn't a factor in drive current until after a reflected pulse returns from the termination to the transmitting device. In a practical TTL circuit the line termination must be high relative to the Z_o of the line.

Assume the voltage E is 5 V in amplitude, the Z_s of the source is 50 Ω, and the Z_o of the line is also 50 Ω. When E makes the transition from 0 to 5 V, the voltage across the input of the line will be (by Ohm's law) 2.5 V. Now for the 50 Ω line to become charged, a 50 mA current must flow onto the line. This current also flows in the ground return, in this case the twisted pair ground.

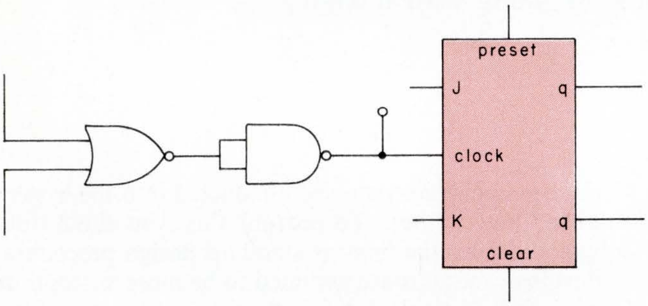
If the line and return are originated and terminated close to the driving and receiving devices, there is no discontinuity in the line. Where the ground is poorly returned, the currents flowing see the discontinuity in the cable as a high impedance, and a noise spike is generated.

Two rules to reduce transmission line current effects to acceptable levels in TTL systems may be set forth:

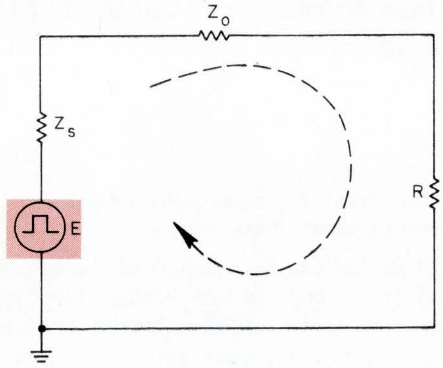
- Carry twisted pair and coaxial returns to a good ground termination close to the driving and receiving devices.
- Decouple V_{cc} of line driving and receiving gates close to the device with a 0.1-μF disc ceramic capacitor. (For V_{cc} decoupling methods see the panel on page 65.)

Noise . . . a sometime thing

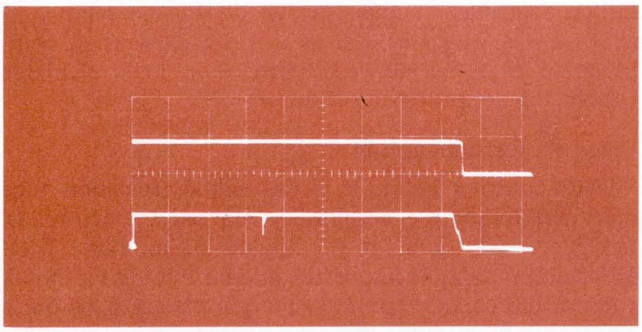
Typical logic circuit



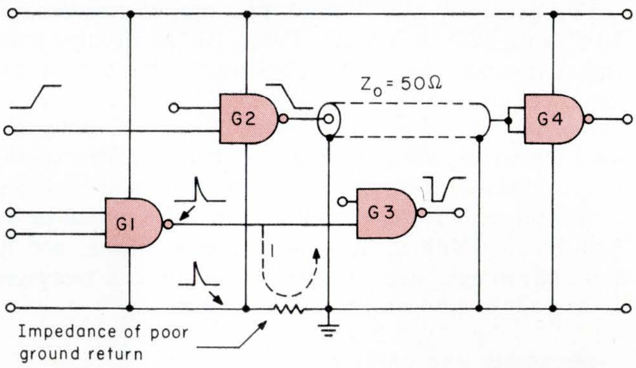
Gate-driven transmission line



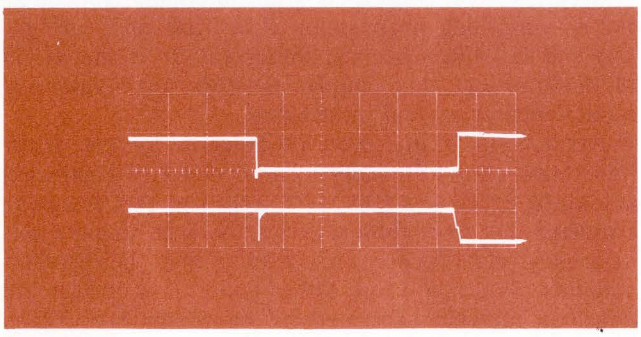
Tolerable noise



Poor return



Harmful noise



Hit or miss. Extraneous noise signals don't always interfere with logic circuit operation. In a typical logic IC—a J-K flip flop—a small noise pulse input (lower trace on the CRO photographs) induces a false response in one case and has no effect in another. The difference is the amplitude of the noise signal—and, of course, the lack of designed-in noise control measures. And, when a gate is used to drive a load transmission line, transients can cause problems.

Besides the IC's propagation time, transition time over the entire frequency spectrum—even though the rep rate occurs at low frequencies—is a factor. The simplified circuit model, used for rf analysis, shows the interplay of characteristic impedance Z_o, source impedance Z_s, and load R. Unless the line termination is high relative to Z_o, reflected induced current will produce a noise spike. Similarly, in a multi-gate subsystem, poor ground returns and uncoupled bias supplies also make the unit prone to spike generation.

Noise spikes on the V_{cc} line that do not force the gate output below the threshold level aren't serious. Downward spikes as great as 3 V have been tolerated on the V_{cc} line without propagating through the logic system. Thus, V_{cc} noise isn't a problem if you give it even minimal attention.

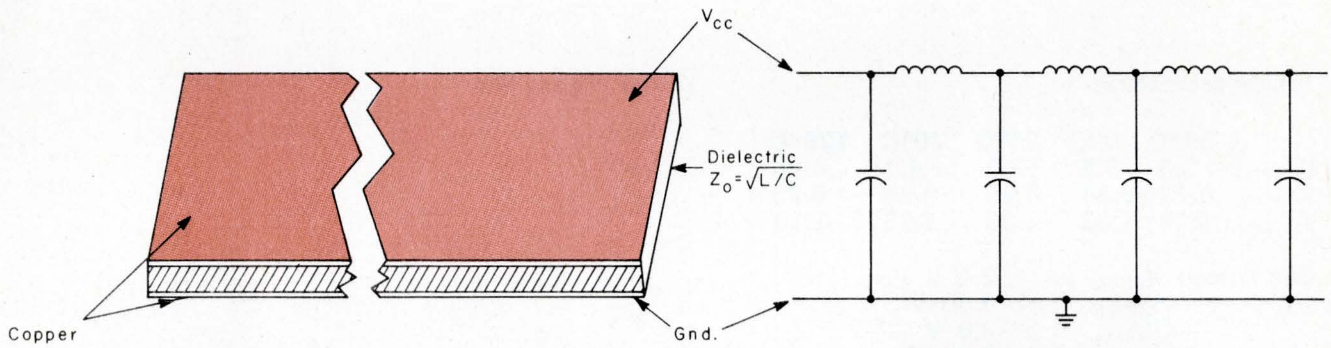
Ground noise is another matter. Pulses on the ground line can readily exceed the noise threshold. Only if a good ground system is maintained can you overcome this problem. A good ground termination is one with low enough resistance and inductance so that negligible voltage develops between the "grounded" point and system ground as currents flow in the ground path. Obviously, what is negligible in one system may not apply to another; similarly, current levels and current frequency components vary from system to system.

As a rule of thumb for TTL, assume that the output swing is 4 V. Since only a 0.400-V noise margin is guaranteed, the ground impedance must be $< 0.1 \times R_{cs}$ of the output transistor, where R_{cs} is $\approx$ 10 to 15 Ω.

The concept of a common ground plane structure as used in rf and high-speed digital systems is quite different from that of the common ground point as used in lf circuits. The more closely the chassis and ground can approach being an integral unit, the better the system's noise suppression characteristics. All parts of the chassis and ground bus system should therefore be bound tightly together electrically and mechanically. Floating or poor-

Handling Transmission Lines

Bus



Sidetracked. Noise may be decoupled in transmission lines to counteract its effect. Consider the V_{cc} line as a transmission line back to a low impedance supply. If you laminate the positive bus with a ground bus, a strip transmission line of low impedance is formed. As is often done in ECL systems, this line may be approximated by lumped elements.

When the V_{cc} bus is viewed as a dc connecting element only, you can provide low-impedance paths to ground to bypass transient currents. This is done in the capacitive storage system where the capacitors must handle changes in current transients for periods greater than the pulse widths. To accommodate changes caused by change in logic state—which occur at lower frequencies—a second capacitive shunt is added to the power distribution system. Thus, one capacitor handles the rf noise and a second the lf transients.

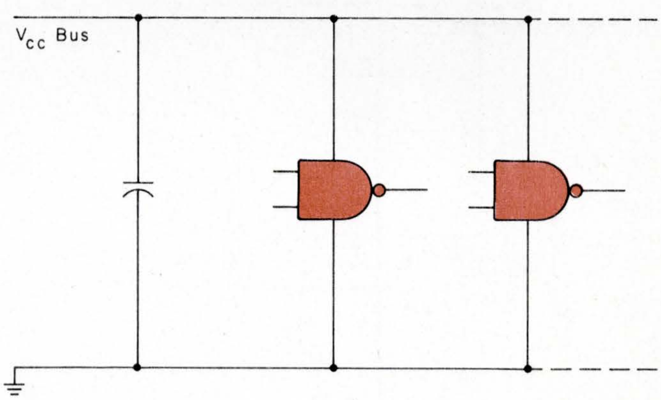
You can find typical values for the rf capacitor, C2, by assuming that:

$\Delta I_{cc} = 50$ mA, $\Delta V < 0.1$ V, and $\Delta T = 20$ ns. Thus $C2 = \Delta I_{cc}/\Delta V/\Delta T = 50 \times 10^{-3}/0.1/(20 = 10^{-9}) = 0.01\ \mu F$.

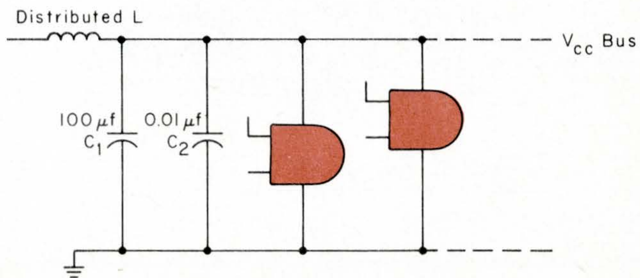
You can use the same approach for the lf capacitor C1. However, ΔT, which was merely a worst case transient time when calculating C2, now becomes a bit hazy. An analysis of the current cycling on a statistical basis is the best approach in all but the simplest systems. The recommended procedure is to use "brute force," and decouple with 10 to 50 μF.

A discrete inductance of 2 to 10 μH is sometimes added for further decoupling. However, its benefits are questionable and its usefulness should be evaluated for the individual system. The low-pass filter formed must be able to keep the transients confined and off the distribution bus. You must also consider the possibility of resonance in the inductor or LC combination.

Storage



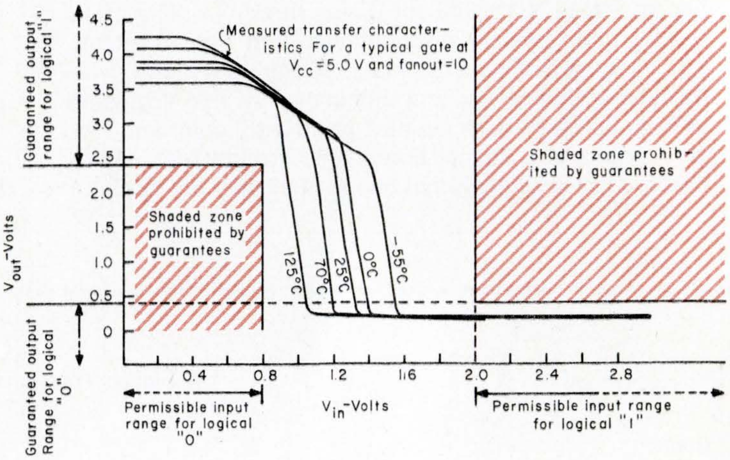
Distributor



Safety margins in TTL

Leveler. Noise in transistor-transistor-logic ICs isn't difficult to handle because of innate low impedance levels. The table of voltage parameters gives the designer permissible and prohibited signal ranges. Added guidance is provided by graphs showing noise margins. These margins hold up well under temperature variation, as shown in the fourth figure. The last figure shows the overall noise immunity of TTL, whose ac noise rejection approaches infinity for narrow pulse widths and approaches the dc margin for pulses of widths approximating the ICs' propagation delay.

Zoned transfer



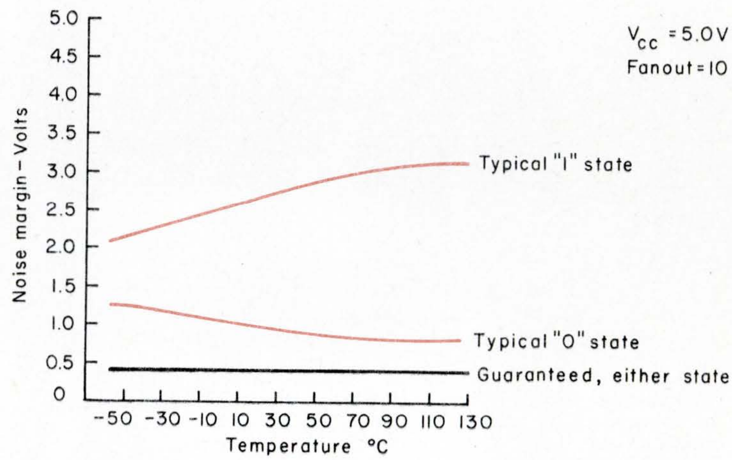
Voltage parameters*

	–55°C	0°C	25°C	70°C	125°C
$V_{OUT(1)}$	3.6	3.8	3.9	4.1	4.25
$V_{OUT(0)}$	0.23	0.24	0.25	0.25	0.25
V_{THRESH}	1.49	1.33	1.26	1.15	1.10

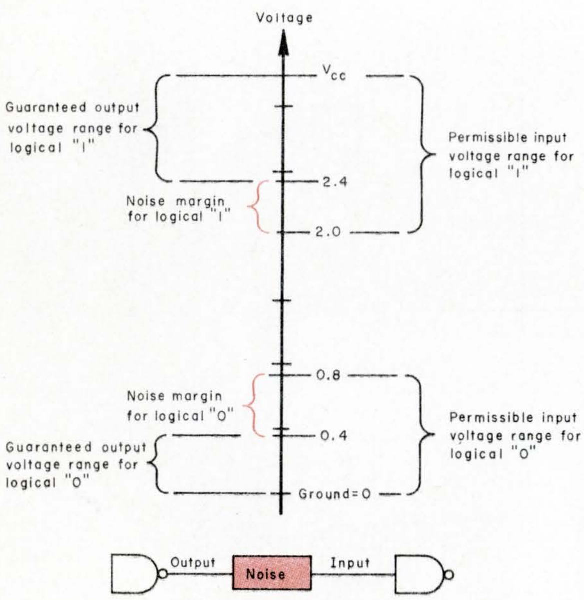
Guaranteed $V_{OUT(1)}$: > 2.4 V
$V_{OUT(0)}$: > 0.40 V
$V_{IN(1)}$: > 2.0 V
$V_{IN(0)}$: > 0.80 V

*(Values given are operating, not worst-case, for SN5400/7400 gates at V_{cc}=5.0 V)

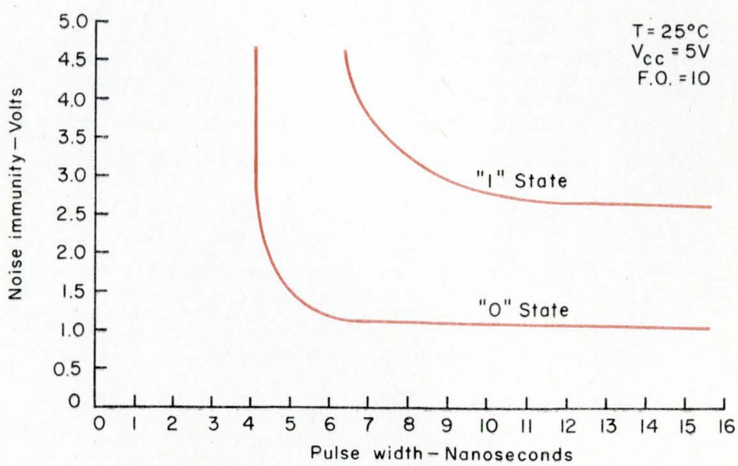
Thermal '1's and '0's



Ruling the margins



Noise immunity



ly grounded sections not only break the integrity of the ground system, but may actually act as a noise distribution system.

On printed boards the best arrangement would be a double clad board with one side carrying the interconnections and the other a solid ground plane. Where component density prohibits this, you should relax the ideal only as far as necessary.

Crosstalk can become a problem on large boards; an adequate board ground mesh will go far in reducing crosstalk as well as ground noise. When a plane is not practical, make the ground strap as wide as possible everywhere, even though this may mean its width varies radically. Also, form a complete loop around the board, bringing both sides of the board through separate pins to the system ground.

If properly decoupled, the V_{cc} line can provide part of the ground mesh on the board. For a TTL system, 0.01 μF per synchronously driven gate, or at least 0.1 μV per 20 gates regardless of synchronization, are good rules-of-thumb. You may lump this capacitance, but it's more effective if you distribute it over the board. As a rule, permit no more than 5 in. of wire between any package V_{cc} point. Also a total of 0.01 μF rf type capacitors are mandatory; disc ceramics are a good choice.

As an option, you can decouple the board from the external V_{cc} line with a 2.2-μH inductor and a 10-μF to 50 μF capacitor, although you'll still need the rf capacitors. Also, gates driving long lines should have the V_{cc} supply decoupled at the gate V_{cc} terminal; and you should bring the capacitor, device ground, and transmission line ground to a common point.

Safety margin

TTL circuits have an excellent composite of electrical properties for noise-free operation (see panel, page 66).

By defining $V_{out(1)}$ as that output present when the input is a typical $V_{out(0)}$ level, $V_{out(0)}$ as that output present when the input is a typical $V_{out(1)}$ level, and $V_{threshold}$ as that voltage at which input and output are equal, you can arrive at typical values for each. These are presented in the table.

Accepted definitions for dc noise margins for the different logic states are also defined in the panel, which indicates the typical and worse case dc noise margins.

In addition to dc noise immunity, there's another type of noise immunity that's defined around noise amplitude and pulse width. At the limits, the ac noise immunity varies from the dc values to a theoretical infinity at very narrow PWs. Pulses shorter than the propagation delay of the devices will not propagate through the system. Thus the effective noise immunity is that noise level and pulse width below which noise signals will not propagate through the system. As shown, ac noise rejection approaches infinity asymptotically at very narrow pulse widths and approaches the dc noise asymptotically near pulse widths equal to device propagation delay.

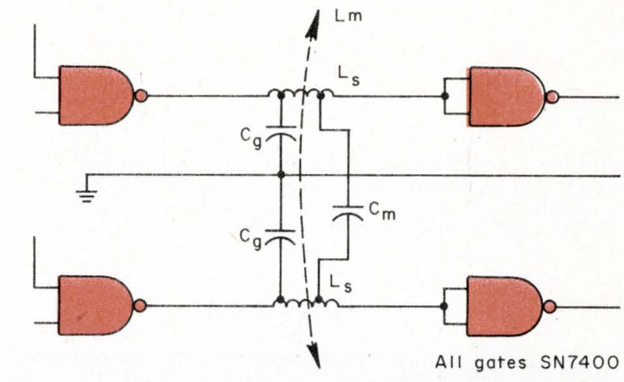
In general, noise coupled from external sources has enough pulse width such that only the dc noise immunity is effected, since only about 6 ns are needed for an IC to respond.

Neighboring crosstalk

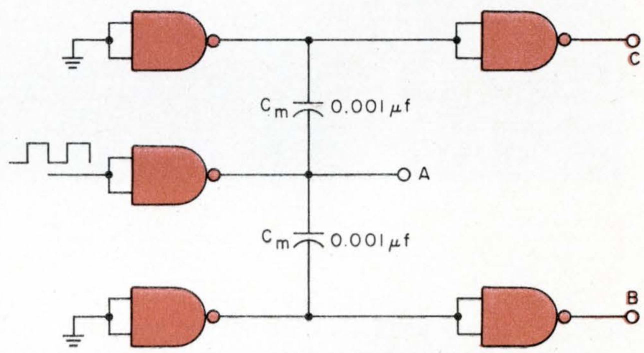
When currents and voltages are impressed on a connecting line in a system, it's impossible for adjacent

Combating crosstalk

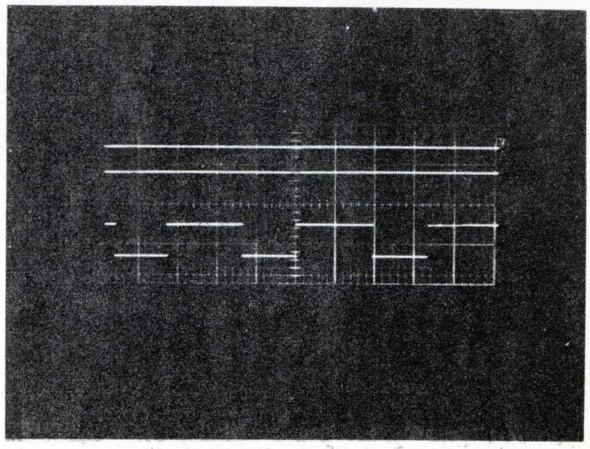
Impedances involved



The static case



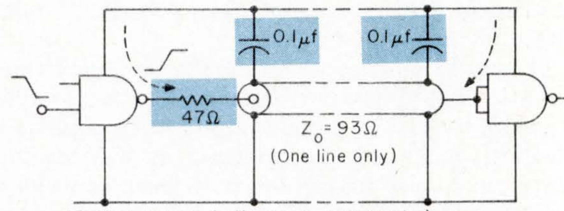
Innate immunity



Fielding problem. Crosstalk effects in digital systems are produced by interaction of adjacent fields. Static and magnetic potentials create opposing ground currents, which in turn induce cross-coupling fields. The impedances in a typical TTL system are mutual reactances L_m and C_m, which form the noise coupling paths, and line parameters L_s and C_g, which govern the Z_o of the lines. Crosstalk is a function of the ratio of mutual impedance to line (characteristic) impedance. With leads or direct leads, TTL can tolerate even large impedances ($C_m \gg C_g$). For the static case shown in the middle diagram, capacitive crosstalk does not appear, as evidenced by the CRO patterns. (Top—A, middle—B, and bottom—C.)

Reflections Remedied

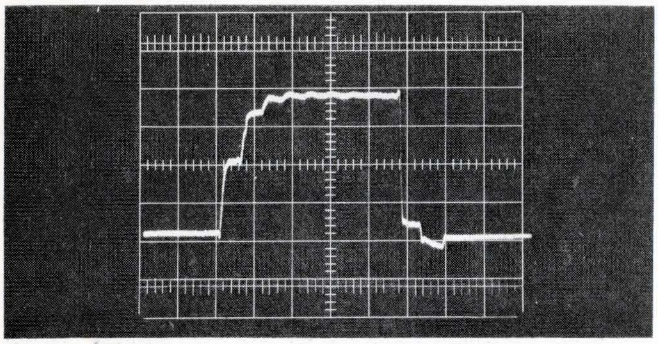
Line driver



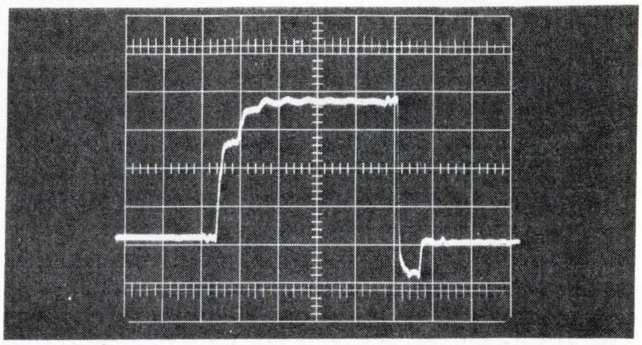
(Broken arrows indicate current paths)

Tie line. To overcome reflections in a gate-driven transmission line, increase the line impedance and use filtering capacitors. CRO patterns of input and output signals show absence of erronerous pulse outputs.

