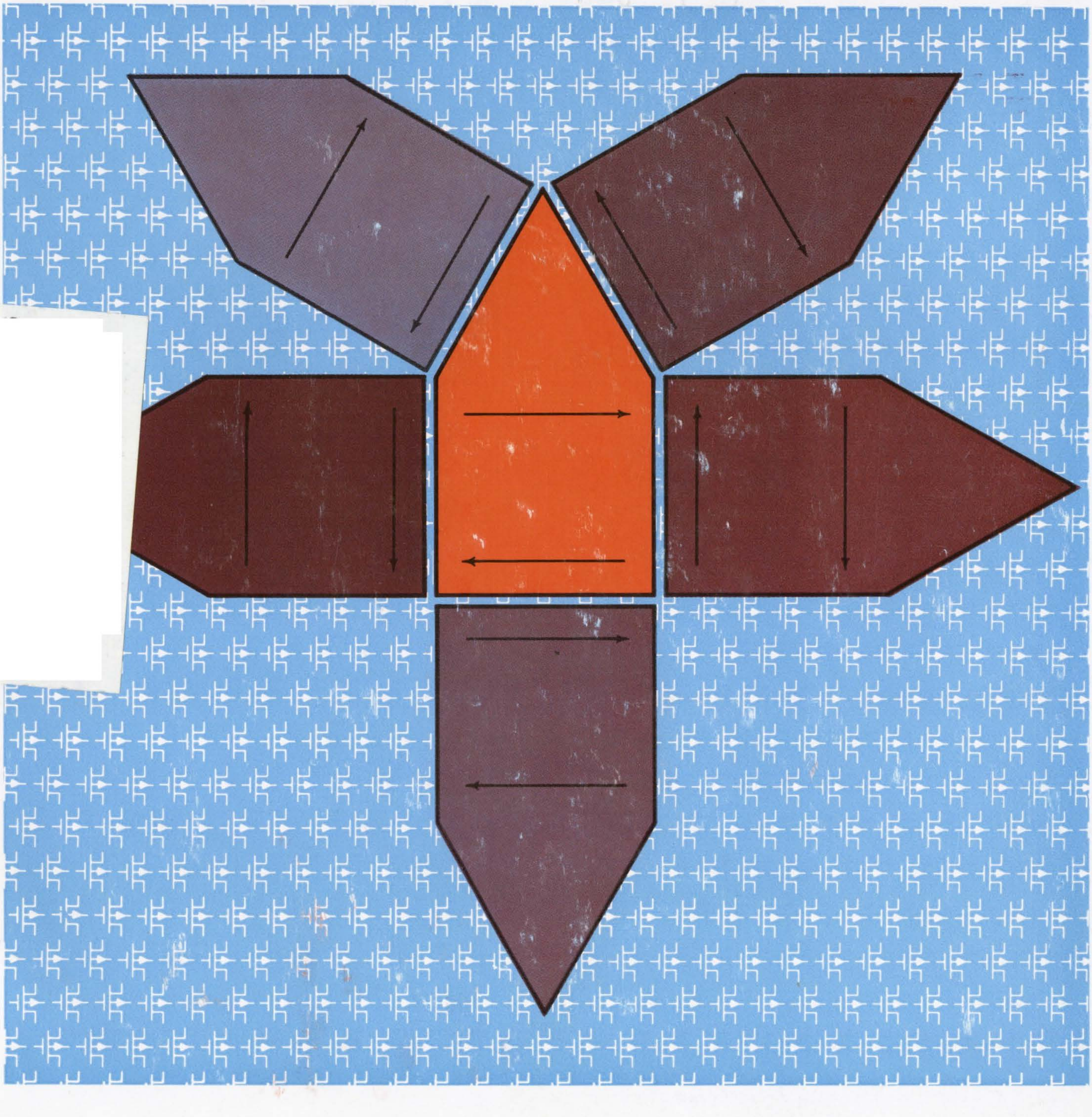
VOL. 14, NO.

Electronic Design 26

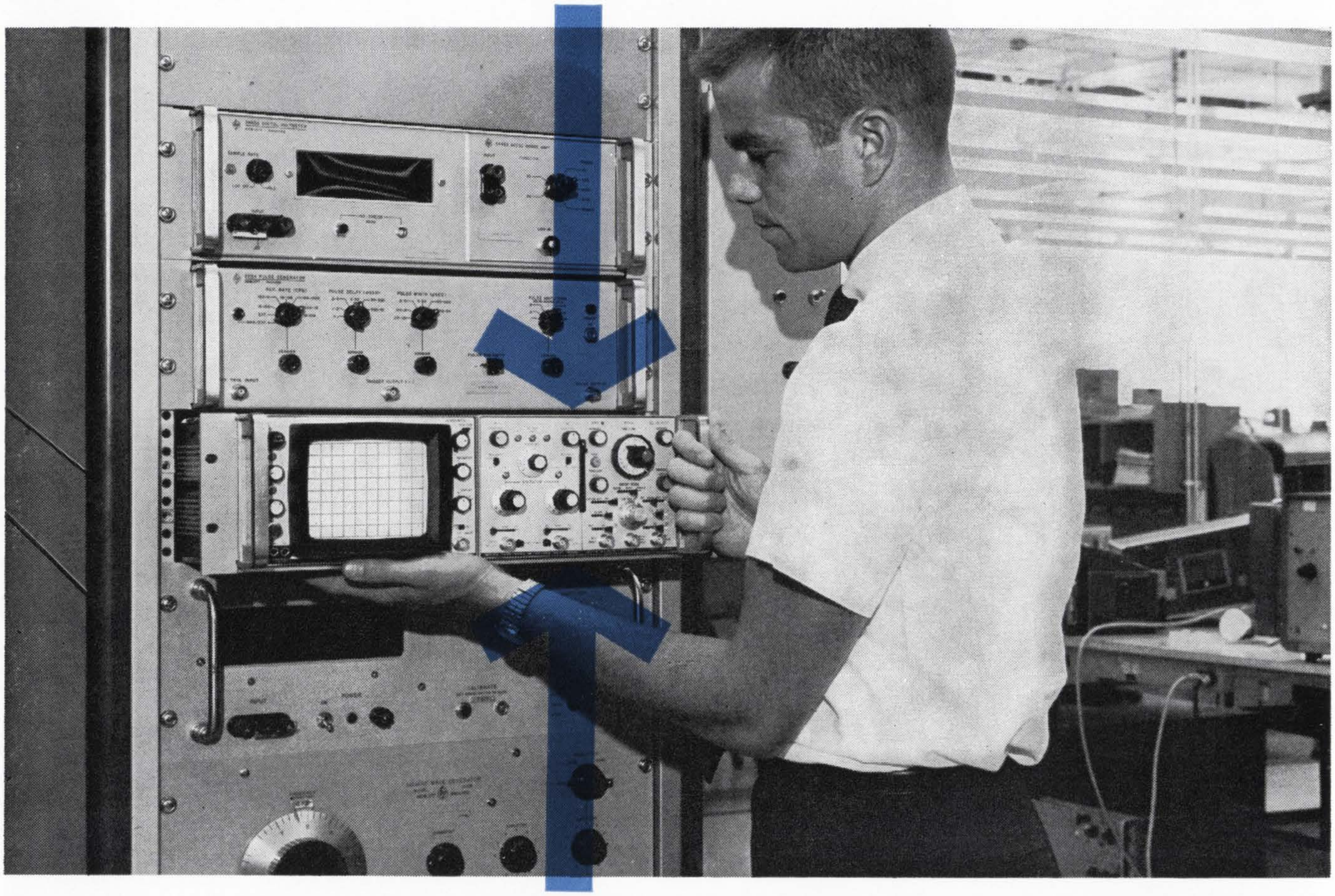
THE MAGAZINE OF ESSENTIAL NEWS, PRODUCTS AND TECHNOLOGY

NOVEMBER 22, 1966

Digital ICs can switch FETs if integrated drivers are put between the chips and switches. For analog signal multiplexing, just connect multi-driver flat-packs, like the one illustrated symbolically below, to similar FET-packs. For step-by-step driver design, see p. 50. For off-the-shelf driver data, p. 106.