Input waveform



Output waveform



lines to remain unaffected. Static and magnetic fields interact and opposing ground currents flow, creating linking magnetic fields. These cross-coupling effects are lumped together as *crosstalk.*

Signal lines are grouped into three categories: coaxial lines, twisted pair lines, and straight wire lines. (The figure in the panel on page 67 shows practical types of signal transmission lines.) Since crosstalk is a function of the ratio of the mutual impedances to the line characteristic impedances, the type of interconnection you use is an important factor.

Coaxial cable combines high mutual reactances with low characteristic impedances and provides shielding and therefore effectively eliminates crosstalk. *Twisted pair lines* have higher characteristic impedances and lower coupling impedances, and thus pose a possible crosstalk problem. *Direct wired connections* are the simplest and cheapest approach, but they are also the poorest for noise rejection.

Fortunately, much of the noise that may be coupled in is subdued by the short time constants and impedance voltage-division which result from the low output impedances of TTL. It is possible to use direct leads of up to 10 in.—and up to 20 in. if the lead is routed close to ground and not cabled tightly together with similar leads. For longer distances, twisted pair or coaxial cable is required. Twisted pairs usually cost less and are easier to work with, but noise levels become objectionable beyond 12 ft. lengths.

When the lines that transfer digital signals become so long that line propagation delay is equal to or greater than the pulse transition times, reflection effects must be considered. You must evaluate factors such as gate output impedance, Z_o of the line, possible terminations, and line length, since they could possibly cause problems in excessive delay, ringing or overshoot.

In the earlier discussion (see panel on page 64) on reflections, only half the generator voltage was developed across the line initially, regardless of the termination. Now, assume that the receiving end load, R, is greater than Z_o. The relative values of R and Z_o determine a positive reflection factor which sends the pulse back down the line to the receiving end after $2T$, where T is the time needed for the signal to propagate the full length of the line.

The TTL gate input in the "1" state presents close to an open circuit termination.

Since the initial step at the line input falls at the threshold of a gate input, any gate having its input connected to this point will be operating within its linear region and instability or oscillation could result. At the very best, its output state would be unknown. Also, since the first step is so low, excessive currents are being drawn from the gate, aggravating ground and V_{cc} noise problems.

At the receiving end, the first step does exceed the threshold and in fact reaches the guaranteed minimum output "1" level, but it dips back with some loss of noise margin. If variations in devices, temperature, V_{cc}, and line impedance are considered, the situation looks much more critical. The receiving gate input could actually remain below the threshold on the first step. If so, another $2T$ delay is added, some undertermined amount of noise margin is lost, and instability could result. Under other conditions the gate input voltage could rise above the threshold and then fall below, causing a double pulsed output.

Remedies call for combinations

There is no one method that will eliminate all these potential problems, but proper combination can be effective. Consider the following techniques.

To increase the amplitude of the input step:

- Lower the driver impedance. Devices can be connected in parallel, or the buffer gate used. In most cases neither is necessary with TTL.
- Increase the transmission line impedance. Coaxial cables of 93 Ω are quite practical in size and cost; or twisted pairs, with impedances from about 100Ω upward, can be used where practical. (See the panel on page 68.)

To retain the line driving capabilities and noise immunity of SN5400/SN7400 TTL without curbing their usefulness, you can take these measures:

- Use direct wire interconnections that have no specific ground return for levels up to about 10 in. only. A ground plane is always desirable.
- Route direct wire interconnections close to a ground plane if longer than 10 in. (they should never be longer than 20 in.).
- When you use coaxial or twisted pair cables, design around (approximately) a 100-Ω characteristic impedance. Coaxial cable of 93-Ω impedance (such as Microdot 293-3913) is recommended. For twisted pair, #26 or #28 wire with thin insulation twisted about 30 turns/ft. works well. Higher impedances increase crosstalk while lower impedances are difficult to drive.
- Insure that transmission line ground returns are carried through at both transmitting and receiving ends.
- Connect reverse termination at driver output to prevent negative overshoot.
- Decouple line-driving and line-receiving gates as close to the package V_{cc} and ground pins as practical; use a 0.1-μF disc ceramic capacitor.
- When gates are used as line drivers, don't use them for any other purpose. Gate inputs connected directly to a line driving output could receive erroneous inputs due to line reflections, long delay times, or excessive loading on the driving gate.
- Gates used as line receivers should have all inputs tied together to the line. Avoid other logic inputs to the receiving gate and use a single gate as the termination of a line.
- Flip-flops are generally unsatisfactory line drivers because of the risk of collector commutation from reflected signals.

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EE DRAWER

Take the guesswork out of fuse selection

Use the forgotten parameter—fuse clearing time—to intelligently decide which fuse to use to protect your power semiconductor.

By F. B. Golden,

Semiconductor Products Dept.
General Electric Co., Auburn, N. Y.

Trying to match a fuse to a semiconductor for semiconductor protection isn't as easy as it sounds. What criteria do you use? Fuse RMS current clearing I^2t and peak let-through current are all important parameters.

However, you must also consider pulse base width or total fuse clearing time to be sure you are properly protecting your power semiconductors. Furthermore, when fuse clearing time is used as the running parameter, a new method of displaying fuse characteristics becomes possible. It allows a direct 1:1 comparison with semiconductor capabilities, thus taking the guesswork out of applying fuses to power semiconductor circuits.

Before setting down a set of logical design steps let's look at a typical fuse-SCR circuit (Fig. 1). To define terms and become acquainted with the waveshapes in the circuit, assume a fault across the load resistance R_{LO}. In Fig. 2, this fault is shown taking place close to the instant of peak source voltage. It can occur at any point of the source voltage waveform but I chose this point because it is the most stringent for the fuse to interrupt under large prospective fault current conditions and high circuit X/R ratios.

X/R ratio as used here refers to the ratio of the series reactive to resistive elements of the circuit when shorted. Since the series reactive component in power circuits is nearly always inductive, the ratio of X/R is a relative measure of the energy a circuit can store. Since this energy must be absorbed by the fuse in its arcing phase it serves as an indication of the severity of the current quenching duty placed upon the fuse. Fig. 3 shows a close-up of the fuse action shown in Fig. 2.

The fuse current waveform is triangular in shape with an effective pulse width of t_c seconds and a peak of $\hat{I}$ amperes. It's important to note that t_c can vary from $<\frac{1}{2}$ ms to >8 ms in 60 Hz circuits, while the variation in $\hat{I}$ is typically from 10 to 100 times rms I rating. Clearly $\hat{I}$ and t_c are the parameters that determine the destructive effects of the short circuit current, both on the semiconductor and on other circuit components. However, neither parameter is used extensively today in matching fuses to SCR's. Rather the $\int i^2{}_f dt$ abbreviated as I^2t is used. Obviously, you can see from equations 3(a) and (b) that I^2t takes into account both $\hat{I}$ and t_c but used alone can result in erroneous fuse application.

Fuse ratings

Many fuse manufacturers give only the following data:

- Fixed values of I^2t at different rms circuit voltages.
- Peak let-through current curves vs rms prospective current.
- Melting time vs rms current curves.

The latter curve's time values shouldn't be confused with t_c since the values given for melting time rarely extend below 10 ms and the time values are for melting time only—not complete fuse clearing time. Thus, these curves are not very useful for short circuit current evaluation of fuse behavior. They are valuable only for long term fuse overload conditions.

Figures 4 and 5 show typical fuse performance in a 480 V circuit. These two curves when taken together characterize the fuse as a function of the circuit parameters, V_{SOURCE} and I_p. For a given I_p, t_c can be found by solving Eq. 3.

$$t_c = \frac{3\ (I^2t)}{I^2}$$

Both $\hat{I}$ and t_c as a function of circuit parameters can be found from the fuse manufacturer's data.

Now let's turn to the SCR's capabilities and manufacturer's ratings for fuse co-ordination.

Fuse circuit definitions

t_m Fuse melting time
t_A Fuse arcing time
t_c $t_m + t_A$ fuse clearing time
$\hat{I}$ Peak instantaneous fuse let-through current

$$I_p \frac{V_{source}}{Z_s + Z_L} \qquad \text{Eq. (1)}$$

Maximum symmetrical rms circuit fault current. Abbreviated prospective current
V_A Peak fuse arc voltage
i_f Instantaneous fuse current

$$I^2t_c = \int_{t_o}^{t_o + t_c} i^2f\ dt = \text{clearing } I^2t \qquad \text{Eq. (2)}$$

$$= I^2t_m + I^2t_A$$

$= (\hat{I}^2/3)\ t_c$ for a triangular waveform
Note: I as used in I^2t_c is a rms current value.

For a triangular waveform:

$$I^2t = \frac{\hat{I}^2t_c}{3} \qquad \text{Eq. (3a)}$$

And for a sinusoidal waveform:

$$I^2t = \frac{\hat{i}^2t_c}{2} \qquad \text{Eq. (3b)}$$

$$\hat{I} = \sqrt{2\frac{(I^2t)}{t_c}}^{\,*} \qquad \text{Eq. (4)}$$

* sinusoidal waveform I^2t value

SCR rating for fuse application

Past practice by SCR manufacturers has been to give a single I^2t value for a fixed pulse width. This was then said to be constant for all PWs. As with fuses, I^2t capability varies greatly with PW. This is shown in Fig. 6. This figure shows that I^2t cannot be assumed to be constant. Furthermore, different manufacturers have published I^2t values based on different pulse base widths. Some have used 1 or 1½ ms and others have used 8.3 ms and more recently, 5 ms. In the absence of an entire curve, values of I^2t based on 8.3 ms should be recognized for what they are to avoid an inflated view of the device's true operating capability under actual fused circuit conditions.

Pulse current waveform's effect

Now what is the affect of pulse shape on I^2t and peak capability of the SCR? Until recently the effect of pulse shape on SCR capability was not considered. For convenience a half sinusoidal pulse shape (Fig. 7) had been used to determine an SCR's capability where both a triangular and sinusoidal pulse are shown having the same I^2t and pulse base width. The far higher peak current of the triangular waveform has led some engineers to speculate that even though the I^2t of two waveforms are the same, their destructive effect on the semiconductor may be different.

An analytical study of waveforms having the same I^2t values, showed that the triangular waveshape produced a far higher virtual junction temperature rise. Based on this initial study we decided to test the hypothesis by failing SCRs to destruction using both triangular and sinusoidal waveforms having the same PW and coming from the same production lot.

We found that an SCR's peak current capability is about equal for the two waveforms but the I^2t's aren't equal, the sinusoidal I^2t value being 150% higher than the triangular waveshape I^2t value. Faced with this discrepancy in I^2t values what course of action is open to the designer? Why not use the peak current value which is the foundation upon which I^2t is built for either triangular or sinusoidal shaped waveforms. Since the SCR's peak current capability is equal for both waveshapes, a way around the problem has been found. Peak current values may be found either directly from the semiconductor manufacturer's data sheet where given, or indirectly from equation 4.

Mating fuse to semiconductor

In the past, we assumed that both fuse let-through I^2t and semiconductor I^2t capabilities were constant. Thus, the only consideration was to determine the I^2t's of the fuse and SCR and to assure that the I^2t capability of the SCR exceeded that let-through by the fuse.

Figure 8 shows a method for taking into account the PW of the peak let-through current as well as the circuit available fault current I_p.

After the fuse characteristics are plotted you can then directly superimpose the SCRs characteristics directly on the same chart and immediately determine the required circuit trade-offs to optimize the design. This chart is also useful for any other circuit components that might be subjected to short term current transients. Its importance becomes increasingly clear as you look at the slope of the semiconductor curve labeled "A." If you applied this semiconductor to a fuse having the characteristic slopes shown, the maximum permissible fuse size would vary over more than a 2:1 range depending upon the maximum prospective short circuit current, I_p, available through the circuit. The reason for showing the semiconductor curves dotted below 1 ms stems from a lack of vigorous test data on the semiconductor's short term surge capability in the 100 to 1000 μs range. It is known that due to di/dt restrictions, peak current capability of an SCR is reduced below 100 μs PW. Until firm test data is available, use discretion in this range.

The "B" SCR I vs t_c curve is obtained by drawing a straight line between two points obtained from the manufacturer's data sheet. When a curve such as that in Fig. 6 is given in the manufacturer's data sheet, it can be plotted directly on Fig. 8.

SCRs and fuses

Referring back to Fig. 1, assume the following problem: You must select a fuse/SCR combination in a 480 V rms circuit with a 20 A rms load. Furthermore, the fuse must protect the SCR if a fault occurs across the load.

Design steps

1) Choose the SCR. Based upon voltage and current considerations, a unit is chosen with a case temperature of 90°C at 9 A average/cell to give a total line capability of 20 A rms.

2) From fuse manufacturer's ratings derive, or request from him, a chart as shown in Fig. 8.

3) Superimpose on chart showing fuse characteristics semiconductor capability derived from SCR data sheet.

4) Determine maximum short circuit current I_p circuit will produce in rms amperes.

You may obtain this in two ways. First you may measure it by adding a circuit breaker in series with the source, shorting out the SCR and fuse and crowbarring the load with another breaker. You then measure the resulting rms current with a memory scope and current shunt or other suitable method. However, on large systems this approach may not be either feasible or practical. The alternative is to determine analytically the approximate prospective fault current by obtaining data on the source impedance and connecting power components.

In most medium and low power applications, I_p will be principally limited by the distribution trans-

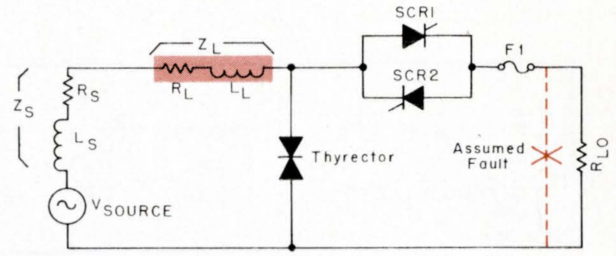

Fig. 1: Typical fuse-SCR circuit.

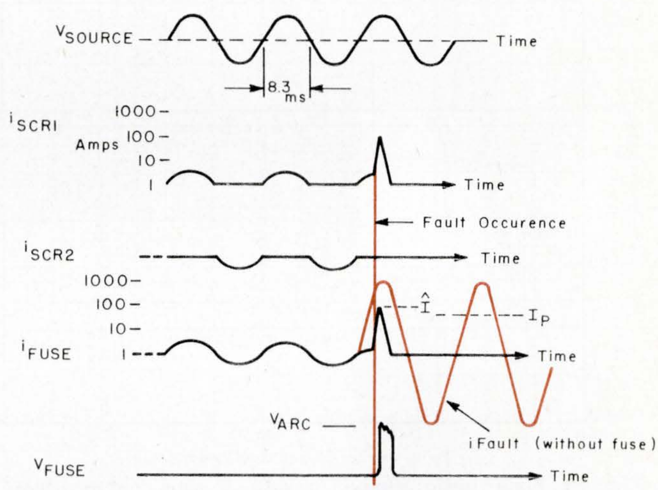

Fig. 2: Circuit waveform (of Fig. 1) under steady state and typical transient fault conditions.

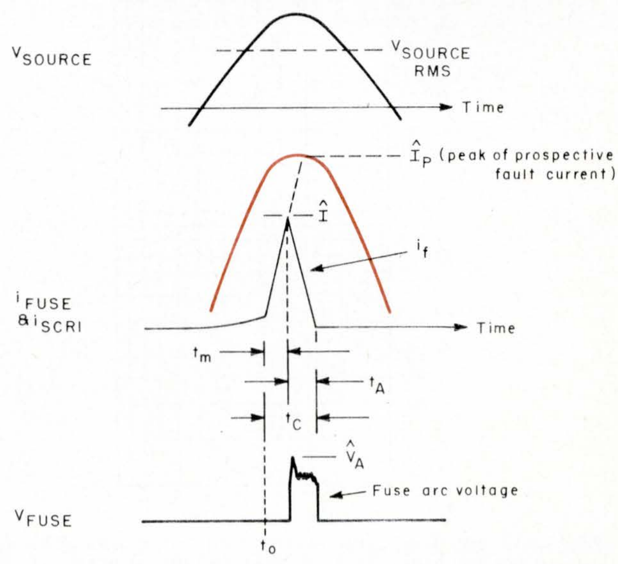

Fig. 3: Circuit waveforms during fuse clearing interval. This figure presents a close-up of the fuse action shown in Fig. 2.

Table 1

		Available fault current symmetrical RMS (Prospective current I_p) in kA							
		0.5	1	2	5	10	20	50	100
1) From Fig. 4	I^2t (A^2s)	52	55	60	65	70	77	85	90
2) From Fig. 5	$\hat{I}_1$ (kA)	0.21	0.265	0.34	0.47	0.6	0.79	1.1	1.3
3) Data from 1, 2 above using Fig. 8	t_c (ms)	3.5	2.5	1.6	0.9	0.58	0.37	0.21	0.16

Fuse data conversion from manufacturer's data sheet to fuse-SCR application chart. 480 V circuit voltage, 16 A fuse.

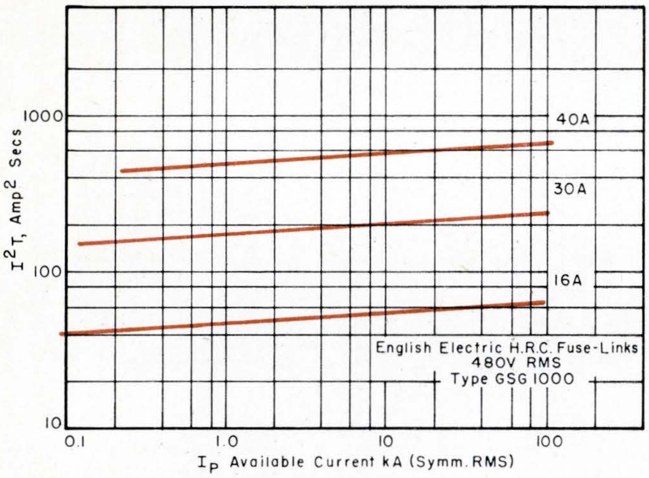

Fig: 4: Fuse performance in 480 V rms circuit. Note how the I^2t varies by a factor of two over the I_p range of 0.1 to 100 kA rms symmetrical.

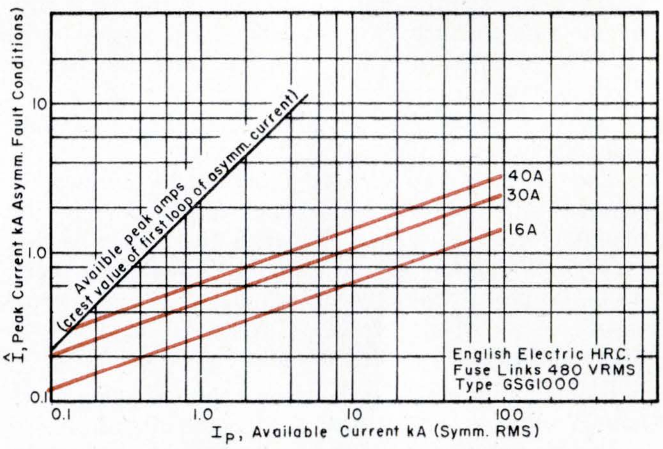

Fig. 5: Fuse performance in a 480 V rms circuit.

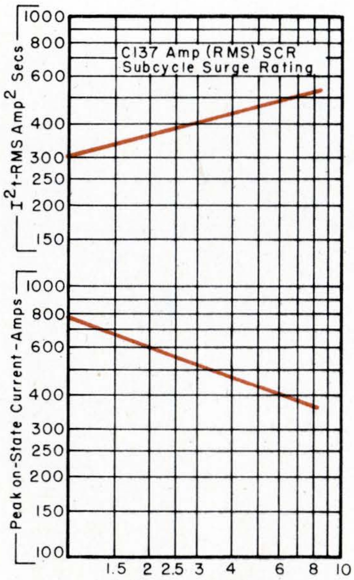

Fig. 6: I^2t and I vs pulse width for a 35 A rms SCR. Both curves are for a half sine wave of current. You can see that I^2t's capability varies greatly with pulse width.

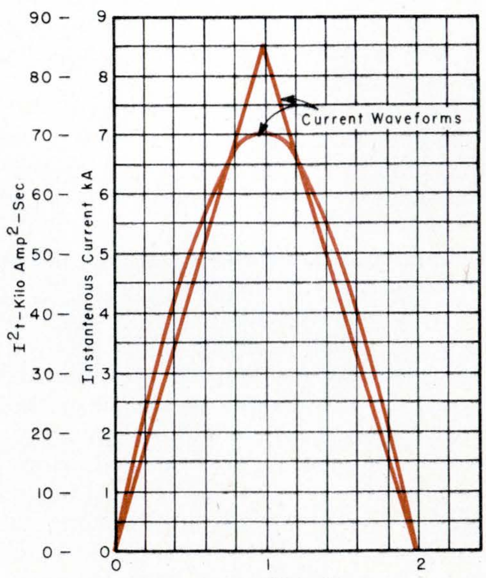

Fig. 7: Peak current and I^2t relationship between sinusoidal and triangular waveforms having the same pulse base width and I^2t.

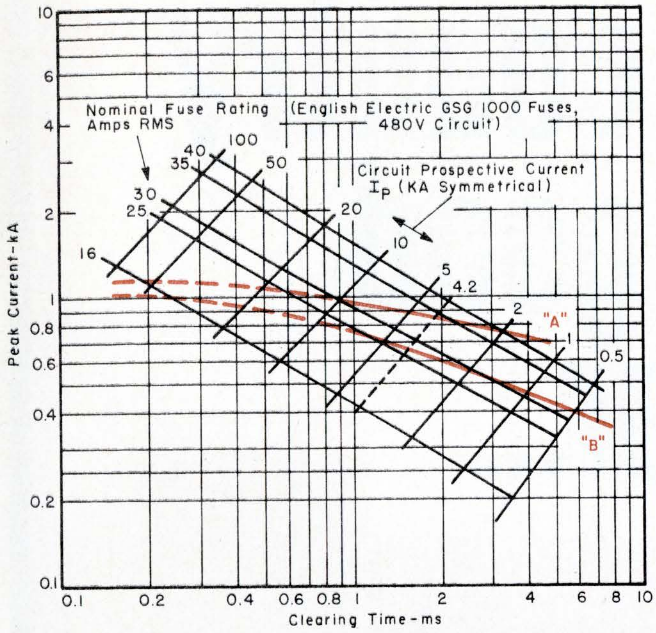

Fig. 8: Fuse-SCR application chart. The fuse portion of the chart is derived from Figs. 4 and 5 and the nomograph shown in Fig. 9. Table 1 shows the derivation procedure for the 16 A fuse line.

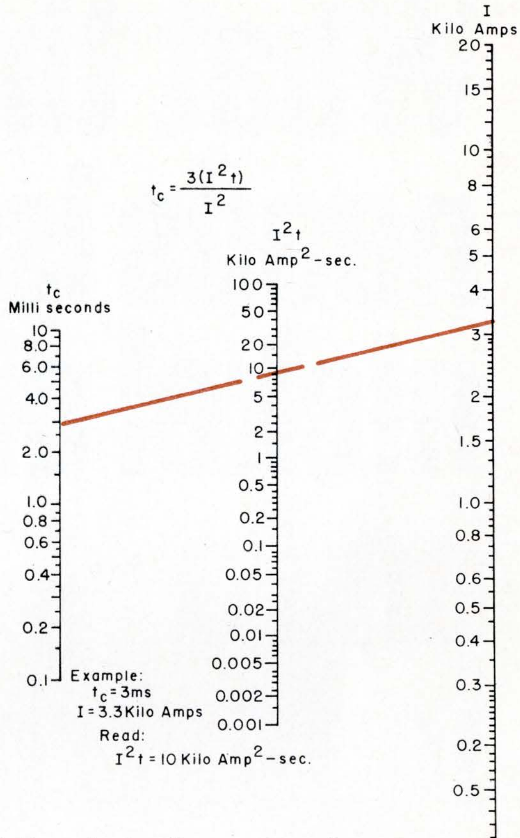

Fig. 9: Fuse clearing time nomograph.

former feeding the load. However, this is not always the case, as long cable runs may help to limit I_p due to the equivalent series impedance of the run. Transmission line data may be obtained from handbooks on power transmission for the purpose of obtaining the short circuit capability of a system.

To illustrate the analytical approach, let's assume a 100 kVA 5% impedance transformer as the voltage source for the example of Fig. 1. Furthermore, the impedance of the primary source feeding the transformer and secondary cable runs will be assumed negligible. Then the transformer is the sole remaining source of circuit current limiting and its impedance may be calculated:

$$Z_T = 0.05 \frac{480 \text{ V}^2}{100k\text{W}} = 0.015\ \Omega$$

or about 300 μH if the impedance is taken to be mainly reactive. I_p is then equal to the source V divided by the source impedance assuming the above calculated 0.015 Ω yields a maximum rms prospective short circuit current of 4.2 kA.