Only 5¼" high! 50 MHz at 5 mv/cm! 8 x 10 CRT! All solid-state! Plug-in versatility! 95 watts—no fan!



NEW hp 180AR OSCILLOSCOPE CUTS SIZE OF TEST CONSOLES!

Your scope no longer has to be the biggest instrument in your test console when you use the new hp Model 180AR Oscilloscope! Although its rack height is only 5¼", this scope has an extra-large 8 x 10 cm CRT display area to give you 30% to 100% greater viewing area than any other high-frequency scope. Add to this feature the all-solid-state circuitry in mainframe and plug-ins for greater reliability and cooler operation (no fans needed, 95 watts), 50 MHz at 5 mv/cm, and plug-in versatility—and you get *more total performance, more usability than any other rack mount scope on the market!* Rugged design, all-solid-state and specified performance at —28°C to +65°C makes the 180AR ready to go anywhere!

Accurate measurements are easier to read and make on the new hp 180AR scope, because a new design breakthrough offers a compact 17-inch long, high-frequency 8 x 10 cm CRT. With the black internal graticule calibrated in centimeters, the bright trace, and a 12 kv accelerating potential, you get sharp, crisp traces for accurate resolution of waveform details—even at 5 nsec/cm sweeps.

Mainframe is the first with power supplies specifically designed for solid-state circuitry—to give you full performance benefits from solid-state devices in all present and future plug-ins. New horizontal amplifier has wide bandwidth with X10 magnification to provide linear 5 nsec/cm sweeps, giving you greater resolution of high frequency signals and fast pulses.

The dual channel 50 MHz at 5 mv/cm vertical amplifier has low-drift FET input stages for accurate DC measurement . . . plus quick, 15-second warm-up. Vertical attenuation, which sets vertical deflection factor, is ahead of the amplifier. This prevents trace jump as you change ranges; bandwidth is maintained on all ranges even when verniers are used.

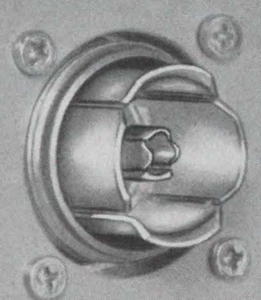
Time base plug-ins offer new easy-to-use delayed sweep for examining complex waveforms in detail. Tunnel diode triggering circuits lock-in waveforms to beyond 90 MHz. Exclusive hp mixed feature combines display of first portion of trace at normal sweep speeds, and simultaneously expands trailing portion of trace at faster delayed sweep speed to allow magnified examination.

To see how the new hp Model 180AR Oscilloscope can help you reduce the size of your test consoles and give you greater total performance, call you nearest hp field representative. Or, write to Hewlett-Packard, Palo Alto, California, 94304. Tel (415) 326-7000; Europe: 54 Route des Acacias, Geneva. Price: hp Model 180AR Rack Mount Oscilloscope, $900.00; hp Model 180A Oscilloscope, $825.00; hp Model 1801A Dual Channel Vertical Amplifier, $650.00; hp Model 1820A Time Base, $475.00; hp Model 1821A Time Base and Delay Generator, $800.00.

HEWLETT hp PACKARD

An extra measure of performance

Why do TEKTRONIX,



TEXAS INSTRUMENTS,

E G & G and others

use GR874 Coaxial Connectors on their products?

Because GR874 Coaxial Connectors are good for pulses

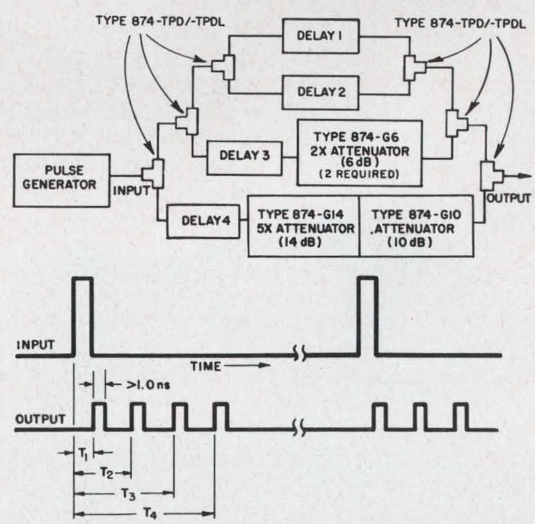
GR874 Coaxial Connectors are wide-bandwidth, low-reflection devices that are made-to-order for fast-rise-time, high-frequency pulse systems. VSWR is less than 1.02 up to 7 GHz, less than 1.08 to 9 GHz for the rigid air-line locking version, which means that these connectors pass pulses faithfully without ringing or deterioration of rise/fall times.

The GR874 is a versatile coaxial system with a wide variety of elements and components . . . power dividers, air lines, trombones, tees, elbows, pads, terminations, adaptors, etc.

The GR874 offers high performance at low cost . . . price of a basic GR874 Coaxial Connector is $2.25, and purchases in quantity yield discounts.

The GR874 saves setup time . . . it is both a hermaphroditic (no male or female versions) and quick-connect/ -disconnect connector.

Here is an example of how GR874 Coaxial elements can be used to produce bursts of high-rep-rate pulses with a low-frequency, fractional-nanosecond pulse generator.



The cascaded GR874-TPD Power Dividers first reproduce the original pulse many times and, later, recombine the individually delayed signals into a higher-rep-rate pulse burst. Rep rates up to several hundred MHz can be obtained by this technique.

GR874 Air Lines can be used to provide small delays (up to 1 ns). GR874 Attenuators can be used when compensatory reductions in amplitude are required (the GR874-TPD Power Divider has a port-to-port insertion loss of 6 dB).

BOSTON • NEW YORK • CHICAGO • PHILADELPHIA • WASHINGTON, D.C.
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CLEVELAND • TORONTO • MONTREAL

BOURNE END, ENGLAND ZURICH, SWITZERLAND

GENERAL RADIO

WEST CONCORD, MASSACHUSETTS

ON READER-SERVICE CARD CIRCLE 3

An oscilloscope picture in 10 seconds: any longer is a waste of time.

Polaroid Land films don't make you wait to see if your trace zigged when it should have zagged.

They let you know in ten seconds.

They give you an oscilloscope picture you can study, attach to a report, send as a test record with a product shipment, or file for future reference.

You have a choice of 5 films for oscilloscope recording.

The standard film has an A.S.A. equivalent rating of 3000. It comes in both roll film [Type 47] and pack film [Type 107]. They both give you 8 pictures 3¼ x 4¼ inches. This emulsion is also available in 4 x 5 sheets [Type 57].

For extremely high-speed recording, there's Polaroid PolaScope Land film [a roll film, Type 410]. It has an A.S.A. equivalent rating of 10,000.

It can take pictures of traces too fleeting for the human eye: such as a scintillation pulse with a rise time of less than 3 nanoseconds.

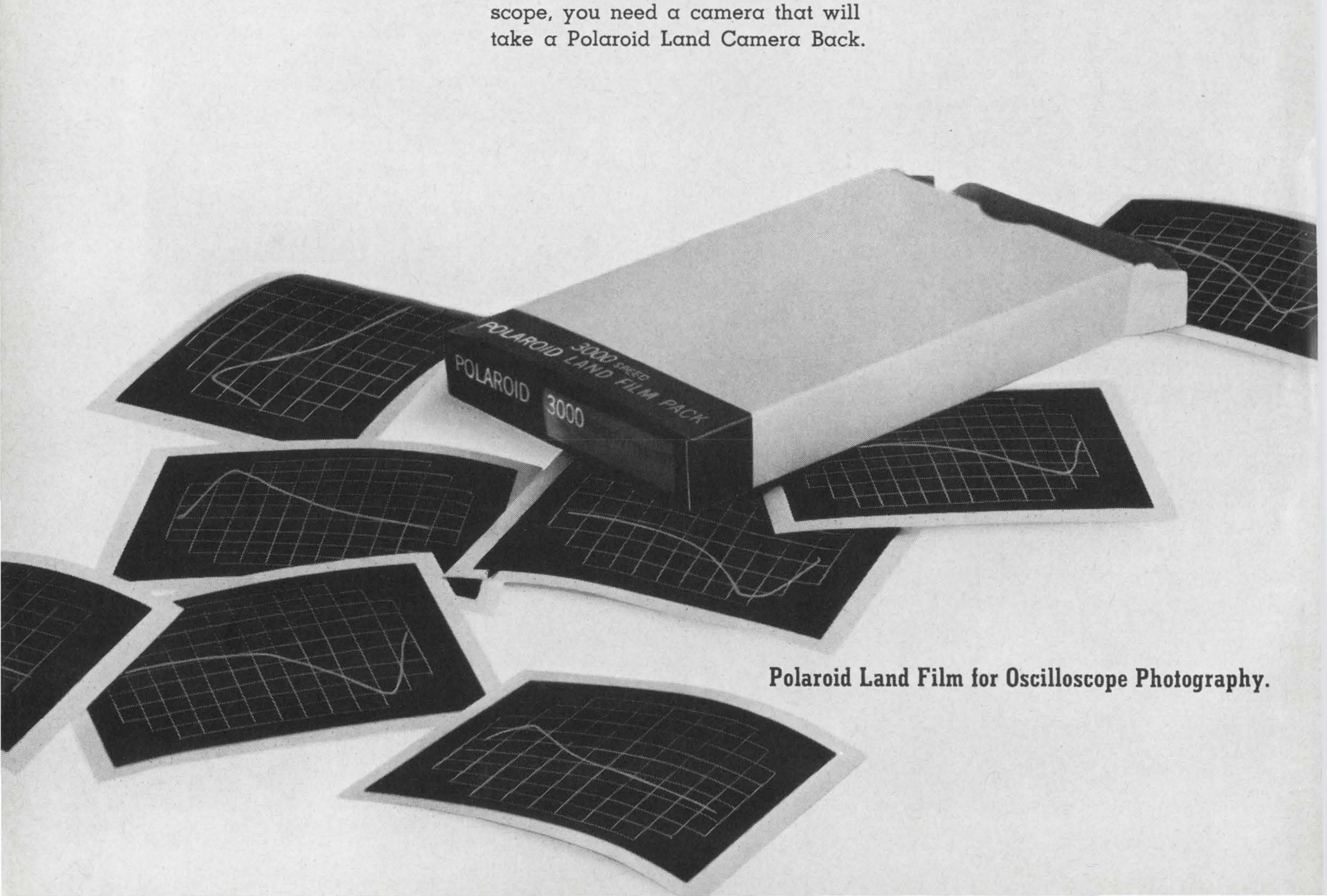
One thing all these films have in common is a sharp, high-contrast image that's easy to read. Because the films are so sensitive, you can use small camera apertures and low-intensity settings.

To put these films to work on your scope, you need a camera that will take a Polaroid Land Camera Back. Most oscilloscope camera manufacturers have one. For instance: Analab, Beattie-Coleman, BNK Associates, Fairchild, EG&G, General Atronics, Hewlett-Packard, and Tektronix.

You can get complete information by writing to Polaroid Corporation, Technical Sales Department, Cambridge, Massachusetts 02139, or by writing to one of the manufacturers mentioned above.

It will probably take a little longer than 10 seconds, but we promise the information won't be a waste of time.

"Polaroid" and "PolaScope"®



Polaroid Land Film for Oscilloscope Photography.

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THE MAGAZINE OF ESSENTIAL NEWS, PRODUCTS AND TECHNOLOGY NOVEMBER 22, 1966

NEWS

TECHNOLOGY

PRODUCTS

Departments

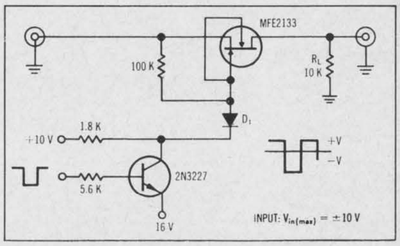
ELECTRONIC DESIGN is published biweekly by Hayden Publishing Company, Inc., 850 Third Avenue, New York, N. Y. 10022. James S. Mulholland, Jr., President. Printed at Poole Bros., Inc., Chicago, Ill. Controlled-circulation postage paid at Chicago, Ill., Cleveland, Ohio, and New York, N. Y. Application to mail at controlled postage rates is pending at St. Louis, Mo. 60,412 copies this issue.

NEW FET CHOPPER-MFE2133 FOR MILITARY/INDUSTRIAL DESIGNS

. . . featuring low r_{ds} "on" — 60 ohms (max)

Here is *one* high-impedance device that can dissipate 1.5 watts. In addition, Motorola's TO-39 package — with low thermal resistance (6.7 mW/°C) — keeps the junction relatively free of troublesome temperature swings. The MFE2133 also offers low transfer capacitance (5 pF) in proportion to the low drain-source resistance. And, the combination makes for better all-around switching performance.

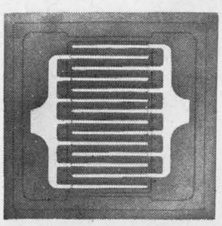
The MFE2133 is suitable for large gate voltage swings as a chopper. The circuit as shown allows input voltages of 10 volts. No transformer is required. The result, of course, is circuit simplicity and savings in component costs.



ON READER-SERVICE CARD CIRCLE 101

MEDIUM-POWER AMPLIFIER JFETs FOR INDUSTRIAL & CONSUMER USES

The industry's first medium-power, high-gain, economical JFETs are Motorola types MFE2097 & MFE2098. Because of their natural high impedances, combined with a medium-power capability, you can often eliminate one transformer as well as large coupling and bypass capacitors in most designs. Even greater savings result from the low 100-up price of $4.90 — *less than half the price of comparable devices!* While these new FETs are ideal for driver stages of audio amplifiers and other audio communications equipment, they are also well-suited for use in analog control systems.



- Medium-power capability results from large geometry with many current paths.
- I_{DSS} ranges from 15 to 50 mA – MFE2097
  40 – 100 mA – MFE2098
- $|y_{fs}| = 10,000$ μmhos (min) – MFE2097
  14,000 μmhos (min) – MFE2098
  . . . for extremely high gain.
- High-dissipation package — TO-39 with 1½" leads.