5) Selection of fuse current rating. The fuse current rating must be greater than the load current but must be limited to a size which, under short circuit conditions, will limit the maximum let-through current, I, to a value below the maximum capabilities of the SCR. Here is where use of Fig. 8 removes the black magic from fuse selection. Any fuse rating falling below the intersection of the SCR locus and the I_p value of 4.2 kA is permissable. In this case the obvious choice of fuse rating is 25 A.

6) Change of circuit constants enables selection of different fuse rating. If a larger fuse is desired or conversely if the load current is increased to 25 A, then the circuit I_p must be reduced below 2 kA if the SCRs are to be protected under all possible short circuit conditions. The necessity for the reduction in I_p can be seen by a glance at Fig. 8. The next size larger fuse from a 25 A value is a 30 A rating. The 30 A curve crosses the SCR rating curve slightly below the intersection of the SCR curve and the prospective current curve of 2 kA. Values above 2 kA show the fuse let-through currents exceeding the maximum allowable SCR current thereby not guaranteeing SCR protection. This reduction in I_p needed to accommodate the 30 A fuse can be accomplished by adding additional impedance in the circuit as shown by R_L and L_L of Fig. 1. If again the added Z is assumed to be purely reactive a current limiting L of 400 μH would be needed. This, then, would allow you to use a 30 A fuse. This limiting reactor would serve double duty, for in addition to limiting the fault current, it would act to minimize RFI and in conjunction with a Thyrector would aid in clipping voltage transients.

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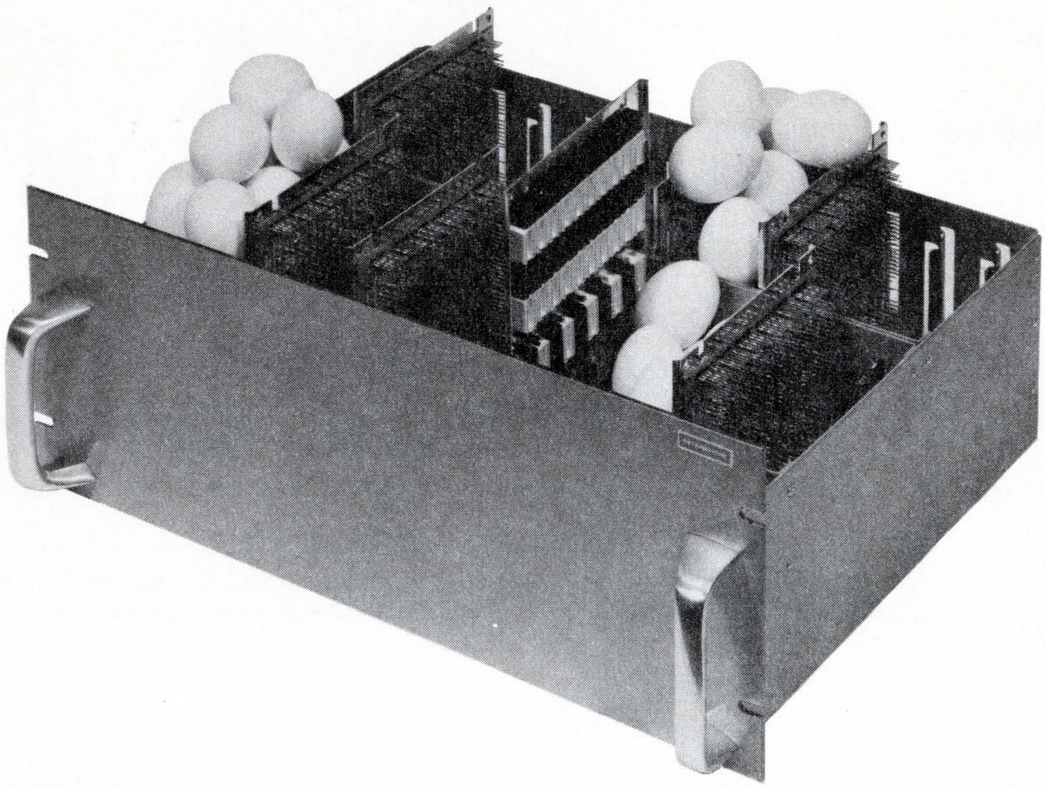

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923 Edger develops fast pulses

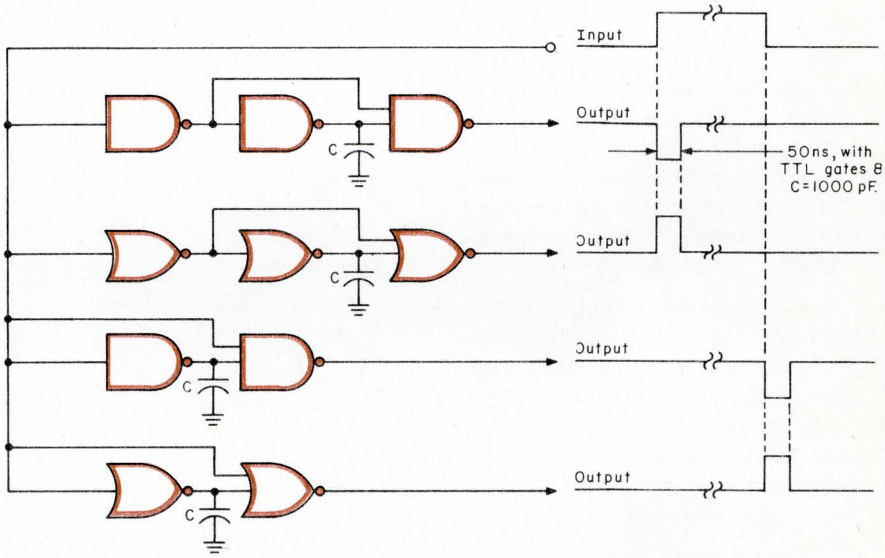
V. R. Aker and F. E. Carter

Lockheed Missiles & Space Co.
Sunnyvale, Calif.

In the design of asynchronous logic systems, you may sometimes find it necessary to develop leading or trailing edges of pulses. An edger circuit is a convenient, low-cost way to do this.

Such a circuit gives you a bonus, in that you can derive a two-phase clock system from it. To do this, simply combine a leading edge and a trailing edge in an OR gate.

If you use TTL gates to build the circuit shown here, then a 1000-pF capacitance value will give you 50-ns pulse widths. Larger capacitance values will give you correspondingly wider pulses.



924 Delay circuit makes handy timer

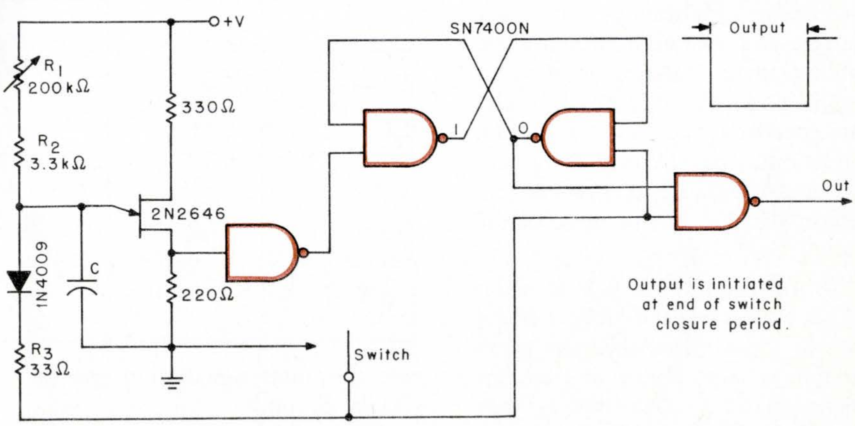
G. Detlof

Tel. AB L.M. Ericsson
Stockholm, Sweden

With a unijunction transistor and an RS flip-flop, you can build a circuit useful in timing and control applications.

Closing the momentary-contact switch RESETS the flip-flop, and simultaneously discharges the capacitor through the diode. (Resistor R_3 limits the diode's current.) When the switch opens, the capacitor starts to charge through R_1 and R_2, and the output goes LOW.

The output stays LOW until the capacitor reaches the UJT's peak-point voltage. When the UJT fires it puts a positive signal into the first gate which, in turn, SETs the flip-flop with a negative signal. The output is again HIGH.



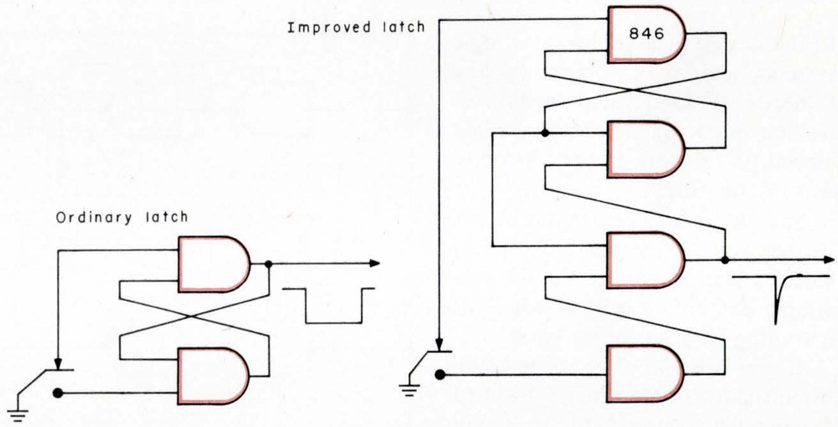
The values of R_1, R_2, and C set the output pulse width, which can be several minutes long.

925 Single-pulse source replaces simple latches

Norman L. Holcomb

Continental Screw Co., New Bedford, Mass.

Here's a circuit that gives you a single, fast pulse—and doesn't use a single capacitor. The circuit is a useful trigger source wherever power supplies are not well filtered. In such situations, line transients can sometimes trigger sensitive circuits connected to capacitive pulse sources.



An ordinary latch's output is undesirably long. This means that you open a window for false triggers whenever its output is LOW.

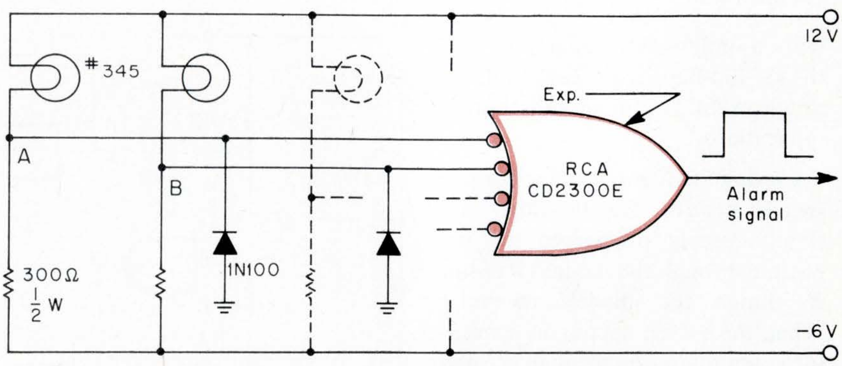
On the other hand, the new circuit shown here has the advantage that when you actuate the switch, the output following the negative pulse *immediately* returns to a +5-V level. There is a single, fast pulse on closure of the switch, which does not repeat when the switch returns to its normal position.

926 What to do before the lights go out

I. Berner

RCA, Camden, N. J.

In some applications of pilot lamps, you may need an automatic indication of failure. A case in point is the use of lamps to excite an encoder's photocells. For such situations, the circuit shown here is useful because it provides an alarm signal if one or more of the lamps opens up.



Normally, there is 6 V at nodes A, B, and so forth. If all such nodes are at this voltage, then the gate's output is LOW. But if at least one lamp filament open-circuits, then its node will be pulled down to about −0.3 V. This, in turn, causes the gate's output to rise. You can use this HIGH signal to trigger an alarm circuit.

Nominal lamp ratings, node voltages, and supply voltages set the resistor value. Each clamp diode must be able to supply the sink current demanded by its resistor, and should be germanium. The fan-in of the gate sets the number of lamps that you can monitor.

Feature article abstracts

Published information is vital to your job. To save time in finding this information, we have abstracted the important technical features from eight electronic engineering publications. Should any of these articles interest you, contact the magazine—names and addresses are listed below. Reprints of articles with an asterisk are available free. Save this section for future reference.

Circuits

***Simplifying impedance matched circuits,** Martin Blickstein, Voltronics, "The Electronic Engineer," Vol. 28, No. 7, July 1969, pp. 84-85. One of the simplest ways to match the output of one circuit to the input of another is to adjust the capacitance of either circuit with a trimmer. When the capacitances involved are small, however, the trimmers required are also small, and their adjustment becomes critical. Mr. Blickstein describes a method that uses a few basic components and a dual trimmer capacitor. Since the trimmer is dual, it can adjust the capacitance in two different parts of the circuit at the same time, maximizing the energy transfer from one circuit to another.

Circuit Design

Nonstop limiter absorbs transients, Martin Kanner, Grumman Aircraft Eng'g Corp., "Electronics," Vol. 42, No. 11, May 26, 1969, pp. 106-112. Protection from line transients is done with a series type regulator that uses a transistor in a full wave bridge. The limiter can be inserted between the input power line and the equipment.

Design wideband uhf power amplifiers, Jerome H. Horwitz, Bunker-Ramo, "Electronic Design," Vol. 17, No. 11, May 24, 1969, pp. 72-77. Designing a wideband uhf amplifier using transistors can be full of problems. The problems and practical solutions are described by the author. Some of the problems are device Q, prasitic impedances, and device gain falling off as frequency increases.

***Muffling noise in TTL,** William Heniford, Texas Instruments Incorporated, "The Electronic Engineer," Vol. 28, No. 7, July 1969, pp. 63-69. Noise is a problem that must always be considered when designing logic circuits or systems. Unfortunately, it's generally assumed that fast logic systems (such as TTL) are more susceptible than slow ones to externally-generated noise. The truth is that high speed transistor-transistor-logic (TTL) isn't affected by noise as much as slower digital IC logic families.

Linearity corrector does double duty, Robin Williams, New York Univ., "Electronics," Vol. 42, No. 12, June 9, 1969, pp. 110-113. Compensating for the non-linear performance of vacuum tubes can be tricky business—especially when using temperature dependent devices like diodes and bipolar transistors. This author describes a much simpler method that uses a forward-biased FET to handle the compensation requirements.

***Graphic analysis of a twin-T network,** John M. Shaull, Harry Diamond Labs, "The Electronic Engineer," Vol. 28, No. 7, July 1969, pp. 54-57. Twin-T networks are popular, especially in control systems. But the mathematics needed to calculate them are complicated. Here is a simplified method that solves the problem with simple graphics.

Transistors replace four-layer devices, Wesley A. Vincent, Motorola, Inc., "EDN," Vol. 14, No. 10, May 15, 1969, pp. 61-66. The concept of using two transistors to simulate a thyristor-type device can be extended to include the simulation of UJTs, by adding two resistors to the pnp-npn transistor pair. The author describes several circuits that use the model in place of an actual UJT.

Simpler digital circuits in a snap, Bernard Siegal, Microwave Associates, "Electronics," Vol. 42, No. 12, June 9, 1969, pp. 105-108. Charge-controlled switching diodes have been used by microwave engineers in frequency-multiplier circuits. But, this device is not well known to digital circuit designers who could use them for sharpening and delaying pulses, generating pulse trains, and converting pulse widths. This article describes how these tasks can be accomplished with the diodes.

Components

***Take the guesswork out of fuse selection,** F. B. Golden, General Electric, "The Electronic Engineer," Vol. 28, No. 7, July 1969, pp. 71-75. One of the most popular components for power circuits, the silicon controlled rectifier, has gained widespread acceptance in industrial circuits. The problem is how to protect those SCRs, since they are expensive, from current overload or overvoltages. In addition, fuses are still the least expensive means of circuit protection. Here, a manufacturer of SCRs advises our reader on how to correlate the characteristics of a fuse with those of the SCR it protects, how to take into consideration not just the size of the load switched on by the SCR, but also the speed and the frequency at which this load is switched.

Tantalum specials and custom design, Donald Stephenson, Transistor Electronics, "EDN," Vol. 14, No. 11, June 1, 1969, pp. 61-64. High capacitance values not available off the shelf may force you to use a custom designed unit. If so, you should have an understanding of tantalum's relative strengths and weaknesses. This article looks at the internal sections of solid, wet, foil, and wet/foil tantalum capacitors, in terms of dissipation factor, CV product, leakage, measurement problems, and so forth.

Magazine publishers and their addresses

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Permanent magnets, Gerald T. Barta, Indiana General Corp., & Lawrence L. Rosine, Editor, "Electro-Technology, Vol. 83, No. 5, May 1969, pp. 43-50. The authors feel that many engineers are not too familiar with permanent magnets and consequently face some difficulty when they must order them. This article describes the magnets and gives tips on how to select them. A list of suppliers and a glossary of magnetic terms are also included.

Identical resonators cut ceramic i-f filter cost, Franz L. Sauerland, Clevite Corp., "Electronics," Vol. 42, No. 11, May 26, 1969, pp. 102-105. Ceramic filters are now making inroads in the consumer field. Because of better and easier to use design information, and of course a better price, these units are going into i-f applications. This article describes how these i-f filters can be applied to consumer products.

Computers and Peripherals

Computer-aided design, act two: Admission price exceeds forecasts, Joseph Mittleman, Senior Assoc. Editor, "Electronics," Vol. 42, No. 12, June 9, 1969, pp. 90-98. This article discusses CAD problems as they exist today. While CAD is now being used, and is proving helpful, it still needs to be developed and refined further in many areas. An interesting area of CAD, not available before, is three-dimensional drawings of objects and patterns.

***Tables of CAD programs,** Robert J. Broda & James O. Young, Chicago Aerial Industries, "The Electronic Engineer," Vol. 28, No. 7, July 1969, pp. 59-60. There is no need today to convince our reader that a computer solution of his electronic circuits is good for him. Rather, the kind of information he needs is how many programs could run, and how long it will take for him to solve his problem.

Rotating disks and drums set peripheral memories spinning, Michael French, BCD Computing Corp., "Electronics," Vol. 42, No. 11, May 26, 1969, pp. 96-101. Because of faster access times, rotating magnetic disks and drums are replacing tape in computer peripheral memories. But, because of so many choices being available selection can be confusing. You must have detailed knowledge of the various units, both from the hardware and software angles.

Physical problems and limits in computer logic, Robert W. Keyes, IBM, "IEEE Spectrum," Vol. 6, No. 5, May 1969, pp. 36-45. The reduction in the dimensions of circuits and devices via transistors and ICs may have increased logic speeds by three orders of magnitude, but the thermal problems that have resulted from increased power densities will eventually limit the speeds possible.

Delay lines—key to low cost in keyboard machines, Robert A. Tracy, Friden; **For sophisticated calculators, core arrays are worth the price,** Thomas E. Osborne, Hewlett-Packard; **Exotic storage applications often revive old memories,** Robert W. Reichard, Honeywell; **Military masses its cores for battlefield conditions,** Bryan W. Rickard, Electronic Memories "Electronics," Vol. 42, No. 12, June 9, 1969, pp. 114-124. These articles constitute four in a series on memories. The first discusses how delay lines are still the cheapest for applications in keyboard machines. The second analyzes the design freedom possible with random-access cores when these are applied to small machines and calculators, and third discusses how exotic storage applications can revive old technologies. The last piece is a detailed look at how military ruggedized memory systems withstand tough environments.

Integrated Circuits

***MOS memories save power,** Dale Mrazek, National Semiconductor Corp., "The Electronic Engineer," Vol. 28, No. 7, July 1969, pp. 49-53. MOS memories, while not as fast as other types available, can save on power requirements. In many cases you do not need "high speed" memories, hence these memories offer you many benefits. This article gives you some good pointers for MOS applications.

Integrated circuits for television receivers, Eizi Sugata, Toshihiko Namekawa, Osaka Univ., "IEEE Spectrum," Vol. 6, No. 5, May 1969, pp. 64-74. Several of Japan's leading manufacturers and universities have joined forces to develop and produce black-and-white and color receivers that use integrated circuits. Optimum density of integration for the receivers is a major goal of this "task force," and the results of the group's work are reported.

Theory and application of a linear four-quadrant monolithic multiplier, Edward L. Renschler, Motorola Semiconductor, "EEE," Vol. 17, No. 5, May 1969, pp. 60-67. Multipliers may eventually be second only to op amps. The article discusses analog multipliers in general and the Motorola MC1595 silicon monolithic IC specifically. The thinking behind the design of analog multipliers and how to apply them are covered. The big application areas for these devices is in the area of control and instrumentation.

I am an integrated-circuit design engineer, Lester H. Hazlett, Motorola Semiconductor, "EDN," Vol. 14, No. 11, June 1, 1969, pp. 39-51. Computer-aided design cuts the delivery time of IC mask masters from many weeks to a day or two. Of this time, the man's role occupies several hours of preparation plus several more at the crt terminal. The article consists of a series of photos of the terminal display, and shows, step by step, the mask design of a presettable toggle flip-flop.

Strategy and tactics for integrated circuits, Jack A. Morton, Bell Telephone Labs, "IEEE Spectrum," Vol. 6, No. 6, June 1969, pp. 26-33. In today's rapidly changing market, a tactical evaluation of a new technology should be based on the answer to the question "Is it adaptable?" And perhaps nowhere is this question more important than in integrated electronics. This article describes the "adaptive strategy" approach of Bell Systems and its use as a guide for selecting the materials and processes for integration.

Designing considerations for building high-frequency hybrid ICs, Don Hoft, Raytheon, "EEE," Vol. 17, No. 5, May 1969, pp. 42-47. This article discusses the building of thick film hybrid circuits, especially in the VHF range. The material is presented in four parts: substrates; screened-on components; discrete components; and packages. Almost all of the material in this article is already known to anyone working with hybrids, but, someone new to the game may find it a good starting point.

Microwaves and Microwave Products

Rx for r-f power transistors, Richard Gundlach, Associate Editor, "Electronics," Vol. 42, No. 11, May 26, 1969, pp. 84-90. This article discusses where transistors stand today in the power/frequency struggle for microwave applications. Taking a look ahead, there are suggestions of what we can expect in the not too distant future. Because packages are important to transistor operation at high power and high frequency, this area is discussed in some detail.

Power Supplies

Power-supply overvoltage protection — making sure it's really there, Robert H. Cushman, N. Y. Regional Ed., "EDN," Vol. 14, No. 11, June 1, 1969, pp. 54-59. Modern digital systems require high-current supplies. With thousands of ICs at stake, you must protect them from overvoltages on the supply bus, and within microseconds after the occurrence. The author describes some overvoltage sources within the power supply itself, and discusses several ways to deal with them. Main emphasis is on the SCR crowbar-type protector.

Semiconductors

Silicon: key to semiconductor advances, Dr. Ronald C. Bracken, Texas Instruments Incorporated, "Electro-Technology, Vol. 83, No. 5, May 1969, pp. 43-50. The author states that despite the publicity given to many of the newer materials, silicon has been and will be the workhorse of the semiconductor industry. He feels that new methods being developed to grow, process, and make silicon devices promise a bright future for the material. He discusses the present state of the art and also what can be expected in the future.

Test and Measurement

Pinning down frequency stability, Irving Engelson, Mercer County Community College, "EDN," Vol. 14, No. 10, May 15, 1969, pp. 43-50. The author decries stability terminology as inexact, vague, and contradictory. He then offers definitions of stability and spectral purity of a more practical nature, and claims that definitions based solely on theoretical considerations are useless in practice. The author presents a spectral analysis of an oscillator signal to establish a division point between frequency- and time-domain measurements.

A double phase-sensitive detector for bridge balancing, Joseph M. Diamond, Danish Atomic Energy Commission, "IEEE Spectrum," Vol. 6, No. 6, June 1969, pp. 62-70. This article describes a fixed-frequency, phase-sensitive detector that has been developed for bridge-balancing applications, and that provides a wide range of measurement at low noise levels. Included is a discussion of the general considerations involved in the design of low-frequency phase-sensitive detectors, a comparison of the various configurations of full-wave chopper circuits having similar or complementary bipolar transistors, and an analysis of the degree of pre-filtering needed to prevent noise saturation.

Simplify op-amp parameter tests, William S. Routh & Mineo Yamatake, National Semiconductor, "Electronic Design," Vol. 17, No. 11, May 24, 1969, pp. 80-87. The author tells you how to test op amps with a standard oscilloscope and a special test circuit. He describes the test circuit and how to use it. The parameters that can be tested are bias current, offsets and transfer function. Complete details are included for building the test circuit.

How to measure delay, Sol Black, Western Electric, "EEE," Vol. 17, No. 5, May 1969, pp. 36-40. Normal delay time measurements by direct oscilloscope display are fast but not always as accurate as required because of scope accuracy and human errors. This article describes how to circumvent these two problems.

Miscellaneous

Psychological testing: true or false?, "EDN," Vol. 14, No. 10, May 15, 1969, pp. 87-91. This is a mated pair of articles—presented side by side—that examines the pros and cons of psychological testing of prospective employees. The "FOR" author, Roger H. Reid, is a counseling psychologist at Reynolds, Merrill, Brunson & Assoc. The "AGAINST" author is James A. Rose, Pres., Communications Management Co.

Select air movers without guesswork, Arthur H. Mankin, IMC Magnetics, "Electronic Design," Vol. 17, No. 11, May 24, 1969, pp. 90-93. Electronic engineers find it difficult to decide what they need in air moving (fans and blowers) devices to keep their equipment to safe operating temperatures. Some of the mystery is taken out of this decision by impedance measuring. This method is described along with basic information about types of air movers.

Magnetic traveling fields for metallurgical processes, Yngve Sundber, ASEA, "IEEE Spectrum," Vol. 6, No. 5, May 1969, pp. 79-88. Electromagnetic stirrers have proved a boon to the metallurgist and steel manufacturer. They provide not only improved homogenization, but also temperature equalization, rapid and complete chemical reactions, and effective degassing.

Breaking in the new engineer, Donald K. Collins, Staff Ed., "EDN," Vol. 14, No. 11, June 1, 1969, pp. 87-91. Many companies have training programs to orient and train newly hired, newly graduated engineers. If you have several years with your company, you may be asked to participate in such a program. This article discusses three types of training programs: the one-trainee/one-engineer type; the departmental rotation type; and the project-oriented program.

***Would you put that probe on your sick grandmother?** Roger Kenneth Field, Contributing Editor, "The Electronic Engineer," Vol. 28, No. 7, July 1969, pp. 35-40. Recently, Ralph Nader testified before a Congressional Committee that about 1200 people are killed each year because of defective medical instrumentation. Mr. Nader based his data on an investigation carried out by Dr. Ben-Zvi, Director of Scientific & Medical Instrumentation at the State University Medical Ctr. in Brooklyn, N.Y.

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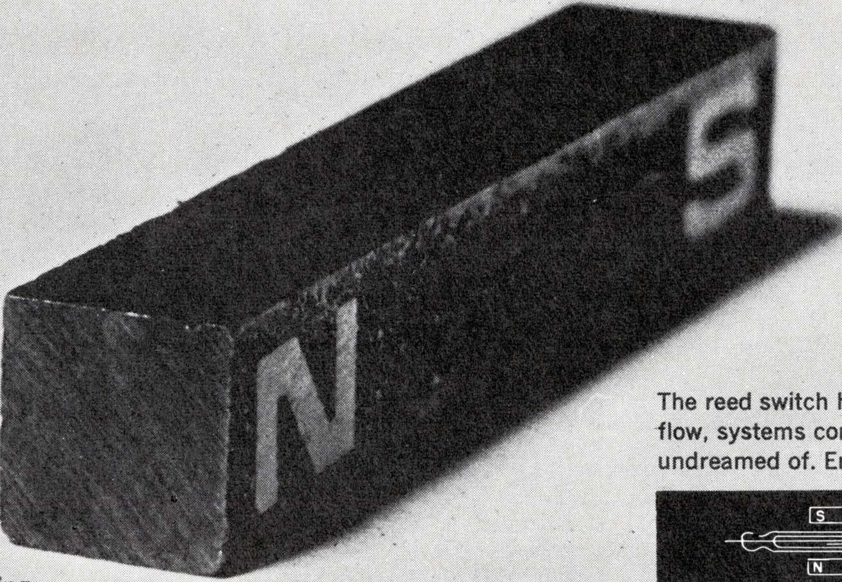
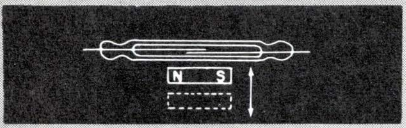
HOW TO COMMAND A DJINNI.

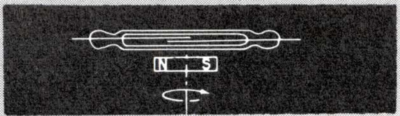


The reed switch, ferromagnetic strips encased in their own little bottle, reacts to a magnetic field. Bring in a bar magnet and . . . snap. You don't even have to rub the bottle. Magnet movement can be designed to actuate the switch for practically every control function conceivable. Magnet

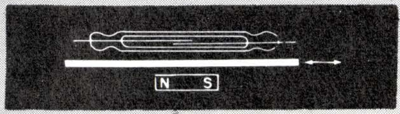


motion can be parallel, perpendicular, pivotal. It can twirl on its own axis, providing two switch closures per rotation. The reed switch, of course, can also be controlled with a coil as in a relay.

Its speed is the closest thing to transistorized logic, with the added advantage of isolation and much lower circuitry cost. It is

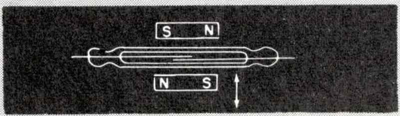


completely practical for RF switching and in its sealed container stays free of dust, damp and corrosion. There are



no armatures, springs or pivots to wear. Life can easily exceed 100 million operations.

The reed switch has machine, flow, systems control uses yet undreamed of. Engineers have



barely scratched the surface in uses for this most versatile electro-mechanical switch yet invented.

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Simplifying impedance matched circuits

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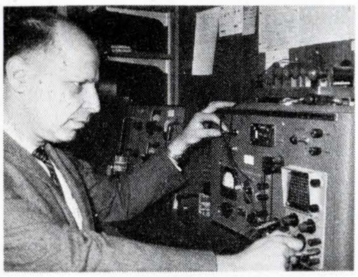


By Martin Blickstein, Chief Engineer
Voltronics Corp., Hanover, N. J.

In any system gain and cost have a very direct relationship, and therefore gain optimization via impedance matching of load to source is a routine design procedure that is followed. There are a number of available means for impedance matching including transformers, transmission lines, filters, and even active circuits. The considerations for selection are usually frequency, dimension, weight, and *always cost.*

The circuit shown in Fig. 1 is an impedance matching procedure which is well suited for frequencies above 100MHz (though not limited to this range). While this example deals with matching from a complex source to a real load, it is equally applicable for matching complex load to complex source, and, by logic inversion, matching real source to complex load.

The procedure is first to develop a load, the real part of whose impedance equals that of the source. The final step is then to introduce a "loss-less" series circuit which is equal in magnitude, but opposite in phase, to the sum of the complex parts of the source and load impedance, thus producing a zero phase angle.

To be feasible in production, at higher frequencies, all parameters must be consistent, identifiable and repeatable. This requirement is helped by an assembly of two piston trimmers with a single common glass dielectric cylinder forming both the capacitors and the common connection. This is shown schematically in Fig. 2. The dual capacitor uses non-rotating piston assemblies whose internal inductance (less than 3 mH) is constant and independent of piston position.

The system can be adapted to application such as output state, antenna matching, interstate coupling, and antenna-input stage matching.

Suppose a transistor requires a load impedance of $25+j10$ at 160 MHz and is driving a 50Ω transmission line ($R_L = 50$). Since the real part of the collector load impedance must be developed by the C_2R_L combination

$$X_{C2} = R_L \sqrt{\frac{R}{R_L - R}} = 50 \sqrt{\frac{25}{50 - 25}} = 50\ \Omega$$

$$X_{C2} = 50\ \Omega$$

$$C_2 = \frac{1}{2\,\Pi\, f(X_{C2})} = 20\ pF$$

The series equivalent of this combination is

$$Z_{2s} = \frac{50\,(-j50)}{50 - j50} = \frac{2500 \mid -90}{71 \quad -45} = 35.2 \angle -45^\circ$$

$$Z_{2s} = 24.9 - j24.9$$

$$Z_1 = Z_0 - Z_{2(L)} = 25 + j10 - (24.9 - j24.9)$$

$$Z_1 = 0 + j34.9$$

While this impedance could be composed of an inductance, use of an LC combination permits adjustment, and minimal network loss.

Now, if we choose an operating Q of 5, (selected to operate into antenna) with the load circuit (equivalent) as shown in Fig. 3, then

$$Q = \frac{\omega L_1}{24.9} = 5$$

$$\omega L_1 = X_{L1} = 124.5$$

$$L_1 = \frac{124.5\ (10^{-6})}{2\pi\ (160)}$$

$$= 124.5 \times 10^{-9} = 124\ \text{nH}$$

$$X_{C1} = X_L - Z_1$$

$$= j124.5 - j34.9$$

$$= j89.5$$

$$C_1 = \frac{1}{2\pi f X_C{}^1} = \frac{1 \times 10^{-6}}{2\pi\ (160)\ (89.5)} = 11\text{pF}$$

While this is one example, many variations of this approach are fairly common. In fact, a further variation is feasible as a four terminal network as shown in Fig. 4. This assembly would have application in mixer circuits as in Fig. 5.

In this case, two of the three capacitors are adjustable, while the third is fixed.

In either of these configurations, all the capacitors and both of the adjustments are on a single glass assembly, making for high repeatability as well as electrical and mechanical stability. Since the unit is integral, there are neither internal nor external interconnections.

References

1. *Motorola Circuit Design Library*
2. *Reference Data for Engineers,* ITT Corp.

INFORMATION RETRIEVAL

Components, Circuit Design

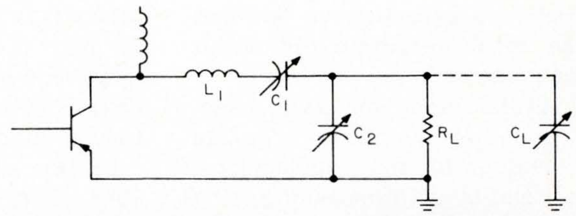


Fig. 1: The load impedance has to be transferred to the output impedance of the selected transistor.

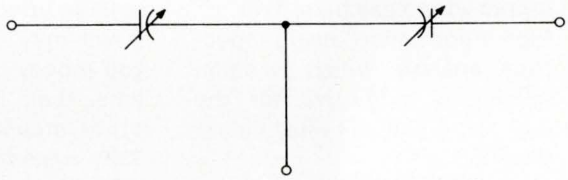


Fig. 2: Dual capacitor is shown schematically.

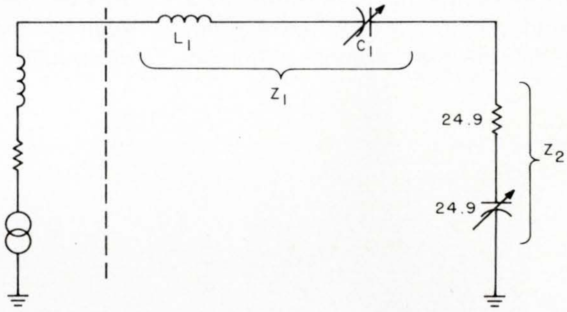


Fig. 3: This is equivalent load circuit for Fig. 1.

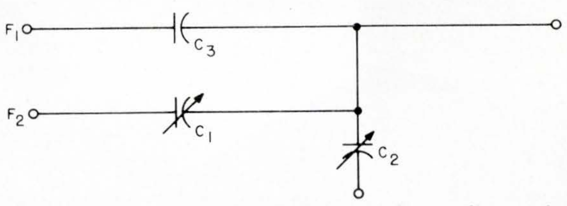


Fig. 4: A four terminal network can be easily made.

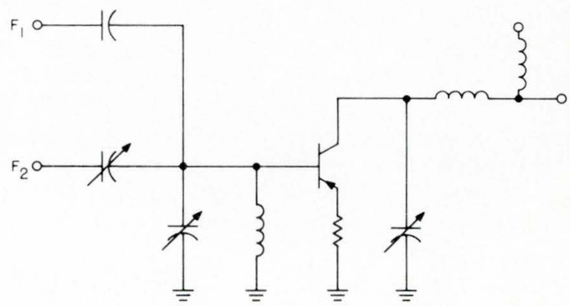


Fig. 5: A mixer circuit is designed using the circuit in Fig. 4.

EE NEW PRODUCTS

Digital techniques for time series analyses

Keyboard-controlled Fourier analyzer becomes a general-purpose digital computer at the flick of a switch.

The HP 5450A Fourier analyzer has a combination of capabilities not previously found in a general purpose computer. It processes, analyzes, and displays information in the time or frequency domain or some combination of both, or performs averaging in either.

The instrument collects and analyzes data in the frequency range up to 25 kHz. It has applications in system and environmental testing, vibration analysis, acoustics, structural analysis, geophysics, oceanography, sonar, biomedical research, and many other areas. A major application is the analysis of signals in the presence of noise: the 5450A can do the averaging necessary to come up with a clean wave shape.

The signal to be analyzed enters the instrument as an analog electrical input to the A/D converter, as digital data from either the punched tape reader or the keyboard, or as binary data through the binary communication channel.

The data then feeds into the dual input A/D converter, and from there to a standard HP digital processor which serves as the memory and computation unit. In the processor, the data is manipulated and fed through a D/A converter to the memory, whose contents are scanned for display on the crt.

The analyzer uses a very elaborate software program which holds the many subroutines needed for each different analytical application. The program is loaded off paper tape into the photo reader. Once loaded, the instrument is ready to do any normal signal processing without additional programming.

Because computer knowledge is generally neither needed nor helpful, anyone can use the analyzer—and effectively, at that—within a few hours. The operator has complete control of all input, output, data manipulation, and arithmetic operations from the keyboard of the 5475A control unit.

Standard push-button control functions include: forward and inverse Fourier transforms, power spectrum, cross power spectrum auto- and cross-correlation, convolution, histogram, Hanning and other weighing functions, real and complex multiplication, standard arithmetic operations, integration and differentiation, and ensemble averaging. *Sequencing commands* allow the automatic execution of repetitive processes such as ensemble averaging, data conditioning, and data collection.

The versatile keyboard control even lets the operator make up his own routines for displaying data. For keyboard programming, there are 100 memory locations that can be used to record a series of instructions for automatic operation.

A crt displays the analyzed event. Since it is a calibrated display, the presentation is always in absolute terms. The instrument displays both magnitude and phase information, in contrast to an analog spectrum analyzer, which is limited to magnitude only.

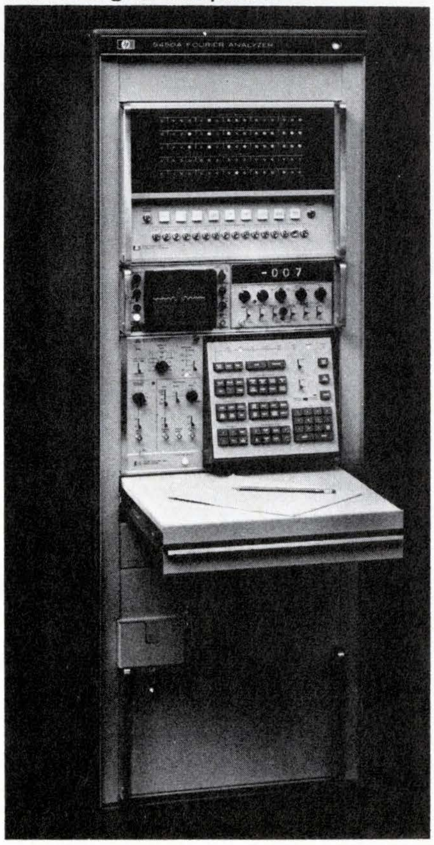
You can display real and imaginary parts of pulses, and Nyquist or bode plots are standard. Simple switching lets you choose among rectangular, polar, linear, or log presentations.

The instrument automatically scales data, so that you always have the largest useable on-scale display. A digital readout shows you the proper scale factor automatically.

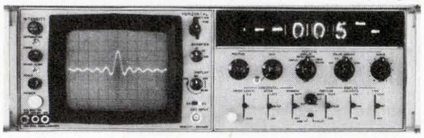
Worst-case calculation accuracy is less than 0.1%, and occurs during the calculation of forward or inverse transforms.

(continued on following page)

HP's new 5450A Fourier analyzer. The operator selects the type of instrument he wants it to be by pushing the appropriate buttons, thus controlling the built-in digital computer.



Here's the 5460A display plug-in. You have your choice of rectangular, polar, linear, or log presentations. The digital readout shows the proper scale factor for the automatically-scaled display.



The 5475A keyboard console. You can give all instructions from this console even without any knowledge of computers or programming. Note the little switch right of center: slide it to the left and you're in command of a general-purpose digital computer.

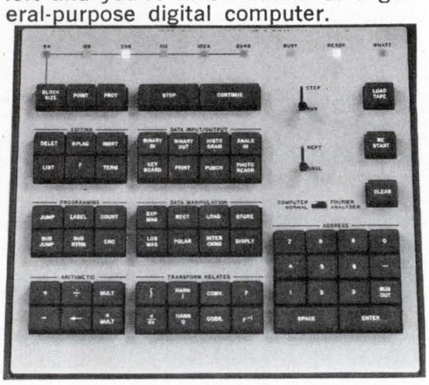


Table of display forms

Display	Vertical	Horizontal
rectangular	real part imaginary part	frequency or time frequency or time
polar	magnitude phase	frequency frequency
complex (Nyquist)	imaginary part	real part

(continued from page 87)

Any data held in memory can be displayed on the 5450A's own CRT; on a large-screen, remote oscilloscope; or on an analog plotter. And you can display such data in any of the forms shown in the table of display forms. You can switch back and forth between the time and frequency domains without losing information.

With the standard 2115A digital processor, containing an 8k memory, the display can show up to 1024 points. This configuration of the 5450A analyzer costs about $49,000. With a 16k memory (a 2116B digital processor), the display goes to 4096 points.

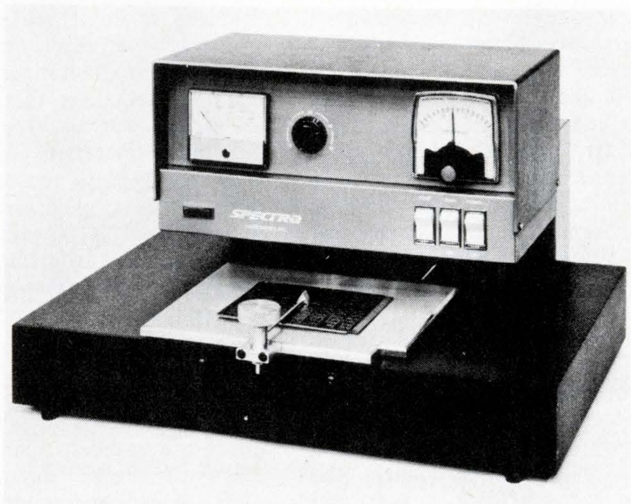
Because it can analyze many types of data, it is possible for several users to share the cost of the 5450A. And those who already own HP computers can acquire the rest of the analyzer for about $20,000. Inquiries Manager, Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 326-7000.

Circle 290 on Inquiry Card

Soldering system gives contactless heating

Model 44 uses a quartz halogen lamp as an infrared heat source for reflow soldering of flat-packs to PC boards. Focused and localized by a specially-designed reflector, a short-duration heat burst causes the board's solder to reflow and wet the flat-pack leads. This forms a reliable bond with no danger to heat-sensitive components. A pick-up arm with a vacuum system to hold the part lets you accurately position the part on the board. The system draws about 1200 W from a single-phase, 115-Vac, 60-Hz line. Model 44 costs $1990. Spectra Instruments, Inc., 1712 S. Olden Ave., Trenton, N.J. 08610. (609) 888-2211.

Circle 291 on Inquiry Card



together for the first time in one package

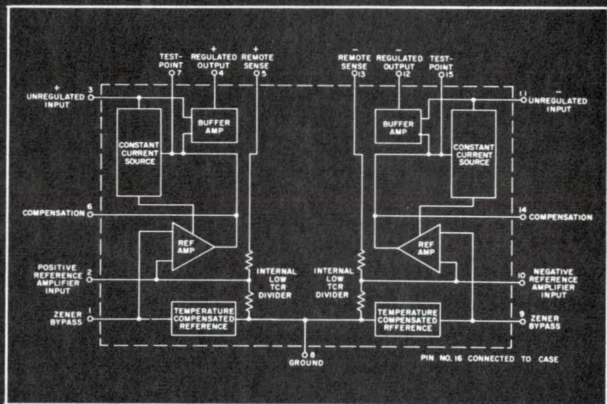
the ± hybrid voltage regulator internally preset to ± 15 VDC

If you use Op Amps, General Instrument's Complementary/Dual Polarity IC Voltage Regulator (NC 572) is made for you. For the first time, + and − 15 V regulators are combined in one IC package providing two isolated and independent control sections of complementary polarity. The NC 572 also provides a combination of features that are superior to those available in any individual positive or negative voltage regulator . . .

For example:

- Output voltages are internally preset to the most popular Op Amp supply voltages, +15 and −15 VDC. Where required, the output voltage can be externally adjusted to any value from ±13 to ±38 VDC or factory preset to any voltage within this range.
- Its high efficiency performance is demonstrated by a minimum required output/input voltage differential of only 1V for the positive regulator and 2V for the negative regulator.
- Other features include: line regulation of 0.0005% Vo/Vin, load regulation of 0.0005% Vo/mA, input isolation of 74 dB min., and a full military operating temperature range.
- The unit price at 1-24 pcs. is $30.80; at 500-999 pcs., $24.20 each.

The ± NC 572 hybrid voltage regulator in one 16-lead TO-8 style package is now in stock and immediately available from your authorized General Instrument Distributor.



Functional Diagram

For complete information, call (516) 733-3244 or write, General Instrument Corporation, Dept. I, 600 West John Street, Hicksville, N.Y. 11802.

(In Europe write to: General Instrument Europe, S.P.A., Piazza Amendola 9, 20149, Milano, Italy. In the U.K. to, General Instrument U.K., Ltd., Stonefield Way, Victoria Road, South Ruislip, Middlesex, England.)

GENERAL INSTRUMENT

GENERAL INSTRUMENT CORPORATION • 600 WEST JOHN STREET, HICKSVILLE, L. I., NEW YORK

Digital panel meter cracks $100 barrier

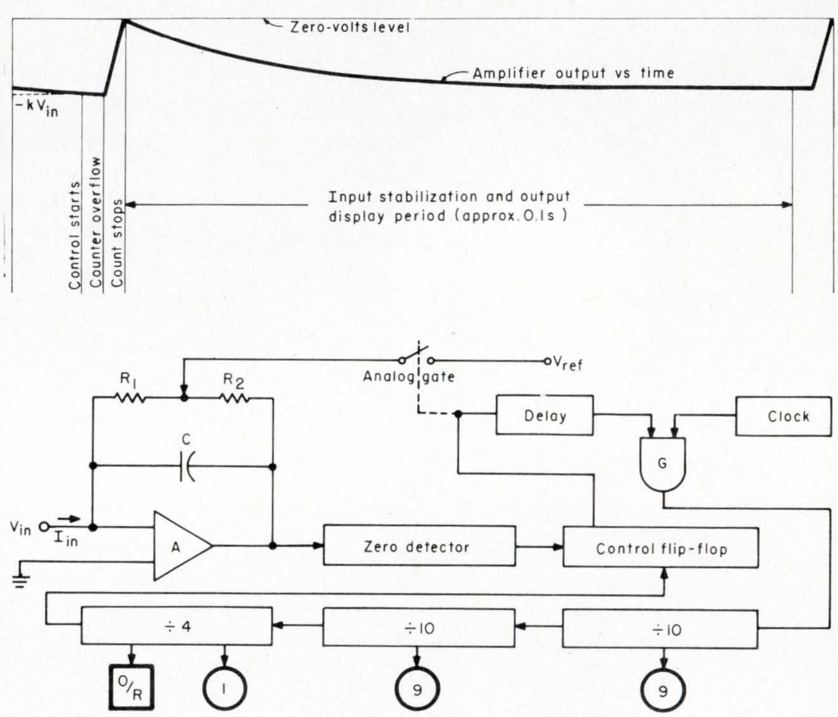
One of the first instrument firms to introduce the digital panel meter to the OEM market has scored another first with a 2½-digit DPM priced at less than $100. Weston's new Model 1260 has a full-scale range of 199 with accuracy rated at ±0.5% of full-scale ±1 digit.

You can order the 1260 with any one of ten dc ranges. These span five decades of current from 20 μA to 200 mA, and five decades of voltage from 200 mV to 1000 V. An over-range capability of 25% is a feature of all but the 1000-V models. A front-panel lamp indicates overrange or negative inputs, automatically.

The 1260 has a circularly polarized filter window to minimize glare. This window is part of a bezel that is easily removable for access to gain and slope adjustments. Each DPM includes a reference current source to check long-term stability.

The 1260 costs $99.75 in lots of 25. Several options, including BCD outputs and remote operation, are available at extra cost. For further information contact Weston Instruments Div., 614 Frelinghuysen Ave., Newark, N.J. 07114. (201) 243-4700.