ON READER-SERVICE CARD CIRCLE 102

MAKE YOUR MOVE TO FETs WITH ANY ONE OF FIVE NEW PIECES FROM MOTOROLA

RCL OFFERS "OFF-THE-SHELF"

1/2" ROTARY SWITCHES

INDUSTRY'S BEST DELIVERY

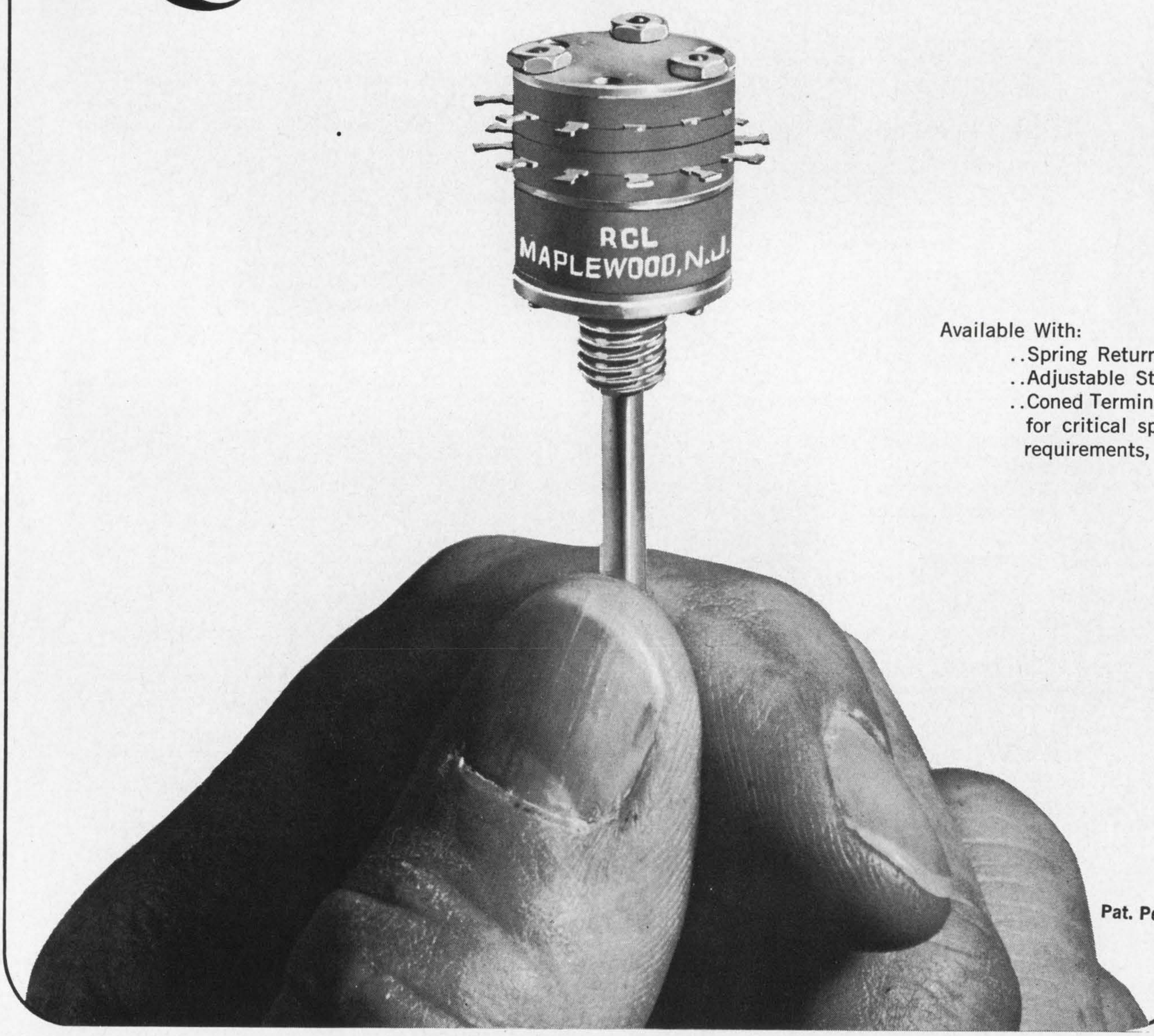
Up to 12 positions per deck . . . up to 6 poles per deck . . . shorting and non-shorting poles can be grouped in any combination on one deck . . . individual deck parts self-contained and permanently molded into place. Extremely low and uniform contact resistance: .0025Ω average. Life expectancy: 200,000 mechanical operations.

RCL

Write for complete engineering information

ELECTRONICS, INC.

General Sales Office: **One Hixon Place, Maplewood, New Jersey**



Available With:
..Spring Return
..Adjustable Stops
..Coned Terminals
for critical space
requirements, etc.

Pat. Pend.

ON READER-SERVICE CARD CIRCLE 6

New Computer Grade Capacitors with proved high ripple ratings

The new line of Mallory CGS Aluminum Electrolytic filter capacitors, designed for 65°C ambient, looks the same as our present CG family . . . same case and top construction, but they're different inside.

A completely new set of specifications for ripple current has been established for this line. The new values are based on Mallory tests of many hundreds of capacitors under a variety of environmental conditions and ripple currents. Maximum ripple values stated for the CGS are the proved currents to which you can design with full confidence of long, reliable life. And they are *higher* than our previous values: for identical case size, about four times higher . . . for identical C-V ratings, over twice as high. ESR specifications are also lower.

Furthermore, you can now get about *twice as much* capacitance in a given case size as was formerly available in Mallory capacitors. Maximum capacitance is now 280,000 mfd at 3 WVDC or 1,800 mfd at 450 WVDC, in the 3″ diameter by 5⅞″ case. And there are 880 other standard ratings from which to choose. For complete data, write for your copy of new Bulletin 4-80. Mallory Capacitor Company, a division of P. R. Mallory & Co. Inc., Indianapolis, Indiana 46206.

50th ANNIVERSARY

MALLORY

ON READER-SERVICE CARD CIRCLE 7

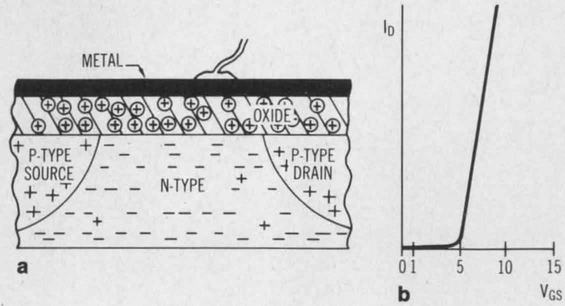
NOW THERE'S PLANAR II.

Fairchild has now added refinements to its patented Planar* process, which result in improved device stability, longer life, and greater reliability without 100% burn-in.

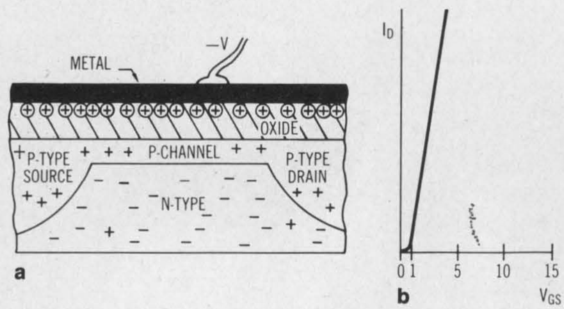
Fairchild invented the Planar process, and by doing so revolutionized the semiconductor industry. Without Planar the reliability of transistors would still be questionable, integrated circuits would not be where they are today, and the whole structure of the electronics industry would be different. But current requirements for ever more reliable systems and components have created a need for a better, purer manufacturing process. No doubt some manufacturers will soon find ways to improve the basic Planar process. We already have.

What is Planar II? Planar II is a refinement of the original Planar process. It is essentially aimed at controlling the behavior of free positive ions in the oxide layer which characterizes the Planar process. Concentration of free ions in the oxide can lead to problems that result in unstable MOS-FET devices, and to outright failure in transistors. The Planar II process keeps the number of these impurity ions to a minimum by using only ultra pure materials, utilizing better metalizing and bonding techniques, and by adding a few steps to the basic process which result in a much purer oxide layer. How does this work?