Circle 283 on Inquiry Card



How it works. In the static mode, the analog gate (shown as a spst switch) is open and the op amp, A, charges C to $-kV_{in}$, a voltage proportional to I_{in}. After a time sufficient to fully charge C, the delay circuit starts the measurement cycle by enabling gate G. Clock pulses now pass into the counter, and the count resumes from its previous state (corresponding to the last measurement). The counter overflows at a count of 300 and sets the control flip-flop, which closes the analog gate. Since V_{ref} is greater than V_{in}, the current flow through R_1 integrates the op amp back to zero. At this point, the zero detector triggers the control flip-flop, which disables the analog gate and triggers the delay circuit. (This delay circuit is synchronized to the ac line, to eliminate display flicker.) The triggered delay output disables gate G and stops the count. The number of clock pulses registered by the counter is a measure of the discharge time of the integrator, which is in turn proportional to the input voltage.

STEP RECOVERY DIODES

Conversion efficiency up to 70%.

This SRD-100 series of microwave diodes is for use in multiplier applications providing 3 W at S-Band and 250 mW at X-Band. The diodes are available in commonly used stud-mount and pill packages. TRW Semiconductors Inc., 14520 Aviation Blvd., Lawndale, Calif. 90260. (213) 679-4561.

Circle 284 on Inquiry Card

SILVER-EPOXY COMPOUND

Highly conductive.

Epo-TeK 417 has an electrical conductivity approaching that of pure copper. Useful as an adhesive, ink, sealant, coating, or for potting applications, it is a 100% solids, soft thixotropic paste containing pure silver. Its vol. res. is 0.00005 to 0.00007Ω-cm. Epoxy Technology, Inc., 65 Grove St., Watertown, Mass. 02172.

Circle 285 on Inquiry Card

REFERENCE DIODES

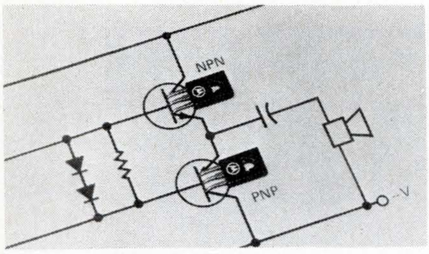
TC is as low as ±0.0005/°C.

New low current diodes provide high temp. stab. and long term reliability. They meet or exceed MIL-S-19500 and can be operated over a range of −55°C to + 100°C. They come in JEDEC types 1N4565 through 1N4584A. Centralab Semiconductor Div., 4501 N. Arden Dr., El Monte, Calif. 91734.

Circle 286 on Inquiry Card

PLASTIC TRANSISTORS

For audio amplifiers

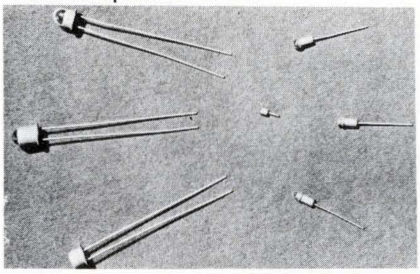


Two pairs of silicon transistors are for use in 20 and 35 W complementary audio amplifiers. They are encased in a Thermopad™ package for easy mounting and efficient heat transfer with its consequent high power dissipation. The NPN MJE205 and PNP MJE105 are 5 A transistors, while the NPN MJE2801 and PNP MJE-2901 are 10 A transistors. Motorola Semiconductor Products Inc., Box 20924, Phoenix, Ariz. 85036.

Circle 287 on Inquiry Card

PHOTOTRANSISTORS

With companion LEDs.

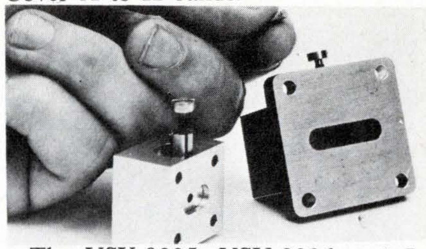


This line of npn, planar high-gain silicon phototransistors and companion, continuous or pulsed operating GaAs light emitting diodes, can be used in card and tape reading, industrial control, intrusion detection, and character recognition. The 918L/402L pair have a total lens acceptance angle of $< 20°$. Electro-Nuclear Labs., Inc., 115 Independence Dr., Menlo Park, Calif. 94025.

Circle 288 on Inquiry Card

GaAs OSCILLATORS

Cover X to K bands.



The VSX-9005, VSU-9006 and 7, and VSK-9008 series of low-power "Gunn effect" oscillators, have a typ. cw output of 8 mW at any center frequency between 8.5 and 26 GHz. They tune ± 500 MHz from center frequency and require a single 10 V supply. Typical bias current does not exceed 250 mA dc. Varian Solid State Microwave Operation, 611 Hansen Way, Palo Alto, Calif. 94303. (415) 326-4000.

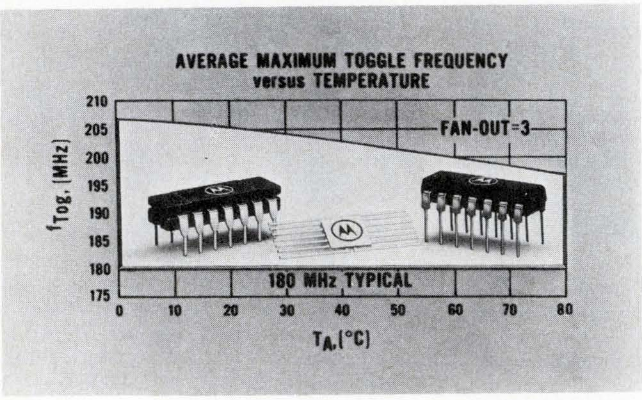
Circle 289 on Inquiry Card

Circle 39 on Inquiry Card

Circle 40 on Inquiry Card

MASTER-SLAVE FLIP-FLOP

Toggles at rates in excess of 180 MHz.

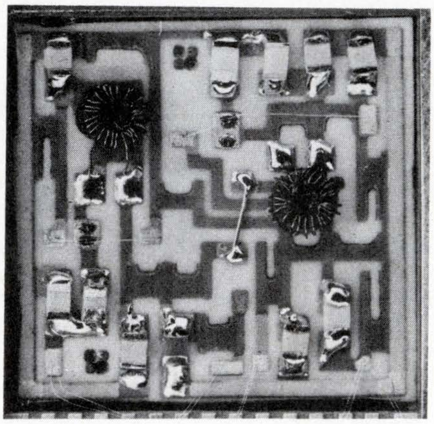


Part of the MECL II family, this type-D flip-flop is for use in high-speed counters and shift registers. The MC1034L's operation depends solely on voltage levels, and is independent of the clock waveform's shape (raceless clocked operation). Direct inputs SET both the master and slave sections. Worst-case propagation delay is 6 ns (25°C); power dissipation, 180 mW typ., with 600-Ω external pull-up resistors; fanout, 25. The MC1034L is housed in a ceramic package, and costs $8.50 ea. in quantities of 1000-up. Technical Information Center, Motorola Semiconductor Products Inc., P.O. Box 20924, Phoenix, Ariz. 85036. (602) 273-6900.

Circle 201 on Inquiry Card

I-F AMPLIFIERS

For hf, vhf, and uhf communication systems.

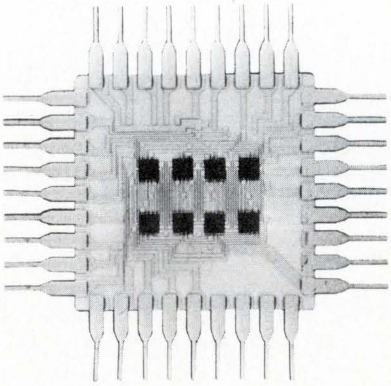


These ceramic-metal film hybrids are for 30-MHz i-f applications. Two versions differ only in noise figure specifications: the MS500 has a 7-dB NF, while that of the MS501 is 14 dB. Both units have a 5-MHz bandwidth (1 MHz special order), 40-dB voltage gain, 10-dB attenuation range, and an agc control. The six-lead packages are 1-in. L x 0.925-in. W x 0.15-in. H; hermetically-sealed, they are designed to meet military requirements. In lots of 1- to 9-pcs., the MS500 is $80 ea., while the MS501 is $75 ea. Hybrid Microelectronics Operation, Sylvania Electric Products Inc., 100 First Ave., Waltham, Mass. 02154. (617) 893-9200.

Circle 203 on Inquiry Card

HIGH-SPEED MEMORY SYSTEM

Multi-chip package is 1-in. square.

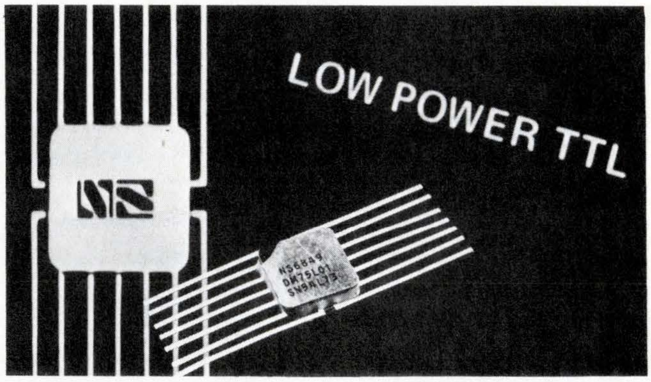


A 128-bit read/write, random access memory with 35-ns access times is the first in a planned series of memory system elements. The MμL4027, a bipolar product, has eight, 16-bit memory-cell chips bonded face-down on a ceramic substrate (two-layer metalization). The memory organization is 64 2-bit words with uncommitted collectors for word or bit expansion. Eight X and eight Y coincident-select address lines simplify the organization. There are TRUE and COMPLEMENT outputs for each bit. In unit quantities, $100 ea.; 100-999 pcs., $66 ea. Fairchild Semiconductor, 313 Fairchild Drive, Mountain View, Calif. 94040. (415) 362-3563.

Circle 202 on Inquiry Card

LOW-POWER TTL PRODUCTS

Replacements for 54/74 Series TTL line.



These circuits dissipate only 1 mW/gate, a tenth that of standard TTL. The DM75L (−55° to 125°C) and DM85L (0° to 70°C) are pin-for-pin replacements for the SN54L- and SN74L-type circuits, respectively. Initially offered are three gates and two flip-flops. The series is primarily intended for military applications, and is processed accordingly. In 100-999 pc. quantities, the DM75L gates cost $7 ea., while the dual flip-flops are $17 ea. The DM85L Series gates are $4.50 ea., and the dual flip-flops are $11 ea., in quantities of 100-up. National Semiconductor Corp., 2950 San Ysidro Way, Santa Clara, Calif. 95051. (408) 245-4320.

Circle 204 on Inquiry Card

Circle 45 on Inquiry Card →

The great digital systems kit!

step 3:

COLLECT DATA FASTER WITH A NEW 12-BIT 90, 135 OR 180 KHz MINIVERTER ™

These three new MINIVERTERS™ combine multiplexer, sample-and-hold amplifier and analog-to-digital converter with throughput rate choice of 90KHz, 135KHz or 180 KHz. And each unit goes faster when short cycled; for example, the 180 KHz MINIVERTER runs at 360 KHz with 8-bit resolution.

They come in 19″ by 5¼″ drawers only 17″ deep. And that includes power supply, exhaust fan and input/output cable breakout. Mode selection, short-cycle and channel selection switches; data display indicators and other controls and indicators are available as options.

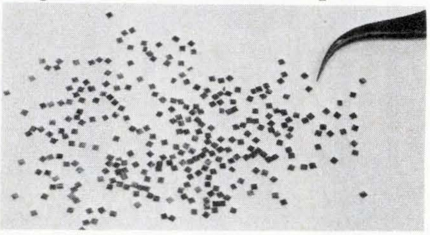
These new high-speed data acquisition instruments are more of the fast-moving products in our great digital systems kit for 1969. Write or call today. Raytheon Computer, 2700 S. Fairview St., Santa Ana, Calif. 92704. Phone (714) 546-7160. Ask for Data File DK-169.

RAYTHEON

EE NEW MICROWORLD PRODUCTS

CERAMIC CHIP CAPACITOR

Single-wafer; 0.82 to 4700 pF.

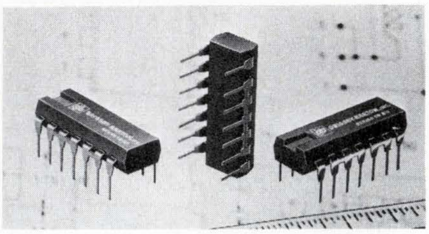


Type 280C comes in sizes from 0.035- to 0.2-in. square, with silver or gold terminations. Four different bodies include temperature-stable, temperature-compensating, and high-K materials. Technical Literature Service, Sprague Electric Co., Marshall St., North Adams, Mass. 01247. (413) 664-4411.

Circle 205 on Inquiry Card

14-PIN DIP REED RELAY

Compatible with 5-V logic.

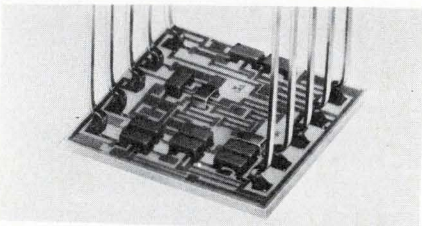


The GB811 has a 3-W contact rating and a 150-V breakdown voltage. Its 5-Vdc input allows direct logic drive. Diode arc-suppression is included. Optional interconnecting webs let you specify pin use. Grigsby-Barton, Inc., 107 N. Hickory Ave., Arlington Hgts., Ill. 60006. (312) 392-5900.

Circle 206 on Inquiry Card

HYBRID VIDEO AMPLIFIER

A sputtered thin-film circuit.

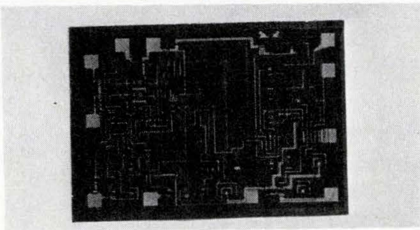


The ATF-416 has 52 ±3 dB gain from dc to 10 MHz, and a 40-dB min. CMRR. You can use it either as a gain- or bandwidth-controlled device or as a straight, broadband amplifier. $14.75 ea. in 1000-up quantities. Amperex Electronic Corp., Microcircuits Div., Cranston, R. I. 02920. (401) 737-3200.

Circle 207 on Inquiry Card

SENSE AMPLIFIERS

With flip-flop outputs.

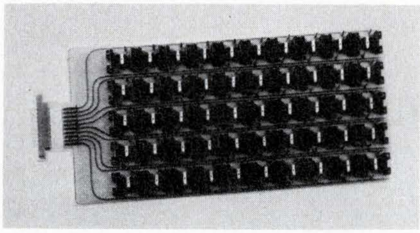


These devices convert low-level inputs from core memories to high-level data for logic circuits. A predetermined threshold classifies the inputs as either ones or zeroes. TSA1150 (MIL-version), $38 ea., 100-up. Transitron Electronic Corp., 168 Albion St., Wakefield, Mass. 01880. (617) 245-4500.

Circle 208 on Inquiry Card

FLAT-PACK BREADBOARD

Three sizes: 25, 50, or 70 devices.

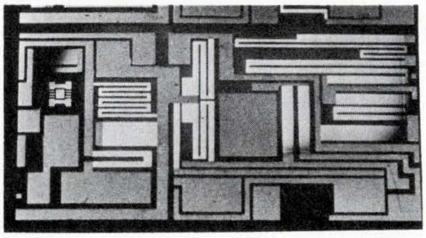


Stacking socket boards allow any combination of other components to plug in. Each position has common power and ground sockets; sockets serve as jumper strips for bussing. Aluminum support rails. All materials good to 150°C. Robinson-Nugent, Inc., 800 E. 8th St., New Albany, Ind. 47150. (812) 945-0211.

Circle 209 on Inquiry Card

CUSTOM RESISTOR NETWORKS

Thin-film on ceramic substrates.

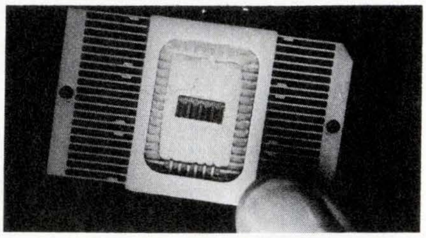


Sized from 0.135-in. square, the substrates can have up to 50 resistors, with values from 10Ω to 1ΩM. Tolerances and ratios are to ±0.05%; TC is less than ±50 ppm/°C. Gold pads mount semiconductor chips, and interconnects are gold also. Hybridyne, Inc., 1950 Cotner Ave., Los Angeles, Calif. 90025. (213) 479-4137.

Circle 210 on Inquiry Card

HIGH-SPEED BIPOLAR MEMORY

For buffer memory, control systems.

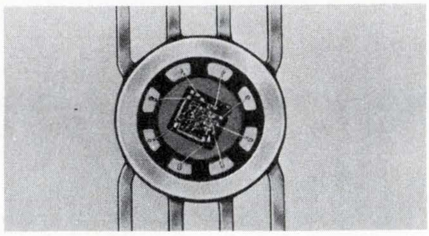


Four basic cells with 32 bits per cell make up this 128-bit, LSI memory device. It has a 60-ns speed capability, and a power consumption of less than 250 mW. The memory is compatible with conventional IC devices. Toshiba-America, Inc., 477 Madison Ave., New York, N. Y. 10022. (212) 758-6161.

Circle 211 on Inquiry Card

OP AMPS

Miniature, hermetic flat-packs.

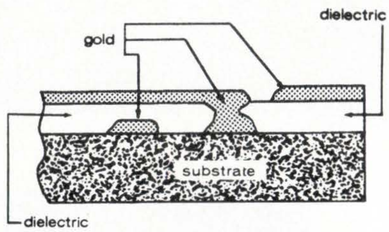


These 201- and 741-type ICs are in 0.175-in. Tiny-Paks™. They reduce by 60% the space needed for standard TO-91 packages. Leads are spaced on 0.05-in. centers. Fully tested and available from stock, they cost $9.50 ea. in 1-24 pc. lots. Mini-Systems, Inc., Box 429, North Attleboro, Mass. 02761. (617) 695-0206.

Circle 212 on Inquiry Card

GLASS-CERAMIC PASTE

Cross-over/multilayer applications.



This paste has negligible flow during firing, and is compatible with most conductive cermet compositions. It is intended for thick-film circuits. ESL #4610 has a dielectric constant of 10. A 2-oz. jar is $36; $20/jar in quantity. Electro-Science Labs., Inc., 1133 Arch St., Phila., Pa. 19107. (215) 563-1360.

Circle 213 on Inquiry Card

TRANSISTOR NOISE ANALYZER

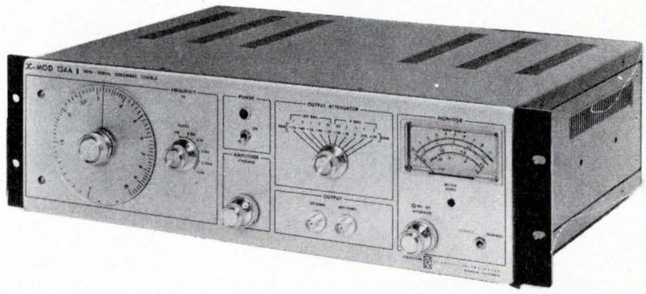
Measures noise voltage and current, noise figure.

Model 4470A gives you all three bipolar transistor noise characteristics directly—without calculation—and also measures the noise voltage and noise figure of FETs. It has a noise figure range of 0 to 40 dB, and source resistances selectable from 10 Ω to 10 MΩ. Full-scale noise voltage ranges are 3×10^{-9} to 3×10^{-6} V/$\sqrt{\text{Hz}}$; bipolar noise current ranges are 10^{-13} to 3×10^{-9} A/$\sqrt{\text{Hz}}$. Accuracy is ±1 dB, 10 Hz to 1 MHz. Measurement bandwidth is 4 Hz; a choice of meter response times lets you trade reading speed for resolution. $4450. Inquiries Mgr., Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 326-7000.

Circle 214 on Inquiry Card

SINE WAVE SOURCE

Less than 2% frequency distortion; 10 Hz to 10 MHz.



Six switch-selectable decades with a vernier cover the frequency range of this instrument. An output meter monitors signal levels that span the ten attenuator positions of 100 µV to 3 V rms (−70 to +20 dBm). The instrument has both 50- and 600-Ω outputs. Combining the precision output attenuator with an expanded sensitivity (x20) capability of the monitor gives a frequency response of ±0.25% of full-scale outputs from 1 mV to 3 V. The X-MOD 134A is suitable where you need a stable, calibrated source. $675 ea., 1-9 pcs. Preston Scientific Inc., 805 E. Cerritos Ave., Anaheim, Calif. 92805.

Circle 216 on Inquiry Card

BIPOLAR DPM

Ballparks below-zero readings.

This DPM provides under-range capability at a low price. Model 525 has accuracies of ±10% of reading for negative inputs, and ±0.1% for positive inputs. This gives you high stability and accuracy for positive levels, and ballparked readings below zero (important when you zero-in the meter). The DPM also has 100% overrange, a no-blink display, programmable decimal points, BCD outputs, and so forth. Meter ranges are 100 mV to 100 V, and 1 µA to 100 mA. $155 ea., 100-pc. lots. Another version, Model 520, has ±0.1% accuracy for both polarities. Datascan, Inc., 1111 Paulison Ave., Clifton, N.J. 07013. (201) 478-2800.

Circle 215 on Inquiry Card

Circle 43 on Inquiry Card

CAPACITANCE METER

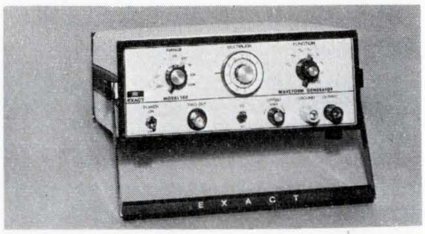
Uses resonant circuit technique.

Type KRT reads capacitances from 1 pF to 100 μF. A 2- to 25-mV test voltage lets you measure voltage-sensitive high dielectric constant, and semiconductor, capacitors. Its 0.5- to 15-V source, gives you varactor data, as well. $455. Rohde & Schwarz, 111 Lexington Ave., Passaic, N. J. 07055. (201) 773-8010.

Circle 259 on Inquiry Card

WAVEFORM GENERATOR

7.38-in. W x 2.85-in. H x 8.5-in. D.

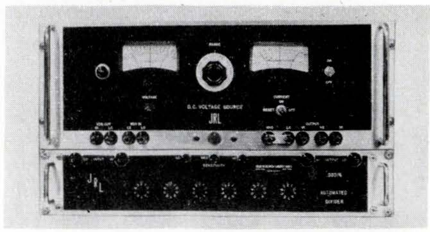


Model 100 gives sine, bipolar square, ground-referenced positive or negative square, triangle, ramp, reverse ramp, pulse, and trigger waves, from 0.001 Hz to 3 MHz (square, triangle to 5 MHz); 20 V pk-pk out into 600 Ω. Exact Electronics, Inc., Box 160, 455 S.E. Second Ave., Hillsboro, Ore. 97123. (503) 648-6661.

Circle 262 on Inquiry Card

DC VOLTAGE SOURCE

Remotely programmable.



Model AVS-106 is a precision source that provides up to 1200 Vdc with 15 ppm accuracy, ±1 ppm. An extended range, six-dial, relay-operated voltage divider is remotely programmable with a ten-line decimal signal. $4685. Julie Research Labs., Inc., 211 W. 61st St., New York, N. Y. 10023. (212) 245-2727.

Circle 265 on Inquiry Card

COMPUTER SUPPLY TESTER

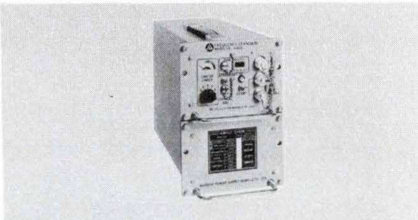
Simulates loading conditions.

Model MPST-06 speeds up power supply testing. Based on a shunt load network, it simulates loads to 40 A, at 3.5 to 40 V. Slew rates are 5 V/μs and 2.5 A/μs. A display option lets you observe the supply under test. Under $1000. Raytheon Computer, 2700 S. Fairview St., Santa Ana, Calif. 92704. (714) 546-7160.

Circle 260 on Inquiry Card

FREQUENCY STANDARD

Lightweight and portable.



Model FE1040B is accurate to within two to five parts in 10^{11} per day. Output frequencies are 100 kHz, 1 and 5 MHz. An ac power failure causes the unit to transfer, automatically, to its built-in battery source. Frequency Electronics, Inc., 3 Delaware Dr., New Hyde Park, N. Y. 11040. (516) 328-0100.

Circle 263 on Inquiry Card

DIGITAL ANGLE INDICATOR

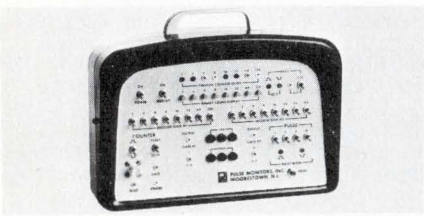
Totally electronic.