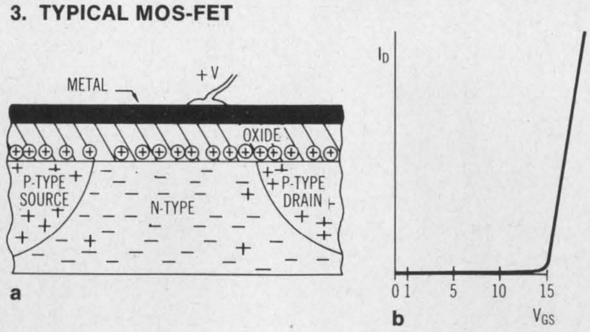
1. TYPICAL MOS-FET



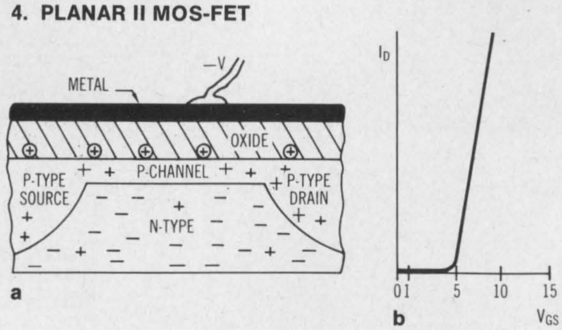
2. TYPICAL MOS-FET



3. TYPICAL MOS-FET



4. PLANAR II MOS-FET



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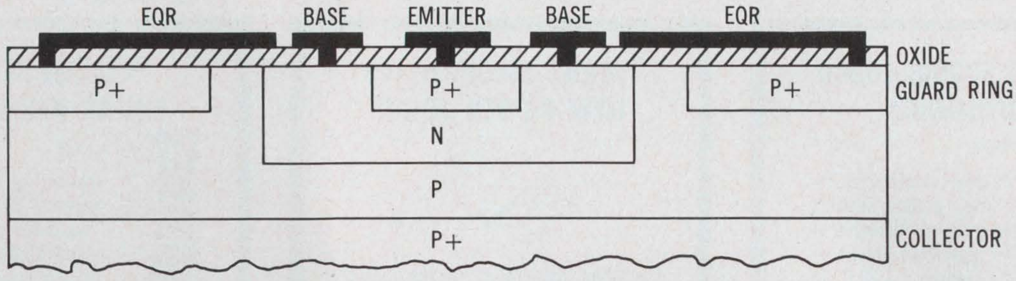
5. PLANAR II PNP TRANSISTOR



Stable MOS devices: In a typical P-channel MOS-FET (Fig. 1a) free positive ions are randomly distributed throughout the oxide layer. If a negative voltage is applied to turn the device on, it repels the free electrons in the N material and allows a P-channel to be formed and current to flow from source to drain. Initially such a voltage could be 5V (Fig. 1b).

As you can see in figure 2a, the negative voltage also attracts the free positive ions, and they concentrate near the oxide-metal interface. When a negative voltage is again applied, a much smaller voltage (about 1V) is required to form the P-channel, since the ions are already concentrated at the metal-oxide interface (Fig. 2a, 2b). Conversely, if a positive voltage preceded the negative turn-on signal, a much higher voltage (15V) is required to form the channel, since the positive ions will be at the bottom of the oxide layer, and will be attracted to the top (Fig. 3a, 3b). Thus, the threshold of the device is degraded and fluctuates between 1-15 volts, depending on the polarity of the previously applied signal.

Figures 4a and 4b show how the Planar II process helps to alleviate this problem. In the Planar II device the number of impurity ions is kept to a minimum, and the effects of their migrations is so small as to be negligible. The result is a threshold voltage that is stable and constant.

Stable PNP devices: To combat ion migrations in PNP transistors we use an equipotential ring (EQR) and a guard ring in addition to controlling the impurities (Fig. 5). The EQR and guard ring prevent the formation of inversion layers which can lead to channeling and device failure. This is accomplished by reshaping the electrical field distribution within the oxide layer to eliminate the lateral component. Ions are inhibited from moving laterally within the oxide layer, thus preventing inversion layers from forming.

The results were dramatically demonstrated in a recent test under severe High-Temperature Reverse Bias (HTRB) conditions. Epoxy devices without EQR and guard ring were subjected to conditions of $T_A = +125°C$, $V_{CB} = 80V$. Over a 1000 hour period, more than 40% of the devices tested had I_{CBO} changes greater than 1000nA. An identical sample of PNP epoxy devices *with* EQR and guard ring went through the same test for the same time period. Not one of these transistors had an I_{CBO} change greater than 1nA.

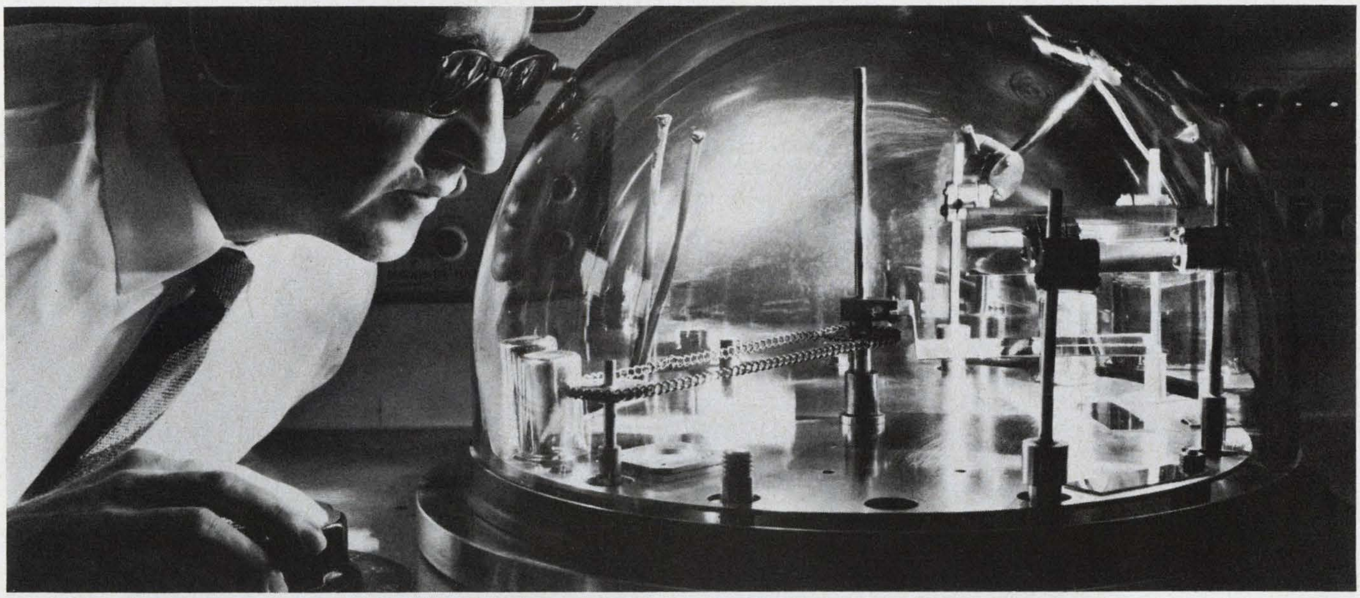
Higher Voltage, lower cost: Because of the Planar II process you can now get high voltage PNP's from Fairchild. Our Series 2N4357, for example, features voltages up to 240V LV_{CEO}. Even in epoxy, high voltages are now practical. Our PNP epoxy series SE7501 features collector-emitter voltages of 140V. This means you can get high voltages at lower epoxy prices. Furthermore, Planar II eliminates the need for 100% burn-in on PNP transistors. This is translated into both lower prices and faster deliveries.

Planar II summary: The benefits of Planar II processing can be summed up as follows: it allows us to make stable MOS field-effect transistors. It allows us to make reliable, high voltage, high performance PNP devices with the flexibility of low cost epoxy packaging. It even improves the stability with time (resulting in longer life) of NPN transistors and integrated circuits. In a word, it allows us to offer you better, more reliable solid-state devices at less cost. Planar II is the purest manufacturing process ever used in mass production. We suspect that in a few years everyone will be using it. You can wait. Or, get it now, from Fairchild.

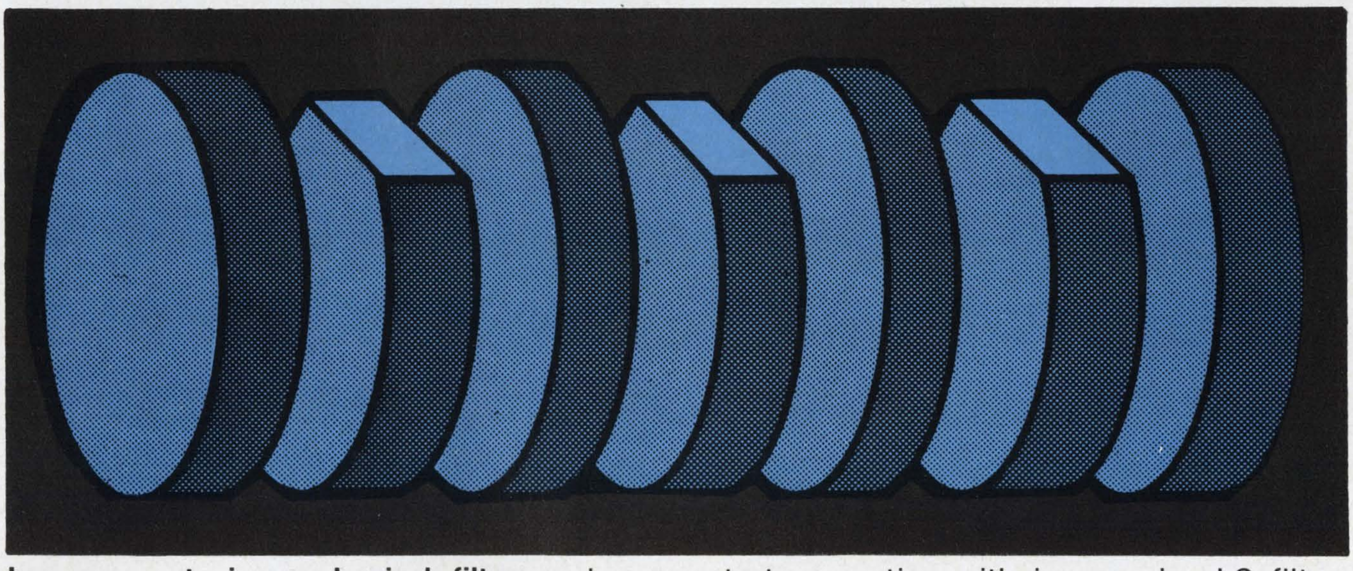
FAIRCHILD SEMICONDUCTOR

*Planar is a patented Fairchild process

News

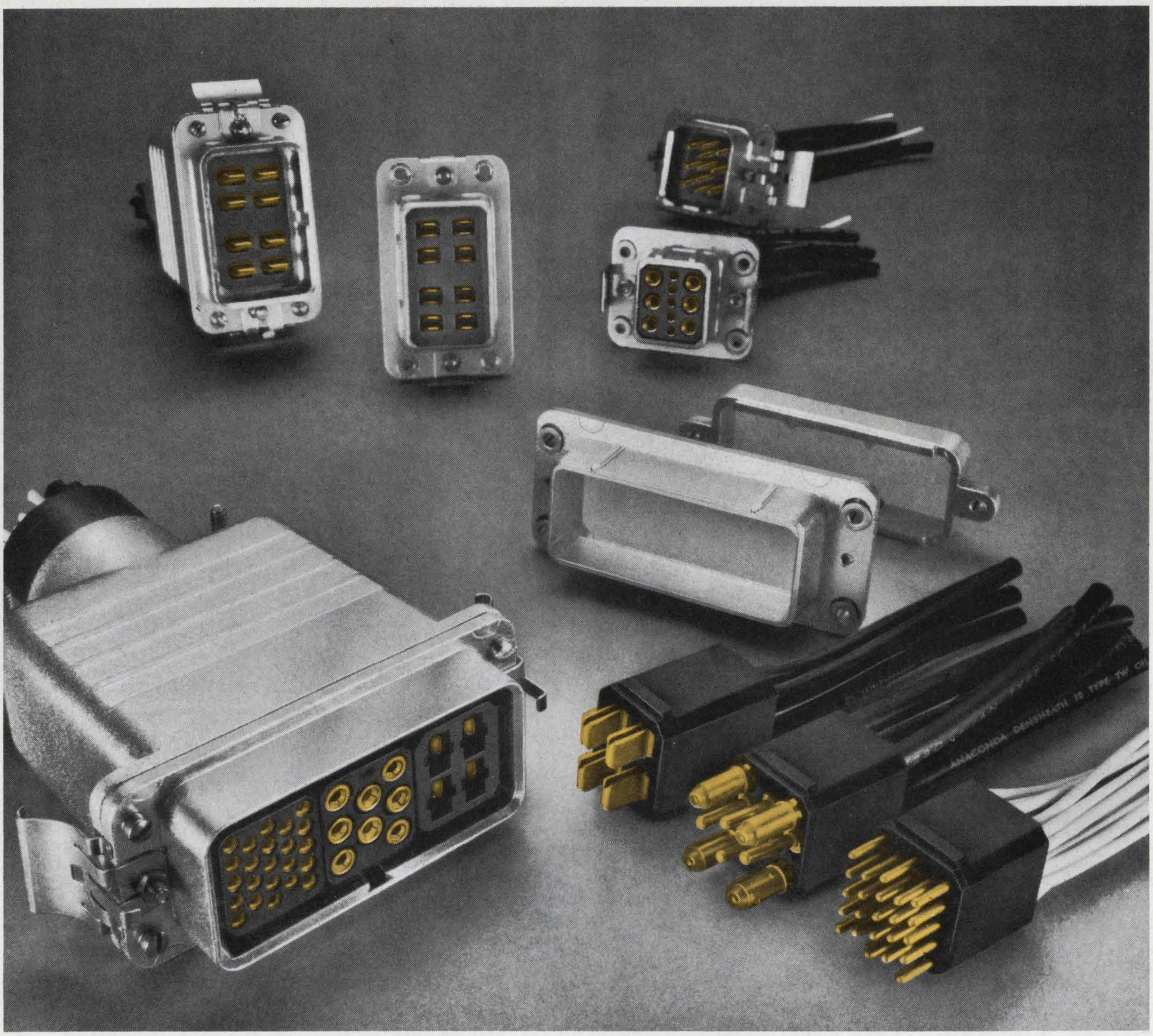


Materials and process research zeroes in on integrated circuits, where advances are being made in complementary transistors, and isolation and fabrication methods. Page 17



Improvements in mechanical filters reduce their insertion losses and enable them to start competing with inexpensive LC filters and highly selective crystal filters. Page 33

Also in this section:



Go 1, Go 2, Go 3 . . . with Series "G"!

As you can see, something new has been added to our connector line. They've gone modular. Now you can stylize your electronic equipment from front to back, get all three kinds of service—signal, power, coaxial—from one basic housing style.

You no longer need a different connector for each type of circuit in your product. AMP's Series "G" Connectors are designed so you can "go" with one, two, or three modular inserts for the exact combination of contact types you want. Inserts are available in either diallyl phthalate or general purpose phenolic with numbered cavities for one or more of these types:

- Type I—#12 screw machine pin and socket power contact
- Type II, III and III(+)—regular signal circuit pin and socket contacts
- Type IV—miniature coaxial contact
- Type XII—new 35-amp stamped and formed power contact
- New subminiature COAXICON* contact

Designed for rugged, dependable performance as well as flexibility, Series "G" Connector shells are two-piece cast aluminum. They consist of a polarized two-piece shell and retainer plate for easy, drop-in assembly of the modules. And, they're available with floating bushings or locking springs, so you can use them equally well for rack-and-panel mounting, service drops, and in-line hook-up applications.