This instrument has a four decade BCD output to drive printers, etc., without an encoder. It accepts synchro or resolver inputs at 11.8, 26, or 90 V line-to-line. Resolution/accuracy is 0.1°; input impedance, 200-kΩ. $1300-$1500. Astrosystems, Inc., 6 Nevada Dr., New Hyde Park, N. Y. 11040. (516) 328-1600.

Circle 266 on Inquiry Card

DIGITAL SYSTEM ANALYZER

For production test, maintenance.

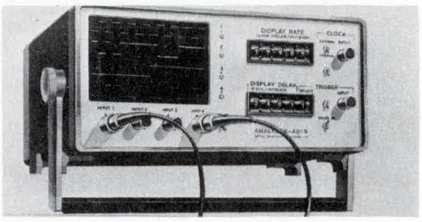


Model 500 breaks down and analyzes timing relationships and performance. An adjustable window samples at predetermined instants or during set time periods. The instrument provides for decoding, gating, display, etc. $950. Pulse Monitors, Inc., 351 New Albany Rd., Moorestown, N. J. 08057. (609) 234-0556.

Circle 261 on Inquiry Card

DIGITAL SYSTEM ANALYZER

For production and field testing.



Model 401-S measures direction and position of signals in transition between logic levels. Four-trace, multicolor display; variable display rate; can show waveforms to 20-megabits/s rates. Resolution is 25 ns. $1595. Data Display Systems, 140 Terwood Rd., Willow Grove, Pa. 19090. (215) 659-6900.

Circle 264 on Inquiry Card

DIGITAL STOPWATCH

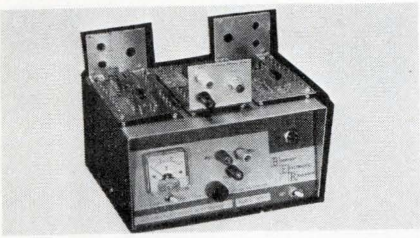
Remote START/STOP/RESET.

Series 330/340 has BCD output, and accumulates more than one time interval. Available with 10-, 1-, or 0.1-s resolution, and with a 3- or 4-digit nixie display. Powered from the ac line. Prices start at $210. Digital Instruments, Inc., 5441 Merriam Lane, Shawnee Mission, Kan. 66203. (913) 236-8717.

Circle 267 on Inquiry Card

IC BREADBOARD

For circuit evaluation.



This kit has most of what you need to study new IC circuits. Everything mounts on the 0.1% regulated, 1- to 17-V, 350-mA, dual polarity, current limited power supply. Modular construction saves circuits for future use. $249. Berkeley Electronics Res., Box 1021, Berkeley, Calif. 94701. (415) 841-2410.

Circle 268 on Inquiry Card

DC NANOAMMETERS

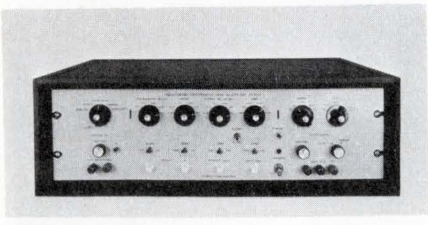
For line and battery operation.

Model 350 has 12 ranges that cover 1 to 300 nA. Voltage drop on all ranges is 1 mV f.s.; accuracy is 2% of f.s.; reaches 95% of final reading in less than a second. Taut-band meter, FET modulator. $245. Battery Model 350B, $235. IB Instruments, 7016 Euclid Ave., Cleveland, Ohio 44103. (216) 431-4790.

Circle 269 on Inquiry Card

PULSE/WAVEFORM GENERATOR

Tests digital and analog systems.



Model 148 has rep rates from 10 Hz to 5 MHz, delay and pulse widths from 50 ns to 0.1 s. It has a trigger level control, sweep output, internal sweep rates to 1 kHz, single pulse, etc. Modulates pulse width, rate, position. $725. Archer Instr. Corp., 134 S. Central Ave., Elmsford, N. Y. 10523. (914) 592-6485.

Circle 270 on Inquiry Card

MILLIVOLT CALIBRATOR

Programmable; has internal register.

Model MV-100P has independently selected decades. Program it with either serial 8421 code or full parallel entry, from punched tape, cards, etc. Output, 166.65-mV f.s. Resolution, 10 μV; accuracy, ±0.015% of setting +5 μV. $1160. Electronic Development Corp., 423 W. Broadway, Boston, Mass. 02127. (617) 268-9696.

Circle 271 on Inquiry Card

VARACTOR TEST SYSTEM

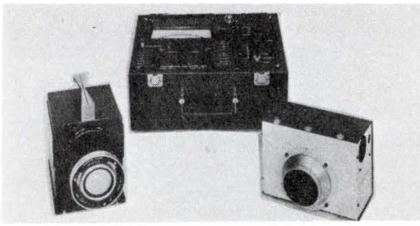
Matches more than 1000 devices/h.

Measure capacitance and ratio at 1 MHz, with a 4-digit readout. Model 1220 reads to 99.99 pF (0.25%); ratio to 9999:1 (0.05%). Readout time varies from 0.5 to 1 s for both capacitance and ratio. Price, $6500. Micro Instrument Co., 12901 Crenshaw Blvd., Hawthorne, Calif. 90250. (213) 679-8237.

Circle 272 on Inquiry Card

RADIOMETER SYSTEM

For laser measurements.

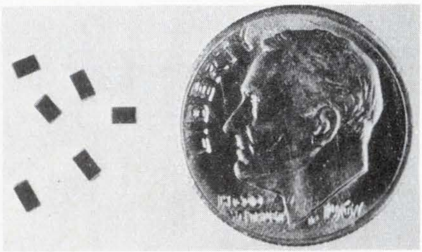


Model 580 measures laser systems operating between 350 and 1200 mμ. Average cw or integrated pulsed power reads directly on a meter. A scope output is for waveform measurements on pulsed lasers with fast (1-ns) rise times. EG&G, Inc., Electronic Products Div., 160 Brookline Ave., Boston, Mass. 02215. (617) 267-9700.

Circle 273 on Inquiry Card

CERMET CHIP RESISTORS

For breadboards, strip lines.



These resistors are made of solid cermet resistive material—not deposited on a substrate. Series 150 is only 0.075 x 0.050 x 0.030 in.; the Series 151 0.090 x 0.050 x 0.030 in. Resistance ranges from 200 Ω to 350 kΩ. CTS Microelectronics, Inc., West Lafayette, Ind. 47906. (317) 743-9602.

Circle 217 on Inquiry Card

TC CRYSTAL OSCILLATOR

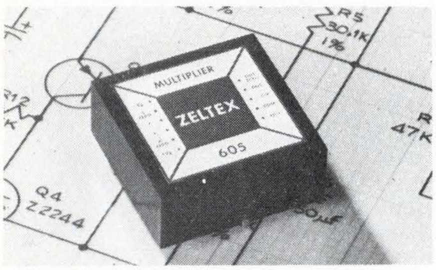
High output over 15 MHz to 25 MHz.

Model MC275X2, low-profile temp-compensated units have typical temp range and stab. characteristics of −40 to 70°C with ±4 ppm max. Input requirements are 17 Vdc (±1.0 Vdc) at 20 mA max. Produced output is 1.0 Vrms (+2 dB) into a 100 Ω load. McCoy Electronics Co., subs. of Oak Electro/Netics Corp., Mt. Holly Springs, Pa. 17065.

Circle 218 on Inquiry Card

MULTIPLIER

Modular four-quadrant unit.

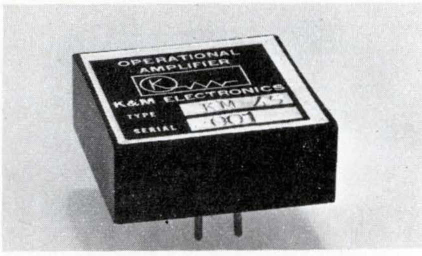


Model 605 requires no ext. amplifiers or components for multiplication and squaring. Without ext. components, it has a max. error of 2% (200 mV at ±10 V output). Output noise is only 1 mV rms from dc to 100 kHz. Zeltex, Inc., 1000 Chalomar Rd., Concord, Calif. 94520. (415) 686-94520.

Circle 219 on Inquiry Card

FET OP AMP

Low drift.

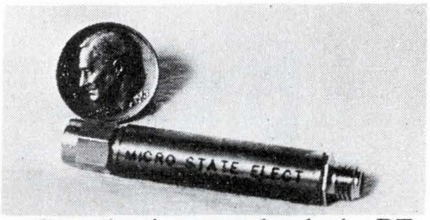


Model KM45 FET op amp has a voltage offset drift of 10 μV/°C. It includes internal freq compensation and short circuit protection. A bias current of 10 pA, a volt. gain of 10^6, an input imp., of 10^{12} Ω, and a price of $16 ea/1-9 qty. K & M Electronics Corp., 408 Paulding Ave., Northvale, N. J. 07647. (211) 768-8070.

Circle 220 on Inquiry Card

MICROWAVE DETECTORS

Provide improved sensitivity.

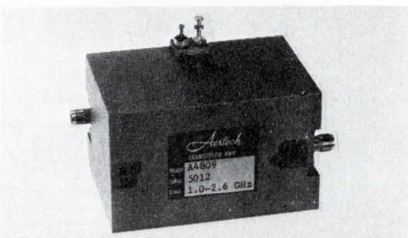


Operating in octave bands the DT-15002, DT-15003 and the DT-15004 detectors cover a range of 2 to 12 GHz. VSWR is 3.5 to 1, 2 to 1 and 3 to 1, respectively, with a tangential sens. of −51 dBm. They can operate at an input power level of 0.5 W pk. for 1 μs with a 0.5% duty cycle. Raytheon Co., Micro State Electronics Operation, 152 Floral Ave., Murray Hill, N.J. 07974.

Circle 221 on Inquiry Card

WIDEBAND AMPLIFIER

Operates over 1.0 to 2.6 GHz band.

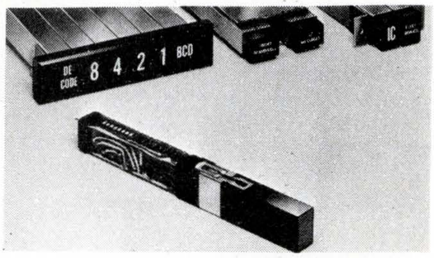


Model A4809 transistor amplifier has 28 dB gain and max noise figure of 7 dB. Output power for 1 dB gain compression is +6 dBm. All silicon construction allows wide temp range of −54 to +71°C. Aertech Industries, 815 Stewart Dr., Sunnyvale, Calif. 94086. (408) 732-0880.

Circle 222 on Inquiry Card

REAR PROJECTION READOUT

Provides large image size.



This readout uses ICs for decoding 8-4-2-1 binary input signals to decimal. The BDR-90 has 12 parallel miniature optical projector systems that display different filmed messages on a single-plane viewing screen. Shelly Associates, Inc., 111 Eucalyptus Dr., El Segundo, Calif. 90246. (213) 322-2374.

Circle 223 on Inquiry Card

CLEAR EPOXY GEL

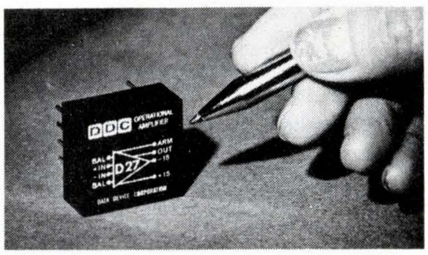
For repairable embedments.

Eccogel 1265 is an epoxy resin which cures to a tough, clear gel. When used for encapsulation, components and circuits are enviromentally protected. If repair is needed, the gel can be cut with a knife to expose the parts, and after repair additional gel can be poured to restore the encapsulation. Emerson & Cuming, Inc., Canton, Mass. 02021. (617) 828-3300.

Circle 224 on Inquiry Card

FET INPUT OP AMP

Provides 1 μV/°C voltage drift.



D-27 series units have dc open loop gain of 108 dB. Output is 12 mA at ±12 V. Initial current offset at either input terminal is 3 pA. Broadband noise is 2 μVrms, CMRR 100 dB, and CMV is ±11 V min. Freq. for unity gain is 2.5 MHz. Data Device Corp. (516) 433-5330.

Circle 225 on Inquiry Card

HIGH Q TUNING DIODES

For UHF.

JEDEC Series 1N5461A thru 1N5476A diodes come in 16 types to cover the range from 6.8 pF to 100 pF with a tol. of ±10%. The Q of over 600 at the lower capacitance values makes them suited for sharp response in tuning circuits at 500 MHz and above. MSI Electronics Inc., 34-32 57th St., Woodside, N.Y. 11377. (212) 672-6500.

Circle 226 on Inquiry Card

VOLTAGE SENSOR

For PC board mounting

DVS-1 senses and indicates excursions (even as short as 50 ns) above or below selected thresholds. It is for applications requiring high accuracy (5 mV or less) and fast response. A strobe capability lets you monitor volt. waveforms to 5 MHz and higher. MCG Electronics, 279 Skidmore Rd., Deer Park, N.Y. 11729. (516) 586-5125.

Circle 228 on Inquiry Card

VANE-TYPE RELAY

Protects air-cooled equipment.

Low-cost Air Flow Relay detects airflow in equipment that depends on forced air for proper ventilation and cooling. Ratings are: 15 A, 125 to 480 Vac; ½ A, 125 Vdc; or ¼ A, 250 Vdc. It is 6-7/16 x 3 x 2 in., including the vane. General Control Div., Westinghouse Electric Corp., Box 868, Pittsburgh, Pa. 15230. (412) 255-3321.

Circle 230 on Inquiry Card

MICROWAVE ICs

Freq. coverage is 2 to 12 GHz.

New line of MICs includes ferrite circulators, 180° hybrid rings, directional couplers, mixers, diode switches, filters and preamps as well as all mounting and interconnecting hardware. They are built on individual substrates and may be mounted on a flat carrier for sub-system breadboarding, in shielded modules or in coax housings. All circuits operate over the temp. range −30°C to +71°C. Western Microwave, 16845 Hicks Rd., Los Gatos, Calif. 95030. (408) 266-4820.

Circle 227 on Inquiry Card

NEGATIVE RESISTOR

Useful from dc to 500 kHz.

Model HR-28 is a Q enhancement device for use with LC networks in telephone and tone signaling applications. It operates from a single supply and contains two identical thick film active networks in a DIP configuration. Negative resistance values from 4000Ω to >300 kΩ are obtainable. Kinetic Technology Inc., 17465 Shelburne Way, Los Gatos, Calif. 95030. (408) 356-2131.

Circle 229 on Inquiry Card

FET SWITCHES

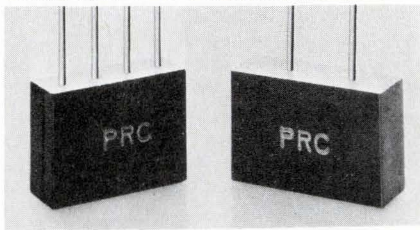
Feature low on-resistance.

These 2N4091, 2N4092 and 2N-4093 switches, can also be used as low-level choppers, video and rf or high-gain and low noise amplifiers. They are used in microvolt amplifiers and meters, multiplexers, commutators, TV equipment, AM and CB receivers and various audio equipment. The devices feature low on-resistance (30Ω), fast switching (40 ns) and low leakage (200 pA). National Semiconductor Corp., 2950 San Ysidro Way, Santa Clara, Calif. 95051. (408) 245-4320.

Circle 231 on Inquiry Card

WIRE-WOUND RESISTORS

Come in 2- and 4-terminal modules.

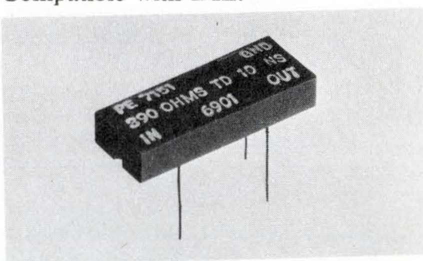


These type MSB resistors offer complete uniformity in physical size and lead spacing. They have ratings from 0.1 to 1 W and a wide range of values from under 10 Ω to 1 MΩ. Tolerances are 1% (standard) to ± 0.01% with TCR 5 ppm/°C. Precision Resistor Co., 109 U.S. Highway #22, Hillside, N.J. 07205. (201) 926-3036.

Circle 232 on Inquiry Card

DELAY LINES

Compatible with DIL.

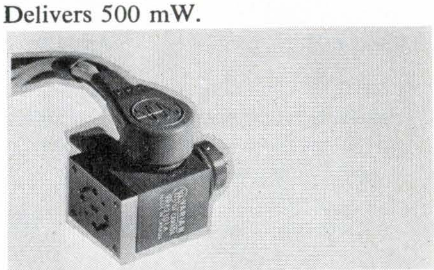


New distributed constant delay line series is compatible with dual in-line integrated circuit packaging. The delay lines are available with impedances of 100 or 390 Ω, and delays of 5 to 100 ns. Rise time is 6-24 ns. Temperature coeff is about 200 ppm/°C. Pulse Engineering Inc., 560 Robert Ave., Santa Clara, Calif. 95050. (408) 248-6040.

Circle 233 on Inquiry Card

KLYSTRON OSCILLATOR

Delivers 500 mW.

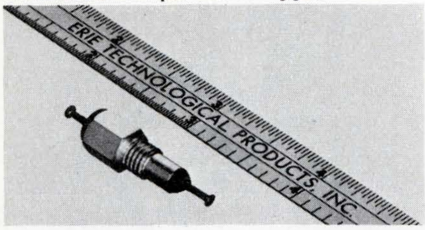


Compact reflex klystron oscillators deliver more than 500 mW at any center freq. between 50.0 and 76.0 GHz. Each tube in the VRE-2101A series has a mechanical tuning range of about 1.5% and an electronic tuning range of at least 100 MHz. Varian Associates of Canada Ltd., 45 River Dr., Georgetown, Ont., Canada. (416) 877-6901.

Circle 234 on Inquiry Card

FEED-THRU CAPACITOR

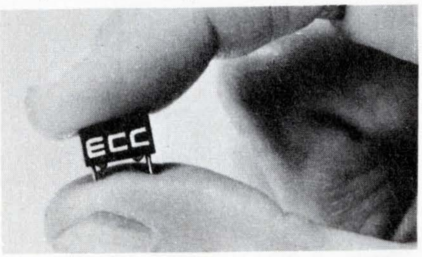
Miniature 1.2 μF GMV type.



Provides improved filtering from 10 kHz to 1 GHz. Arrangement of electrodes provides a short path to ground, minimizing inductance and eliminating hf dips. Monobloc® construction provides equivalent impedance paths at either end. Erie Technological Products, Inc., 644 W. 12th St., Erie, Pa. 16512. (814) 456-8592.
Circle 235 on Inquiry Card

METALIZED CAPACITORS

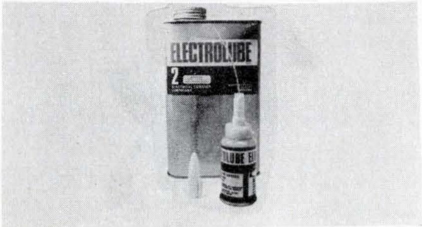
Only 0.225 in. high.



These metalized polyester "Flat-Pak" units are compatible with IC packaging. Package width is 0.385 in. with lead breakout at 0.300 in. cen. to cen. Length varies from 0.100 in. for the 0.001 μF unit to 0.900 in. for the 1.0 μF unit. Engineered Components Co., 2134 W. Rosecrans Ave., Gardena, Calif. 90249. (213) 321-6565.
Circle 236 on Inquiry Card

CONTACT LUBRICANT

Improves electrical contacts.

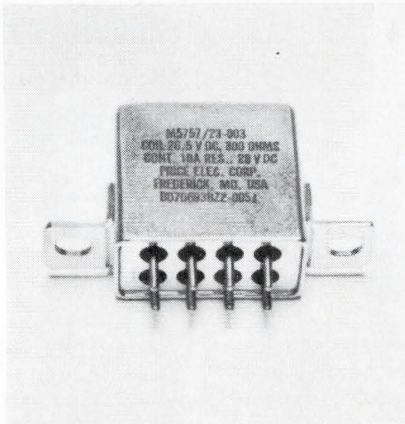


Electrolube acts as a conductor when applied between contact surfaces by increasing the contact area and thereby reducing contact resistance. It has a negative temperature/resistance coeff. which prevents overheating of contacts at high loads and can be used up to 240°C. Trans Atlantic Electronics, 55 Bloomingdale Rd., Hicksville, N.Y. 11801.
Circle 237 on Inquiry Card

When you need a relay to meet these specifications:

MS 27245
MS 27247
MIL-R5757/23

Specify this:



Conelco Style 7 Relay DPDT 10 amp military

You can't get a better 10 amp relay for your money than the Conelco Style 7. It was developed specifically for the aerospace industry.

So it's durable and dependable. For 3-phase AC requirements, an arc chamber is used to assure trouble free operation to 100,000 times, minimum. And all welded construction makes it absolutely reliable for the most stringent avionic applications. Independent tests have proven that the Style 7 Relay stands up against the effects of altitude, vibration and temperature extremes.

We've got a Style 7 Relay designed specifically for your needs. Send for our exclusive Select and Specify Chart.

FEATURES:
All welded construction for positive contamination control.
20% smaller than similar relays.
Arc chamber: —10 amp AC rating 115 volts single and three phase with case grounded.

CHARACTERISTICS:
DPDT 10AMP 28VDC/115VAC res.
Coil: 565 MW typical: 26.5VDC 300 ohms
Ambient temp: —65 to +125 C
Vibr: 20G up to 2000 Hz
Shock: 50G 11msec
Mil-Spec: MS 27245 MS 27247 MIL-R 5757/23

PRICE ELECTRIC COMPANY

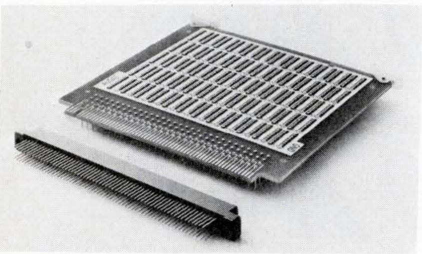
A Division of North American Philips Corporation
relays and electromechanical devices / Conelco switching devices
Frederick, Maryland 21701 / (301) 662-5141 / TWX (710) 826-0901

Circle 47 on Inquiry Card

EE NEW PRODUCTS

PACKAGING PANEL

With mating edge connector.

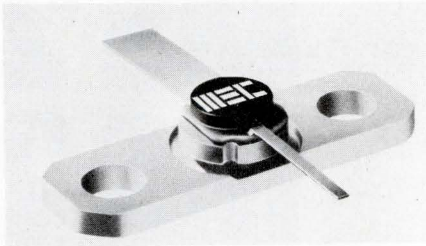


The 8136-R panel will accept 14- and 16-lead DIL ICs. Printed on two sides, it comes with 0.025 in. solderless wrap terminals. Panel accepts new edge connector with 60 dual contacts on 0.100 in. spacing and 120 terminations with polarization key. Augat Inc., 33 Perry Ave., Attleboro, Mass. 02703. (617) 222-2202.

Circle 238 on Inquiry Card

EPITAXIAL TRANSISTOR

Provides 1 W at 2 GHz.

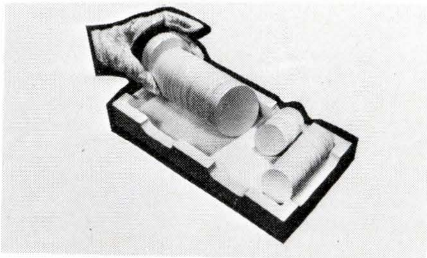


The MSC 2001 is for Class A, B, and C amplifier or oscillator uses. Max power gain and efficiencies at L and S band freqs. are achieved through a new Matrix pellet structure. Patented Stripac package is for stripline ckts. Microwave Semiconductor Corp., 100 School House Rd., Somerset, N. J. 08873. (201) 469-3311.

Circle 241 on Inquiry Card

BORON NITRIDE

Has uniform sheet resistance.

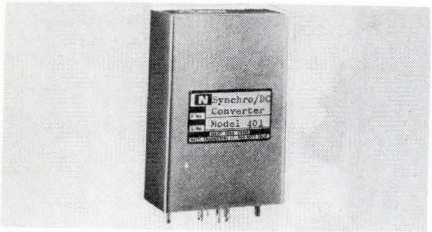


Combat™ boron nitride is now available in wafer form for use as a dopant source for semiconductor silicon. These wafers are non-reactive, quite pure, strong, and have reasonably high thermal conductivity. The Carborundum Co., Electrical and Electronics Branch, Box 339, Niagara Falls, N.Y. 14302. (716) 278-2521.

Circle 244 on Inquiry Card

CONVERTER

Accurate to ±3 minutes.