Try this new connector concept in your engineering designs. You'll get all kinds of service . . . with style! It's the practical way to cut inventory costs, too. Write today for complete details.

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ON READER-SERVICE CARD CIRCLE 10

News Scope

Hewlett-Packard breaks into computer market

Exhibition at this month's Fall Joint Computer Conference in San Francisco of a small, rugged instrumentation computer marked Hewlett-Packard's first entry into the computer market.

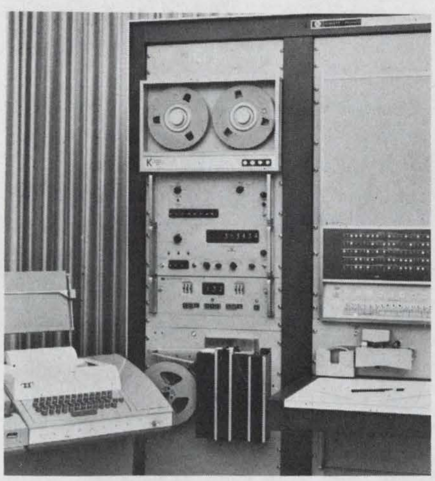
The 225-pound unit, which uses integrated circuits, accepts and manipulates data from counters, nuclear scalers, thermometers, voltmeters, ac/ohms converters, data amplifiers and input scanners, and many others.

Commands are fed into the computer by typing them on a teletype keyboard. The unit, housed in a 32-in.-tall rolling frame, processes the commands, controls the intended measurements, and finally delivers the data in standard forms, such as magnetic or punched tape or typed message.

The new instrumentation computer's main advantage is that it provides built-in interfaces with standard test instruments, according to Noel Eldred, vice-president of marketing, Hewlett-Packard's Dymec Div., Palo Alto, Calif.

The computer can also tolerate the same working environment as that in which test instruments commonly operate. This includes temperatures ranging from 0°C to 55°C, line voltages that vary ± 10%, line frequencies between 40 and 70 Hz and humidity up to 95%. The unit has a 4096-word memory and a 1.6-μs memory cycle.

The new instrumentation computer (designated HP Model 2116A) is an important step toward freeing engineers and production workers from the task of monitoring test instruments. Such easily relocated small computers can be expected to present an attractive alternative to the consoles of large time-shared computers.



HP's latest progeny—a computer.

Poseidon okay means millions for electronics

Secretary of Defense Robert S. McNamara's recent announcement that the U.S. will begin production of the Poseidon missile will entail an estimated federal outlay of almost $2 billion. The weapon's deployment may cost "several additional billions," according to McNamara. A large part of this total is likely to be spent on electronic equipment.

His announcement that he would recommend to Congress that the U.S. should employ the Poseidon comes in the face of "considerable evidence" that the Soviet Union is busy building an antimissile network. Despite this, McNamara has still taken no decision on whether to go ahead with the United States' Nike-X antiballistic missile system.

Poseidon is a large, submarine-launched missile able to penetrate sophisticated defense systems better than the Polaris missile, which it will eventually replace. Poseidon would be able to carry roughly twice the payload of a Polaris, and could thus be packed with a variety of penetration devices designed to evade an enemy's defenses and slip through to its target.

The Defense Secretary said that deployment of Poseidon would mean completely re-engineering the firing tubes of the Polaris fleet. This and other "refitting" would cost "somewhat in excess" of 60 per cent of the initial cost of the Polaris submarines (about $106 million each), McNamara said.

More than $2 billion has been spent so far on developing the Nike-X missile defense system. Total deployment of an operational system could cost upwards of $20 billion. The Administration defense planners are still not convinced that such a system is worth the money, since it would not prevent an all-out nuclear attack from killing tens of millions of U.S. citizens.

Gemini-12 shows man can work in space

The signal for Project Apollo is green now that the successful four-day Gemini-12 mission has proved conclusively that, with proper equipment and by pacing himself, man can work efficiently in the weightlessness of outer space.

Major Edwin Aldrin, Jr., spent more than two hours outside his spacecraft. He plugged in electrical connections, turned bolts, cut cables, looped a tether around the nose bar, wiped his windshield and snapped a series of pictures.

Unlike previous astronauts, Maj. Aldrin did not become exhausted, did not perspire heavily and his helmet visor did not fog up. His task was made easier by frequent rest periods, and by the use of handrails for moving from place to place and of restraining tethers to keep him in position while he worked.

The first three-man Apollo space flight is now scheduled to be launched early next year.

New Gatling gun shoots laser beams, not bullets

A four-barrel one-of-the-kind device with four neodymium lasers was delivered recently to Bethesda National Cancer Institute, Md., by the U.S. Army Missile Command from the Redstone Arsenal Center, Huntsville, Ala.

The four lasers are placed in a rotating head, driven by a servo motor. Knife switches make and break contact between each laser and a 5-kV charging capacitor. The speed of rotation is such that each laser is fired once every minute, achieving a total repetition rate of four 800-joule pulses per minute.

The laser beam is then guided through a series of mirrors and lenses which are installed in a flexible arm that covers an area roughly equivalent to a human body. Hence the laser beam used in treating malignant cancer, can scan a patient without moving either the patient or the laser source.

Computer trainer solves problems, teaches users

A digital computer trainer, said to be the first to incorporate a full-scale, general-purpose computer rather than simulating the computer, is being used by the Army to train operators, technicians and programers. The system actually performs a dual role. When it is not in use in the classroom to demonstrate the operations of military, scientific and business functions, it can be used as a normal general-purpose computer.

The basic system, which was built by Data Machines, Inc., of Newport Beach, Calif., consists of a 4- by 6-foot dynamic display, a Data/620 computer, and an input/output teletype unit.

The computer is a 16-bit, 4096- or 8192-word system-oriented machine. Contents of all the registers are displayed by illuminated pushbuttons. Pushing a button will alter the contents of a register with visible results. An internal maintenance panel makes the data bus and critical timing and control signals available for observation on an oscilloscope.

The large display panel, easily visible up to 30 feet away, contains a color-coded computer organization diagram. As each instruction is executed, lighted areas of the display show the register contents information flow and the cycle, phase and mode of operation.

The manufacturer says that the system incorporates the concepts of many general-purpose computers to make it an effective training aid, no matter what computer the student will eventually be working with. Operations that can be visually demonstrated include program interrupt applications and common addressing modes including direct, indirect, immediate, indexing, and relative addressing. Available options permit the demonstration of byte and extended addressing.

Basic software of the system includes assembler, library subroutines, AID, maintain diagnostics and Fortran.

Five systems were delivered to the Army under a development contract and are being used in a pilot program to develop a curriculum for a regular Army course. Another system was installed at Arizona State University.

Gunn-effect device taken off market

International Semiconductor, Inc. Newburyport, Mass., has halted production of its gallium arsenide Gunn-effect oscillators, and has put the device back into the development laboratory.

None of the devices put on the market has lasted beyond 24 hours of operation, the company said.

The company reported that it has been unable to find suitable uniformly doped gallium arsenide material that could reproduce the oscillator's earlier test results. The oscillator was announced last August as the first commercially available Gunn-effect device.

Cantilevered transducer to power pacemakers

A tiny ceramic wafer shaped like a contilever beam may soon be powering implanted cardiac "pacemakers" with electrical energy derived from the heart itself.

The piezoelectric transducer, described at last week's Engineering in Medicine and Biology Conference in Cleveland, is unique in that the wafer does not need to be in contact with the heart.

The device, housed in a package only 10 cm^3 in volume, consists essentially of a beam weighted at one end and anchored at the other to a crystal operating in the resonant, rather than the deflection, mode.

The mechanical motion of the heartbeat causes the beam to vibrate and thus generate a train of electrical impulses.