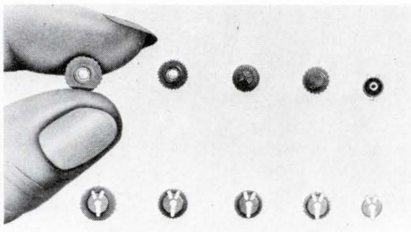


New improved Model 401 synchro-to-sine/cosine converter accepts input of std. 3-wire ungrounded synchro stator and converts it into two dc voltages, one proportional to sine, the other to cosine of the rotor shaft angle. Models are available to accept any synchro voltage, 50 Hz or higher in freq. Natel Electronic Industries, Inc., 7129 Gerald Ave., Van Nuys, Calif. 91406. (213) 782-4161.

Circle 239 on Inquiry Card

CARBON POT

Microminiature 3/16 in. dia.

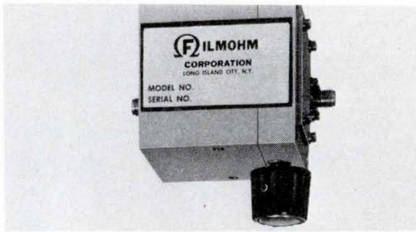


The Model 10 pot has a body diameter (without knob) of < 3/16 in. Units come in 1/20 W linear or 1/10 W audio tapers for left or right hand rotation. Pot has < 10% resistance change after 5000 rotations. Four knob styles and two terminal configurations are available. Centralab, Electronics Div. of Globe-Union Inc., 5757 N. Green Bay Ave., Milwaukee, Wis. 53201. (414) 228-2769.

Circle 242 on Inquiry Card

STEP ATTENUATORS

Ultra-broadband with flat response.

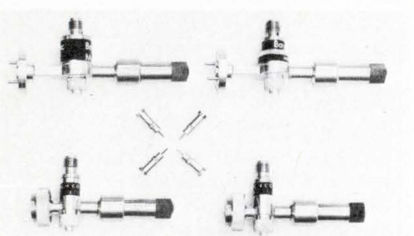


Series TA-1150, SMA (mates with OSM) type attenuators are smaller than a 2 in. cube and weigh < 14 oz. They come in 10-, 50-, and 100-dB units with steps of 1, 5, and 10 dB respectively for use from dc to 18 GHz. Many other attenuations are available. Filmohm Div., Solitron Microwave, 37-11 47th Ave., Long Island City, N.Y. 11101. (212) 937-0400.

Circle 245 on Inquiry Card

DETECTOR MOUNTS

Series covers 50 to 325 GHz.

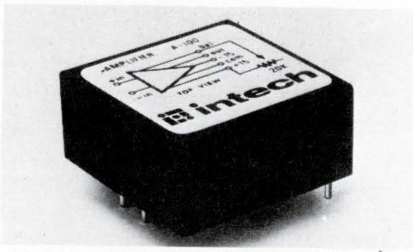


This series of millimeter detector mounts features in-line windowed coaxial cartridges. They have a readily replaceable element for use in high mm detection. They are also useful as single or double-ended mixers where high intermediate frequencies are desired. Varigraph, 194 South Rd., Bedford, Mass. 01730. (617) 396-5011.

Circle 240 on Inquiry Card

FET OP AMPS

Slew rate is 10 V/μs min.

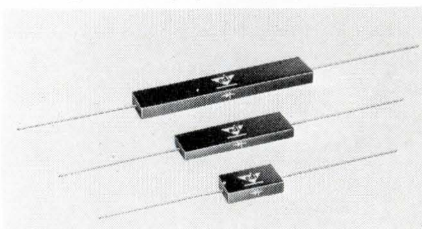


The models A-100 and A-101 offer guaranteed min. gain of 100,000. Typical settling time is 5 μs to reach 0.01% of final value. The A-100 has a max. sensitivity of 50 μV/°C; the A-101, 20 μV/°C. Available from stock, they are priced at $20 and $25 respectively. Intech Inc., 1220 Coleman Ave., Santa Clara, Calif. 95050. (408) 244-0500.

Circle 243 on Inquiry Card

HV RECTIFIER STICKS

For high density packaging.

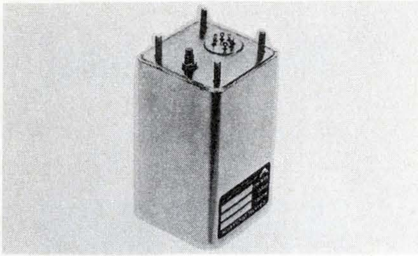


The KVF (Kilovolt Flatpack) series of Si rectifier sticks has a PIV range of 5 kV to 25 kV and a 500 mA current rating. Typical is the KVF 10, a ¼ in. wide, ½ x 2 in. long 10 kV PIV flatpack Si rectifier. Electronic Devices, Inc. 21 Gray Oaks Ave., Yonkers, N.Y. 10710. (914) 965-4400.

Circle 246 on Inquiry Card

VHF CRYSTAL OSCILLATOR

Fixed output in 25-125 MHz range.

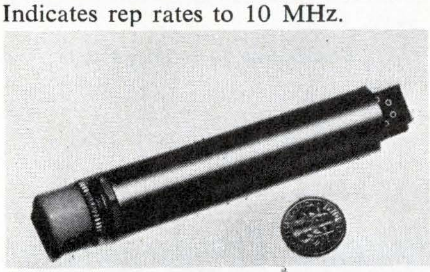


CO-221 series units are for use either directly at the oscillator output or for multiplication to higher freq. A high-gain IC proportional oven control system results in a stability $> \pm 5 \times 10^{-8}$ over 0-50°C. Output level is $>$ 10 mW into 50Ω. Vectron Laboratories, Inc., 146 Selleck St., Stamford, Conn. 06902. (203) 324-9225.

Circle 247 on Inquiry Card

INDICATOR

Indicates rep rates to 10 MHz.

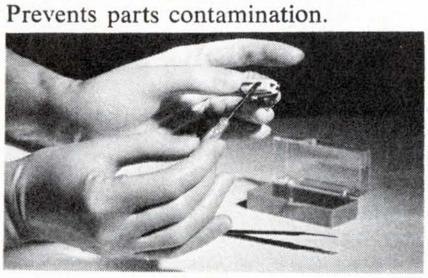


The logic lite indicates quiescent logic levels and displays and identifies single pulses as narrow as 50 ns. Lamp flashes on for a positive pulse or off for a negative pulse. It will also display symmetrical or non-symmetrical waveforms and is not sensitive to rise or fall times. Automated Control Technology Inc., 3452 Kenneth Dr., Palo Alto, Calif. 94303. (415) 328-6080.

Circle 248 on Inquiry Card

RUBBER GLOVE

Prevents parts contamination.



Product protection, finger dexterity, and touch sensitivity, essential in handling and assembling electronic components, are provided by Wil-Gard glove. The glove is strong, yet thin and snug-fitting. Edmont-Wilson, Div. of Becton, Dickinson and Co., 2083 Walnut St., Coshocton, Ohio 43812.

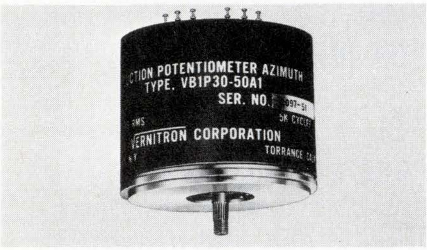
Circle 249 on Inquiry Card

Circle 48 on Inquiry Card

Circle 49 on Inquiry Card **Circle 57 on Inquiry Card**

BRUSHLESS POT

Linear range of ±165° shaft rotation.

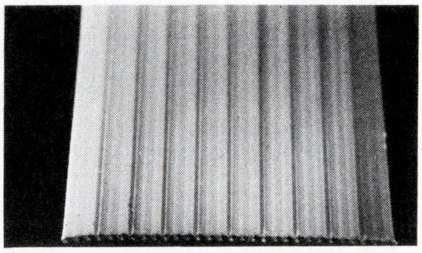


Model VBIP-30 induction pot produces an ac output voltage proportional in amplitude to the shaft rotation. The extended linear range and the brushless feature make it suitable for applications formerly impossible for an inductive device. Freq is 5 kHz ±250 Hz and input volt. (pk to pk sq. wave) is 20 ±1. Primary impedance is 418 Ω. Output volt. is 2.0 ±5% Vrms, at 165°. Linearity is ±1% of full scale output. Vernitron Corp., 2440 W. Carson St., Torrance, Calif. 90501. (213) 328-2504.

Circle 250 on Inquiry Card

FLAT CABLES

Made of flame retardant polyolefin.

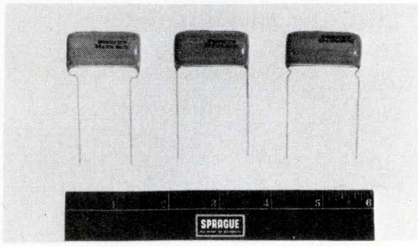


New 90, 50 and 75Ω fixed impedance round-conductor flat transmission cables are designed to replace coaxial lines in computer and related equipment. They come in three-wire, ground-signal-ground, modules. They are designated "Scotchflex" No. 3358 (50Ω), No. 3359 (90Ω), and No. 3409 (75Ω) cable. Dielectric constant is 2.6, dielectric strength 500 V/mil and vol. res. is > 10^{10}Ω-cm. Dept. E19-24, 3M Co., 3M Center, St. Paul, Minn. 55101. (612) 733-4962.

Circle 251 on Inquiry Card

FILM CAPACITORS

Units are self-healing.

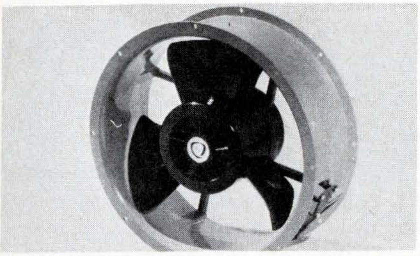


Type 277 Metfilm 'E' Orange Drop capacitors have a coating of orange epoxy resin to protect them against moisture. Metallized dielectric makes them self-healing in the event of dielectric breakdown. The polyester-film capacitors come in ratings of 100, 200, 400, and 600 Vdc for operation from −55°C to +85°C. With suitable derating they may also be used in 60 Hz ac applications. Sprague Electric Co., 233 Marshall St., North Adams, Mass. 01247.

Circle 252 on Inquiry Card

CONDOR FAN

Cools electronic enclosures.

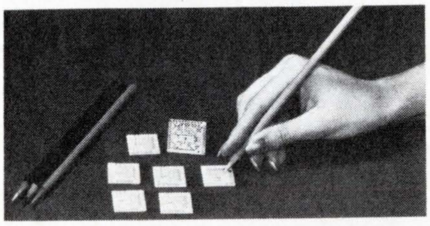


Delivering up to 575 ft^3/min. in free air, this fan removes damaging heat from equipment against back pressure. The 10 in. dia. fan projects 3.5 in. into the work area. Acoustical disturbance measures < 49 dB. There are six models for 115 or 230 V, 60/50 Hz operation. IMC Magnetics Corp., 570 Main St., Westbury, N.Y. 11591. (516) 334-7195.

Circle 253 on Inquiry Card

HIGH TEMP. PENCILS

Identify thick film substrates.

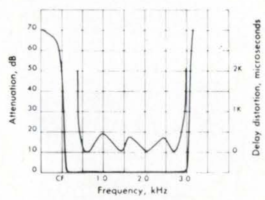


These pencils are for writing on ceramics. Once applied the deposit will withstand the high temps. of print and fire processes. After exposure the marks are permanent and will not be removed by any common solvent or cleaner. Starnetics Co., 10639 Riverside Dr., North Hollywood, Calif. 91602. (213) 769-8437.

Circle 254 on Inquiry Card

CRYSTAL FILTER

Equalized-delay.



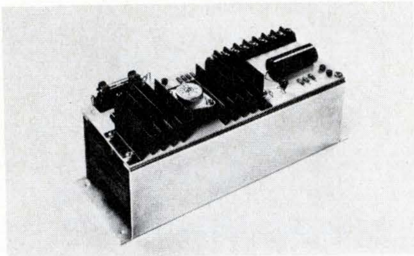
EQUALIZED ENVELOPE DELAY
curve shows response of one channel

Filters sophisticated in equalizing delay-distortion are useful for high-speed data transmission equipment. The Model F11234 filter with envelope delay of <500 µs over 90% of the 1.5 dB BW., eliminates the need for discrete equalizers. Reeves-Hoffman Div. of Dynamics Corp. of America, 400 W. North St., Carlisle, Pa. 17013.

Circle 255 on Inquiry Card

DC POWER SUPPLY

General purpose regulated unit.

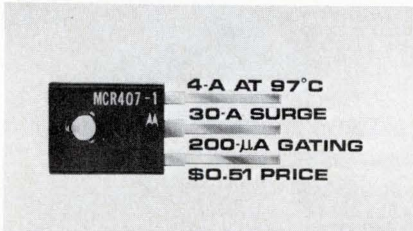


The PM728 is a compact (3.0 x 3.7 x 8.4 in. overall), low-cost regulated supply. Output is adj. from 4.8 to 6.3 Vdc at 3 A and will operate from 115 Vac ±10 Vac at 60 to 400 Hz. Line and load reg. is ±0.05% each and ripple and noise is < 1.0 mV rms. Computer Products, 2709 N. Dixie Hwy., Box 23849, Ft. Lauderdale, Fla. 33307. (305) 565-9565.

Circle 256 on Inquiry Card

PLASTIC SCRS

Carry 4 A rms at 97°C case.

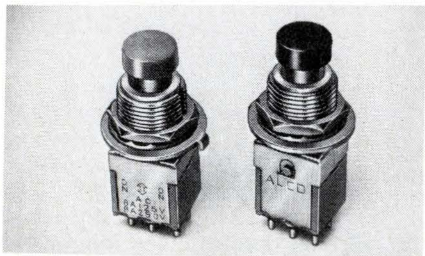


The high-temperature operating ability of these MCR406 Thermopad™ SCRs reduces the need for heat sinking. The 30 A peak forward current surge capability improves reliability. They come with ratings of 30, 60, 100, and 200 V. Motorola Semiconductor Products Inc., Box 20924, Phoenix, Ariz. 85036.

Circle 257 on Inquiry Card

PUSHBUTTON SWITCH

Miniature with a 15/32 in. bushing.

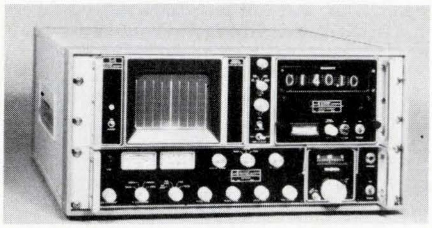


Miniature switch has a std. 15/32 in. hole mounting but the rear panel space requirements are those of miniature switches. These DPDT switches have a 6 A rating and feature solid silver contacts. Alco Electronic Products, Inc., Box 1348, Lawrence, Mass. 01843.

Circle 258 on Inquiry Card

VHF RECEIVING SYSTEM

Signal display and digital readout.



Model RS-160 handles am, fm, and pulse signals from 30 to 300 MHz. Two sweeping modes supply signal display voltages while a digital afc feature permits receiver freq. settings in 1 kHz increments. Watkins-Johnson Co., 6006 Executive Blvd., Washington Science Ctr., Rockville, Md. 20852. (301) 881-3300.

Circle 274 on Inquiry Card

CCTV SYSTEM

With good picture detail.

Basic 6000 series system consists of a Model 6100 TV camera and 6900 camera control unit. The SS camera comes in 8, 16, or 32 MHz video bandwidths and can provide vert. center picture resolution up to 825 lines. It has a horiz. scan rate of up to 1225 lines. Cohu Electronics, Inc., Box 623, San Diego, Calif. 92112.

Circle 277 on Inquiry Card

KEYBOARD

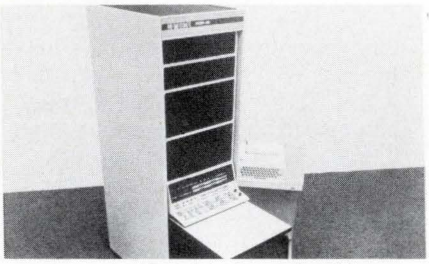
Finger-contour square key.

Keykode KA series keyboards come assembled and wired to PC edge for std. mating connector or for hardwiring to ext. circuitry. Has a low profile (1 in. deep), a short throw (0.1 in.), a light touch (3-5 oz. contact pressure), and a long life (rated at 5 million cycles). Nutronics, Box 72, Paramus, N.J. 07652.

Circle 280 on Inquiry Card

MEDIUM-SCALE COMPUTER

Prices begin at $16,500.

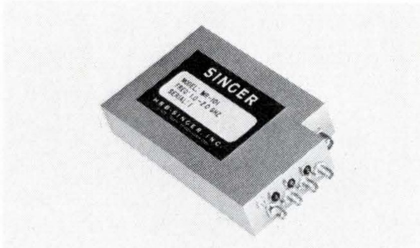


Model PDP-15 is for scientific control uses. There are four basic configurations with basic memory sizes from 4096 words to 131 k words. Word length is 18 bits/word and memory cycle time is 800 ns. System contains operational software and TTL ICs. Digital Equipment Corp., Maynard, Mass. 01754. (617) 897-5111.

Circle 275 on Inquiry Card

MICROWAVE RECEIVER

It's only 2¼ x 4⅝ x ¾ in.

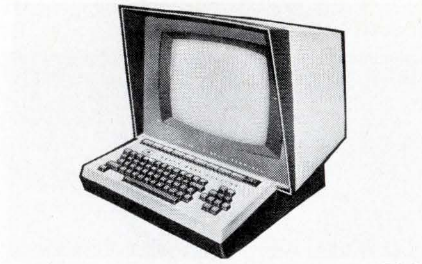


All SS automatically swept superhet receiver covers from 1.0 to 2.0 GHz. It provides a 1 MHz video output with crystal calibration markers at 125 MHz intervals, as well as a 10 MHz crystal video output. Minimum prim. power drain is only 2.5 W at ±15 Vdc. HRB-Singer, Inc., Box 60, Science Park, State College, Pa. 16801. (814) 238-4311.

Circle 278 on Inquiry Card

CRT DISPLAY TERMINAL

Has computer I/O compatibility.

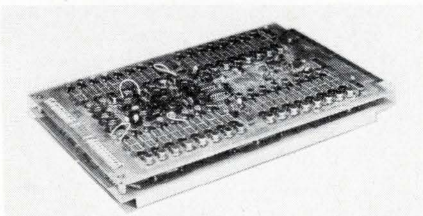


Delta 1 terminal has computer I/O and video compatibility. Its flexible data communication permits it to transmit a line, a message or the entire screen. Terminal operates at line speeds up to 2400 baud (asynch.) Parallel high speed data transfer rate is up to 800,000 char./s. Delta Data Systems Corp., 613 W. Cheltenham Ave., Philadelphia, Pa. 19126.

Circle 281 on Inquiry Card

CORE MEMORY

Has 900 ns full cycle time.

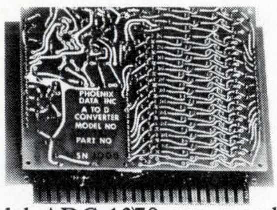


Model 140 has 900 ns full cycle and 200 ns access time. Modular design permits a wide range of word capacity/word size memory systems from this basic building block. Module capacity is 4096 words x 8, 9, 10 bits. Micro Systems, Inc., 644 E. Young St., Santa Ana, Calif. 92705.

Circle 276 on Inquiry Card

A/D CONVERTER

Accuracy is ±0.015% of full range.

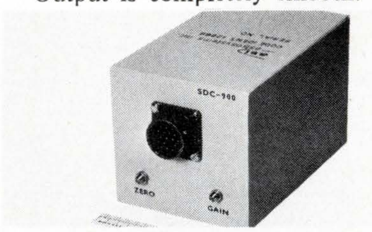


Model ADC 1370 can encode ±10 V full range inputs into 13 binary bits of data with a min. thruput time of 14 μs. Successive approximation measurement is used to provide a resolution of 1 part in 8,191. Temperature coeff. is ±5 ppm./°C. Phoenix Data, Inc., 3059 Fairmount Ave., Phoenix, Ariz. 85017.

Circle 279 on Inquiry Card

SYNCHRO TO DC CONVERTER

Output is completely smooth.



Model A205 converter transforms a 3 wire synchro or 4 wire resolver input to a linear dc output proportional to the equivalent input angle. Accuracy of standard units is ±6 minutes of arc at high tracking speeds. Astrosystems, Inc., 6 Nevada Drive, New Hyde Park, N.Y. 11040.

Circle 282 on Inquiry Card

EE READ THESE BOOKS

CONTROLS: STRAIGHT TO THE POINT

Introduction to Control Theory for Engineers

By Allan Sensicle. Published 1969 by Hart Publishing Co., Inc., 510 Sixth Ave., New York, N. Y. 10011. Price $10. 246 pages.

Here is an excellent book to introduce you to the world of control theory. In its simple and clear presentation, it gets the message across without relying heavily on mathematics. All the basic topics are covered in depth—root-locus, Nyquist, Bode, and so forth.

The engineer or student who wants a book for self study, one that can clear up those frustratingly simple questions that the advanced texts never seem to answer, should get this book. It is easy to read and has a complete set of problems and answers at the end of every chapter.

Thick Film Microcircuitry Handbook

Published 1969 by DuPont Co., Room 2507, Nemours Bldg., Wilmington, Del. 19898. Annual subscription fee is $50.00.

The information is contained in two loose leaf note books and will be updated periodically, as required, for your year's subscription fee. Several new sections have been prepared in addition to those that have existed. Each will focus on methods of translating discrete circuit functions into hybrid microcircuits.

Much of the materials-oriented information in the basic handbook will also be expanded and additional sections will discuss such discrete elements as multilayer capacitors, chip resistors and other components using thick-film micro-circuitry.

If you are in the thick-film hybrid business or if you intend to work in the field either manufacturing, prototyping or merely specifying hybrid circuits, you should have a copy of this publication.

An Introduction to Electrical Engineering

By Allen E. Durling. Published 1969 by The MacMillan Co., 866 Third Ave., New York, N. Y. 10022. Price $10.95. 460 pages.

Studies in Feedback-Shift-Register Synthesis of Sequential Machines

By Robert L. Martin. Published 1969 by The MIT Press, 50 Ames St., Cambridge, Mass. 02142. Price $12.00. 195 pages.

The State-Variable Approach to Continuous Estimation with Applications to Analog Communication Theory

By Donald L. Snyder. Published 1969 by The MIT Press, 50 Ames St., Cambridge, Mass. 02142. Price $7.50. 114 pages.

Digest of Literature on Dielectrics

Prepared by The Conference on Electrical Insulation and Dielectric Phenomena, division of Engineering National Research Council. Published 1969 by Printing and Publishing Office, National Academy of Sciences, 2401 Constitution Ave., Washington, D. C. 20418. Price $27.00. 433 pages.

EE LITERATURE

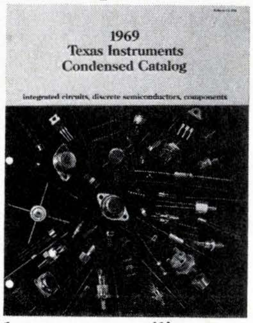
MSI functional arrays

In this 24-page catalog you'll find schematics and descriptions of Sylvania's monolithic, digital, functional arrays. Included is a chart which lists the typical characteristics of 20 different arrays. Another handy chart compares the firm's MSI devices to conventional integrated circuits. Sylvania Electric Products, Central Advtg. Distribution Dept., 1100 Main St., Buffalo, N.Y. 14209.

Circle 321 on Inquiry Card

Semiconductor ICs, discretes

Bulletin CC-200, a 56-page condensed catalog, features a listing of new semiconductor products, and a rundown of the company's popular integrated circuits, discrete semiconductors, and components. Covered are



semiconductor ICs, silicon and germanium transistors, microwave components, diodes and rectifiers, thyristor and trigger diodes, optoelectronic devices, and resistors. Case outline drawings, a military device listing, and a handy cross index are included in the 1969 catalog. Texas Instruments Incorporated, Inquiry Answering Service, Box 5012, MS/308, Dallas, Tex. 75222.

Circle 322 on Inquiry Card

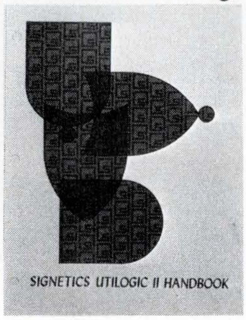
A/D converters

Application Topics, an 8-page publication, discusses a line of A/D converters which operate on the principle of dual-slope integration. Topics include: What is A/D conversion?, Is an A/D converter a digital voltmeter?, and five common methods for achieving conversion. Features and specs of the company's converters are listed, and a glossary of terms is given. Theta Instrument Corp., 22 Spielman Rd., Fairfield, N.J. 07006.

Circle 323 on Inquiry Card

Digital IC family

A revised 56-page handbook covers the Utilogic II family of digital integrated circuits, which consists of 20 different elements. Loading charts,



typical applications, and interface guidelines are some of the useful data given. There is also a section that discusses how to design with Utilogic II. Signetics Corp., 811 E. Arques Ave., Sunnyvale, Calif. 94086.

Circle 324 on Inquiry Card

Capacitors

Suggested as a reference for design engineers, a set of catalogs provides data on a line of capacitors. These include wrap and fill, hermetically-sealed, ceramic-cased, phenolic-cased, and polystyrene devices. Details and performance curves are given in the brochures. Del Electronics Corp., 250 E. Sandford Blvd., Mt. Vernon, N. Y. 10550.

Circle 325 on Inquiry Card

PC connectors

A brochure lists, in chart form, specs for a variety of printed circuit connectors. Twenty different sizes from three to 210 single or dual contacts are covered. Included is a table explaining the basic identifying nomenclature. Continental Connector Corp., 34-63 56th St., Woodside, N. Y.

Circle 326 on Inquiry Card

Magnetic tape

An 8-page brochure, T-349, describes the low-abrasive characteristics of the 700 series magnetic instrumentation tape. Tips for tape selection and instructions for tape care and storage are given. Also covered are design features of the tape reels. Ampex Corp., Mail Stop 7-14, 401 Broadway, Redwood City, Calif. 94063.

Circle 327 on Inquiry Card

Teletypewriter terminals

Two 8-page brochures discuss the application of refined data communications and processing by two different companies. Of particular interest to EEs is the case history that describes how teletypewriter terminals provide direct access to a time-sharing computer. This system gives immediate information on idea and design feasibility, or on the technical worth of engineering changes. Dept. SP-82, Teletype Corp., 555 Touhy Ave., Skokie, Ill. 60076.

Circle 328 on Inquiry Card

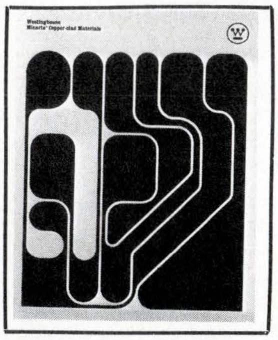
Measurement instruments

Catalog TM-153 summarizes the specs for a line of telecommunication measurement instruments. Covered are instrumentation for Type T-1 PCM carrier systems, instruments for measurement and maintenance on Type N cable carrier systems, and a noise loading test set. Also described in the 16-page catalog are an envelope delay test set, frequency-selective voltmeters, and tracking signal generators. Sierra Electronic Operation, Philco-Ford Corp., 3885 Bohannon Dr., Menlo Park, Calif. 94025.

Circle 329 on Inquiry Card

PC materials

A comprehensive 12-page guide covers copper-clad materials for use in rigid, multi-layer, and flexible printed circuits. Catalog B-9542 provides, in tabular form, technical data on the

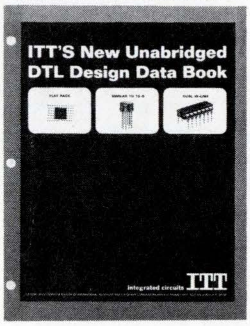


specs, properties, methods of testing, and applications of the various materials. Production and quality control procedures are also discussed. Westinghouse Electric Corp., Industrial Plastics Div., West Mifflin, Pa. 15122.

Circle 330 on Inquiry Card

DTL integrated circuits

This DTL Design Data Book (67 pages) covers ITT's 930 series, a family of compatible integrated circuits using diode-transistor logic. A general description of the series is given, including data on loading factors, noise immunity, propagation delay, and transfer characteristics. A handy



glossary defines terms used with the 930 series and an interchangeability guide serves as cross-reference, listing the company's part numbers as well as those of other leading manufacturers. ITT Semiconductors, 3301 Electronics Way, West Palm Beach, Fla. 33407.

Circle 331 on Inquiry Card

Laminar flow clean rooms

A revised third edition of a 200-page handbook discusses the basic principles of laminar flow clean air devices and how to apply them to work processes. The source also contains case histories of laminar flow applications, design guides for clean rooms, a check list of items needed for construction of clean rooms, and other useful data. Agnew-Higgins, Inc., Box 857, Garden Grove, Calif. 92641.

Circle 332 on Inquiry Card

Switches and selectors

Catalog B-200 (34 pages) provides a guide to the characteristics of standard stepping switches and circuit selectors. It also describes building blocks which form the basis for more complex designs. An "Engineering Considerations" section covers common methods of remote switching, fundamentals of operation, application of basic control and load circuits, and terminology. Ledex Div., Ledex Inc., 123 Webster St., Dayton, Ohio 45402.

Circle 333 on Inquiry Card

Matched impedance connector

Application Note 94 tells you how to design cable connectors for minimum impedance discontinuity, using time-domain reflectometry for performance evaluation. The 17-pager discusses the hermaphroditic design concept, the mechanical specs required for high reliability, and the electrical specs required for undistorted pulse transmission. Titled "Electromechanical Design of a Matched Impedance Connector," it also covers such topics as the use of computer-aided design. Inquiries Manager, Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304.

Circle 334 on Inquiry Card

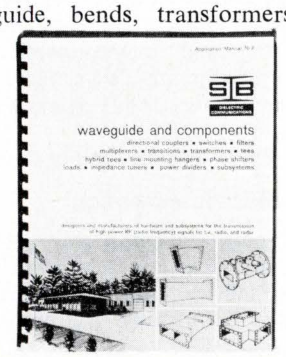
Instrumentation

A 15-page pocket-size catalog provides a condensed look at the company's industrial instrumentation. Mechanical recording instruments; pneumatic, electric, and electronic control systems; telemetering and supervisory control systems; digital equipment; and electromechanical components are among the products surveyed. Bristol Div., American Chain and Cable Co., Inc., Box 1790, Waterbury, Conn. 06720.

Circle 335 on Inquiry Card

RF components

Application Manual 70-2, a 58-pager, covers a line of large waveguide and rf components. Among the products listed are seam-welded aluminum waveguide, bends, transformers, hy-

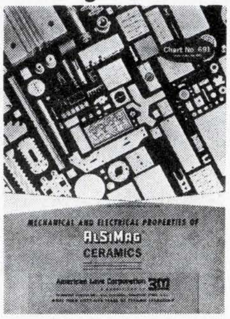


brids, high power terminators, tuners, phase shifters, and attenuators. Application data and engineering design constants are given. Dielectric Communications, Div. of Sola Basic Industries, Raymond, Me. 04071.

Circle 336 on Inquiry Card

Ceramics chart

A foldout chart, No. 691, details the mechanical and electrical properties of AlSiMag® ceramics. Various



graphs provide other useful design data. American Lava Corp., Chattanooga, Tenn. 37405.

Circle 337 on Inquiry Card

Lasers

Featured in this 12-page brochure is the LPM (Laser for Precision Microfabrication) series. Various applications and available accessories for this laser system are described. Hadron, Inc., 300 Shames Dr., Westbury, N.Y. 11590.

Circle 338 on Inquiry Card

DTL and TTL circuits

In this 88-page catalog you'll find descriptions, logics, and schematics for a line of DTL and TTL devices. These include the 200 and 930 series DTL ICs and the RAY I, II, and III series TTL ICs. Also covered are the company's complex circuits and linear circuits. Raytheon Co., Semiconductor Div., 350 Ellis St., Mountain View, Calif. 94040.

Circle 339 on Inquiry Card

Components compendium

A 17-page catalog describes a line of microwave, rf, and i-f receiving systems and components. It includes sections on ICs, microwave receivers, converters, and mixer preamplifiers. Strip line components are also covered. Varian, LEL Div., Akron St., Copiague, N.Y. 11726.

Circle 340 on Inquiry Card

Drafting aids

A line of drafting aids and symbols particularly for PC board design and drafting is the subject of a 7-page catalog. Die cut shapes, multi-pin connector patterns, precision-cut artwork tape, and symbols for dual-in-line IC elements are among the products listed. Centron Engineering Inc., 1518 W. 132nd St., Gardena, Calif. 90249.

Circle 341 on Inquiry Card

Microwave ICs

Of special interest to engineers who design microwave subsystems using integrated circuits, Catalog MIC-713 describes over 70 microwave ICs and corresponding hardware. Among the devices listed are ferrite circulators, mixers, couplers, hybrid rings, filters, and preamplifiers. Module systems for mounting and interconnecting individual circuits are also covered. Western Microwave, 16845 Hicks Rd., Los Gatos, Calif. 95030.

Circle 342 on Inquiry Card

Piezoelectric ceramics

A 6-page brochure (PD-9247) describes what piezoelectric materials are best suited for specific applications. Included is a table listing ceramic properties, their definitions, and MKs units. Charts describing basic actions of ceramics and electromechanical properties are also given, as is a nomograph for finding resonant frequencies. Clevite Corp., Piezoelectric Div., 232 Forbes Rd., Bedford, Ohio 44146.

Circle 343 on Inquiry Card

DC measuring instruments

A 25-page brochure, titled "Some Suggestions Toward Equipping a Standards Laboratory," deals with dc electrical measuring instruments and standards. Topics include: Why a standards lab?; resistance, voltage, and temperature measurement; temperature and humidity control for a standards lab; and so forth. For a copy, write on company letterhead to Leeds & Northrup Co., North Wales, Pa. 19454.

Receivers and transmitters

This 17-page condensed catalog lists a line of receiving and transmitting equipment. Covered are receivers, tuners, frequency extenders, signal monitors, predetection converters, demodulators, AGC units, digital readouts, readout extenders, and ancillary equipment. Prices and specs for each unit are given. Watkins-Johnson Co., CEI Div., 6006 Executive Blvd., Rockville, Md. 20852.

Circle 344 on Inquiry Card

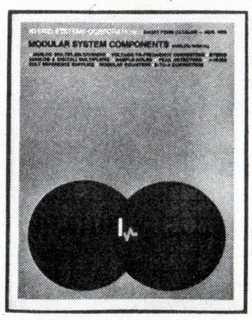
Integrated-circuit sockets

Catalog No. 1268, an 8-page publication, covers IC sockets, systems, and accessories. Products include miniature pin sockets, IC breadboards, the RN universal circuit system, and so forth. Application ideas, photographs, specs, and test data are given. Robinson-Nugent, Inc., 800 E. 8th St., New Albany, Ind. 47150.

Circle 345 on Inquiry Card

Analog/digital modules

Encapsulated modules for analog and digital processing systems are the subject of this catalog. Among the products listed are D/A converters,



analog multipliers, voltage-to-frequency converters, and peak detectors. Application data, electrical specs, waveform information, and ordering information are given. Hybrid Systems Corp., 95 Terrace Hall Ave., Burlington, Mass. 01803.

Circle 346 on Inquiry Card

Electromechanical components

A 576-page catalog covers about 44,000 precision electromechanical components. Of special interest is the 120-page technical section which includes data on precision gearing and

gear train design. Application information, a series of technical tables, and a bibliography are highlights of the 1969 catalog. Sterling Instrument, Div. Designatronics, Inc., 76 E. Second St., Mineola, N.Y. 11501.

Circle 347 on Inquiry Card

Electronic calculator

A high-performance desk-top calculator, Model 700, is introduced in this 8-page brochure. Especially suitable for scientific and engineering calculations, the programmable unit can handle trigonometric, hyperbolic, and exponential functions in milliseconds. Wang Laboratories, Inc., 836 North St., Tewksbury, Mass. 01876.

Circle 348 on Inquiry Card

Spectrum analyzers

Methods of performing calibrated frequency-domain measurements using narrow-band and wide-band signals are discussed in "Monograph No. 2." The 14-page brochure tells you how to calibrate real-time spectrum analyzers using sinewaves and broad-band noise to obtain power spectral density plots. Federal Scientific Corp., 615 W. 131st St., New York, N.Y. 10027.

Circle 349 on Inquiry Card

Delay lines

Listed in a 12-page handbook are specs for six standard types of delay lines. These include lumped constant, distributed constant, miniature, subminiature, variable, and econoline module delay lines. The source also gives definitions of the various characteristics of electromagnetic delay lines, specifying data, and standard test circuits. RCL Electronics, Inc., 700 S. 21st St., Irvington, N.J. 07111.

Circle 350 on Inquiry Card

Switches and assemblies

Featured in a 20-page catalog is an expanded line of miniature electronic switches and keyboard assemblies. Toggle switches, push button switches, rotary switches, and snap switches are some of the products covered. General switch data, specs, dimension drawings, and prices are given. Alcoswitch®, Div. of Alco Electronic Products, Inc., Box 1348, Lawrence, Mass. 01842.

Circle 351 on Inquiry Card

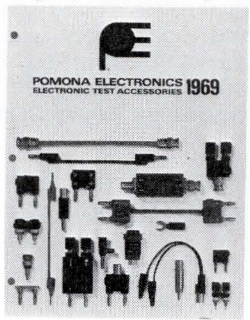
Spectrum analysis

This first issue of a technical journal on test instrumentation and measurement features an article on a new approach to wideband interference-free microwave spectrum analysis. There is also a section on spectrum analyzer applications. The 8-pager is available from The Singer Co., Instrumentation Div., 915 Pembroke St., Bridgeport, Conn. 06608.

Circle 352 on Inquiry Card

Electronic test accessories

Directed at design and test engineers, a 52-page 1969 catalog covers a large line of electronic test accessories. Products include banana plugs, adapters, patch cords; plastic and



shielded metal black boxes; and cable assemblies. Others are: test probes, tube socket and conversion adapters, socket savers, and breadboard sockets. Pomona Electronic Co., Inc., 1500 E. 9th St., Pomona, Calif. 91766.

Circle 353 on Inquiry Card

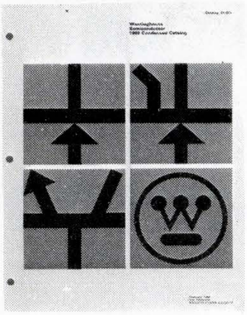
Energy discharge capacitors

Energy discharge capacitors, heavy-duty Types 208P and 212P, are the subjects of Engineering Bulletin 2149. These devices can supply a high-frequency oscillating pulse due to their low inductance construction. The 4-pager provides complete details. Technical Literature Service, Sprague Electric Co., Marshall St., North Adams, Mass. 01247.

Circle 354 on Inquiry Card

Power semiconductors

This 1969 condensed catalog (54-000) describes a variety of power semiconductor devices, including rec-



tifiers, transistors, rectifier assemblies, and thyristors. Specifications, charts, and dimensional diagrams are given in the 20-pager. Westinghouse Electric Corp., Box 868, Pittsburgh, Pa. 15230.

Circle 355 on Inquiry Card

Underwater test center

Entitled "The 100,000 Gallon Mini Ocean," this 4-page bulletin describes an underwater acoustic test and evaluation center. This facility offers a program capability of test and calibration of transducers and arrays. Scientific Atlanta, Inc., Ocean Sciences, Box 13654, Atlanta, Ga. 30324.

Circle 356 on Inquiry Card

Motors and controls

Stock Catalog S-4A contains 16 pages of data on over 325 standard motors, gearmotors, and dc motor speed controls. Also treated are the company's new SCR adjustable speed/torque drive systems. Bodine Electric Co., 2500 W. Bradley Pl., Chicago, Ill. 60618.

Circle 357 on Inquiry Card

Electrostatic recorder

An 8-channel electrostatic recorder, the Statos™ 3, is the subject of an 8-page brochure. System description, principles of operation, a specimen chart, specs, and a list of accessories and optional equipment are provided. Varian, Electrographics Div., 611 Hansen Way, Palo Alto, Calif. 94303.

Circle 358 on Inquiry Card

Rotary switches

Thumbwheel rotary switches—both miniature and subminiature types—are covered in an 8-page booklet. Switching characteristics, mounting diagrams, and truth tables that show the electrical input-output relationships for each thumbwheel or leverwheel position are features of the brochure. Cherry Electrical Products Corp., 1650 Old Deerfield Rd., Highland Park, Ill. 60035.

Circle 359 on Inquiry Card

Relays and monitors

Industrial Catalog No. 100 describes a line of control products. These include solid-state time delay relays, voltage band monitors, phase sequence and phase loss monitors, phase indicators, current monitors, and over and under voltage monitors. Diversified Electronics Inc., Box 6231, Evansville, Ind. 47712.

Circle 360 on Inquiry Card

Hybrid expansion system

The Series 16 hybrid expansion package, designed for use with the TR-48 analog computer, is the subject of a 16-page booklet. The source describes hardware, software, and interface characteristics. It also gives specs and sample applications and problems. Honeywell Computer Control Div., Framingham, Mass. 01701.

Circle 361 on Inquiry Card

Glass sealing wire

Data Sheet 8100-a describes Dumet glass sealing wire for the lamp and electronics industries. Chemical, metallurgical, electrical, and physical properties of the wire are covered in the 4-page user's guide. Lamp Metals and Components Dept., General Electric Co., 21800 Tungsten Rd., Cleveland, Ohio 44117.

Circle 362 on Inquiry Card

Signal averaging method

Application Note NPA-1 (3 pages) describes a method for nanosecond pulse signal averaging. Called the LRS signal averaging method, it uses high-resolution digital techniques to perform analytical measurements on repetitive waveforms whose parameters are obscured by noise. LeCroy Research Systems Corp., 126 N. Route 303, West Nyack, N.Y. 10994.

Circle 363 on Inquiry Card

Terminal junctions

A 12-page booklet, J-1, covers a line of terminal junctions and junction devices. Listed are terminal junctions, distribution junctions, feed-thrus, frames, junction devices, and component junctions. The source also outlines the tool and assembly procedure step by step. Deutsch, Electronic Components Div., Municipal Airport, Banning, Calif. 92220.

Circle 364 on Inquiry Card

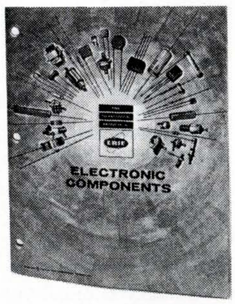
Silicon power modules

Bulletin 112A, an 8-page catalog, describes the new Series N silicon power modules. These modules feature an integrated circuit regulation system for minimizing load- and line-induced thermal drift. Some other features are: convection cooling to 71°C, built-in RFI/EMI suppression, electrostatically shielded transformers, adjustable cutback current limiting, remote sensing and programming, and so forth. Deltron, Inc., Power Div., Wissahickon Ave., North Wales, Pa. 19454.

Circle 365 on Inquiry Card

Electronic components

This 32-page catalog lists a variety of fixed and variable capacitors, as well as EMI filters, resistors, and semi-



conductor devices. Photos, diagrams, and charts are included. Write on your company letterhead to Erie Technological Products, Inc., 644 W. 12th St., Erie, Pa. 16512.

Ion sources

A short-form catalog covers five ion sources for various requirements. Discussed in the 5-page folder are radio frequency, duoplasmatron, diode, and complete laboratory ion sources. Accessories and auxiliary equipment are included. High Voltage Engineering, Equipment Div., Burlington, Mass. 01803.

Circle 366 on Inquiry Card

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EE

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Index to Product Information

Listed below are all products and new literature that appear in this issue, along with the page number they appear on and their Reader Service Numbers (RSN). For more information, see the appropriate page and circle the corresponding number on the reader service card.

Components

ICs and Semiconductors

Instrumentation

Materials and Packaging

Microwaves & Optoelectronics

Modules, Networks, & Subassemblies

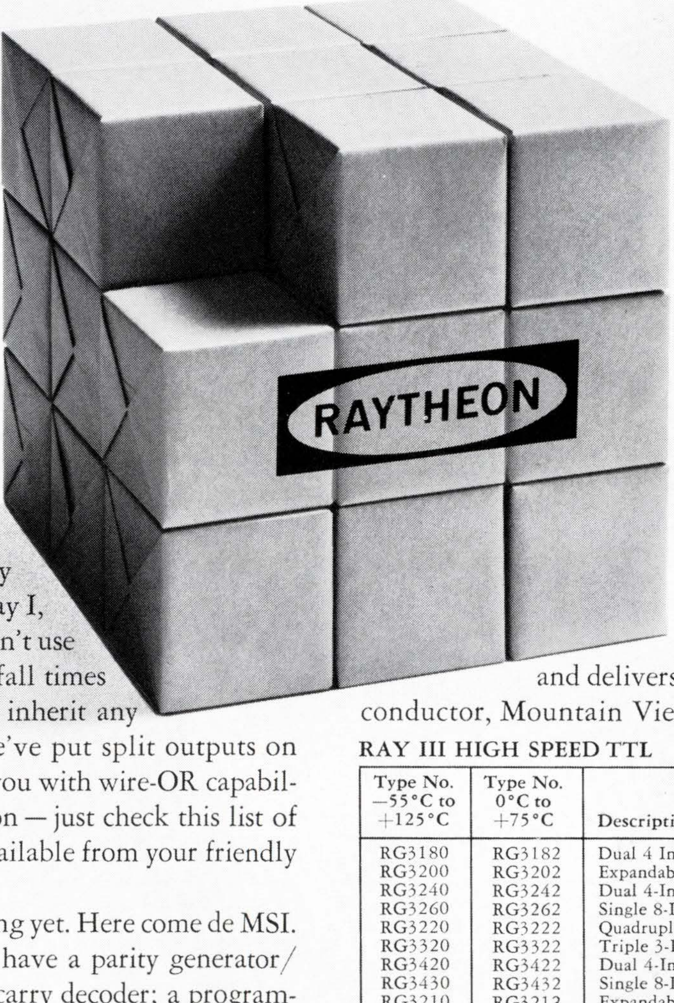
Production and Manufacturing

Systems Equipment

New Literature

We invented the world's fastest TTL. We sell the industry's broadest TTL line. We're at full production now.

But we're improving.



In January Raytheon burgeoned their TTL line by introducing Ray III, the market's fastest saturated logic. With 4½ nanosecond gate delays and 9 ns flip flops, it's nearly twice as fast as Ray II, SUHL II and 54H/74H.

But speed's just a chunk of it. Ray III is electrically and pin-compatible with Ray I, Ray II and the rest, but doesn't use any more power. Rise and fall times are the same, so you don't inherit any new wiring problems. We've put split outputs on some functions to provide you with wire-OR capability. As for function selection — just check this list of Ray III types. All 26 are available from your friendly Raytheon distributor.

And you ain't seen nothing yet. Here come de MSI. On the way right now we have a parity generator/checker; a 4-bit adder and carry decoder; a programable up/down counter; and a 4-bit universal shift register, with more to follow. After that? Ray VI, a 2 ns T^{2}L MSI line with shallow diffusions, washed emitters, Shottky barrier Baker clamps, high density gold interconnects and tunneling Shottky barrier resistors.

Send for Ray III data sheets and franchised distributor list from the company that gets the ideas and delivers the goods. Raytheon Semiconductor, Mountain View, Calif. (415) 968-9211.

RAY III HIGH SPEED TTL

Type No. −55°C to +125°C	Type No. 0°C to +75°C	Description
RG3180	RG3182	Dual 4 Input AND Expander
RG3200	RG3202	Expandable Single 8 Input NAND Gate
RG3240	RG3242	Dual 4-Input NAND Gate
RG3260	RG3262	Single 8-Input NAND Gate
RG3220	RG3222	Quadruple 2-Input NAND Gate
RG3320	RG3322	Triple 3-Input NAND Gate
RG3420	RG3422	Dual 4-Input NAND Gate, Split Outputs
RG3430	RG3432	Single 8-Input NAND Gate, Split Outputs
RG3210	RG3212	Expandable 2-wide, 4-Input AND-NOR Gate
RG3230	RG3232	4-Wide 2-2-3-3 Input AND-NOR Expander
RG3250	RG3252	Expandable 4-Wide, 2-2-2-3 Input AND-NOR Gate
RG3270	RG3272	2-Wide, 4-Input AND-NOR Expander
RG3300	RG3302	Expandable 3-Wide, 3-Input AND-NOR Gate
RG3310	RG3312	Dual 2-Wide 2-Input AND-NOR Gate, One Side Expandable
RG3440	RG3442	2-Wide 2-Input AND-NOR Gate, Split Outputs
RG3450	RG3452	4-Wide 2-2-3-4 Input AND-NOR Gate
RG3380	RG3382	Hex Inverter
RG3390	RG3392	Dual 4-Input AND Gate, Split Outputs
RG3400	RG3402	Quad 2-Input AND Gate
RG3410	RG3412	Quad 2-Input NOR Gate
RF3200	RF3202	AND Input JK Flip Flop
RF3210	RF3212	OR Input JK Flip Flop
RF3120	RF3122	Dual JK Flip Flop (Separate Clocks)
RF3130	RF3132	Dual JK Flip Flop (Common Clock)
RF3220	RF3222	Triple Latch Cell
RF3230	RF3232	60 MHz Dual-D Flip Flop

All types available in hermetic or plastic DIP's, or in flatpacks.

Circle 2 on Inquiry Card