At a rate of 80 pulses per minute, with a movement equivalent to that of a dog's heart, the maximum output from the experimental device is 4 volts and 160 μw.

Professor Ko, director of Case Institute's Microelectronic Laboratory for Biomedical Sciences in Cleveland, which developed the energy conversion device, said the power output is more than enough to drive over long periods the "pacemakers" that have been developed to stimulate electrically the activity of a failing heart.

Superconductive magnet on sale off the shelf

Radio Corporation of America has announced that it is offering the industry's first off-the-shelf line of superconductive magnets.

Ranging in field strengths from 60 to 125 kilogauss, the high-field superconductive magnets will be marketed for research in such areas as high energy physics, plasma phenomena, medicine and biology.

The starting price of the new magnets, which use RCA's Vapodep niobium tin superconductive ribbon, is about $8500.

Satellite-to-aircraft communications tested

The practicability of sallellite-to-aircraft communications is under investigation by the U. S. Air Force.

Experiments to determine the atmosphere's effect on radio signals transmitted from an orbiting satellite to an airborne receiver at rates from 128,000 to billions of impulses per second have been undertaken by the Air Force Systems Command at Wright-Patterson AFB, Ohio. Special radio receiving equipment aboard a KC-135 jet aircraft will intercept 360-MHz signals transmitted continuously from the two-year-old orbiting geophysical observatory.

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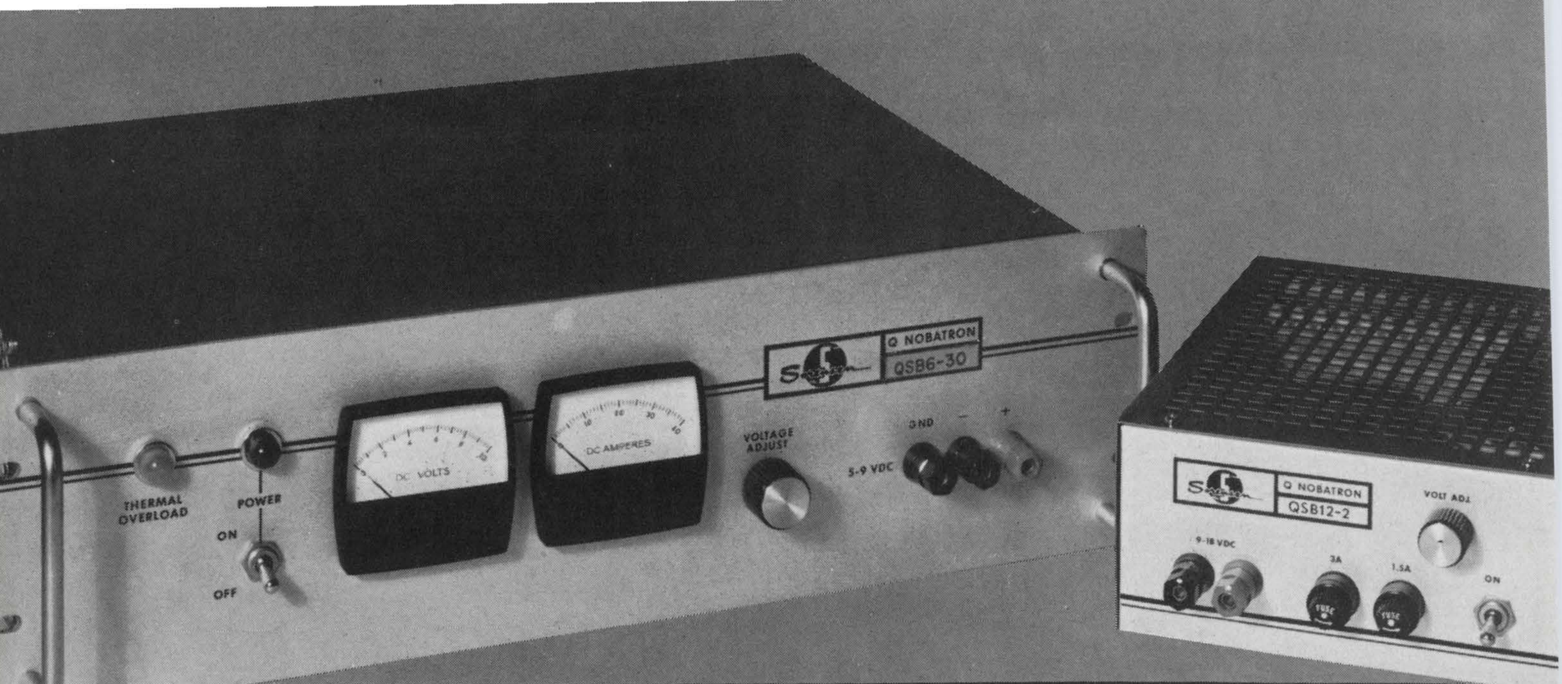
ON READER-SERVICE CARD CIRCLE 11



MODEL SELECTION CHART

Voltage	Amps.	Model	Price	Amps.	Model	Price	Amps.	Model	Price	Amps.	Model	Price
5-9	4	QSB 6- 4	$115	8	QSB 6- 8	$170	15	QSB 6-15	$225*	6	QSB 6-30	$295*
9-18	2	QSB 12- 2	115	4	QSB 12- 4	170	8	QSB 12- 8	225*	15	QSB 12-15	295*
13-26	1.5	QSB 18-1.5	115	3	QSB 18- 3	170	6	QSB 18- 6	225*	12	QSB 18-12	295*
18-36	1	QSB-28- 1	115	2	QSB 28- 2	170	4	QSB 28- 4	225*	8	QSB 28- 8	295*

*For optional voltmeter and ammeter add $30.

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Researchers push IC performance higher

Focus is on isolation techniques, complementary transistors, small geometries and electron guns.

Rene' Colen
Microelectronics Editor

Today's integrated circuits may not be sophisticated enough, fast enough or have high enough voltages to satisfy many designers, but the gap is being closed fast.

Though much of the work is still in the laboratory stage, material and process researchers are making major headway in the areas of multidevice manufacture, techniques and isolation methods.

Progress in these three areas drew considerable attention at the recent International Electron Devices Meeting in Washington, D. C.:

- **Multidevice manufacture**—Devices, previously separated by process incompatibilities, are now being effectively mated. Complementary pnp and npn transistors are diffused on the same chip; unipolar (MOS-FET) transistors are combined with bipolars; and thin-film resistors are deposited on monolithic chips. The result gives the microcircuit designer more flexibility.
- **Manufacturing techniques**—Devices are becoming so small that more complex lithographic techniques are necessary. Electron and ion bombardment of materials may resolve resolution and processing problems.
- **Isolation methods**—Parasitics, generally associated with junction isolation, are now being eliminated with new isolating techniques that employ glass and ceramic insulators. Key advantages are higher operating speeds, voltages and power dissipations.

Npn-pnp pairs make great strides

Lateral pnp transistors, like the Westinghouse device that is representationally shown in Fig. 1, provide greater design flexibility for the integrated circuit designer. As a result, an unusual amount of attention was centered on the manufacture of integrated circuits with complementary transistors. In summary, the devices range from the practical to the promising, depending on process sophistication, and thus cost. Typical specifications for lateral pnps varied from $h_{FE} \approx 200$ and $f_T \approx 4$ MHz (Westinghouse) to $h_{FE} \approx 23$ and $f_T \approx 225$ MHz (Radiation Inc.).

Some of the circuit advantages of using complementary transistors were discussed at length in a paper from Texas Instruments.

One example, a J-K flip-flop, dissipates less than 300 microwatts with rise and fall times less than 1 µs and 1.5 µs. respectively. To achieve this, transistor-transistor logic (TTL) was used with multiple emitter inputs and the complementary pairs at the outputs.

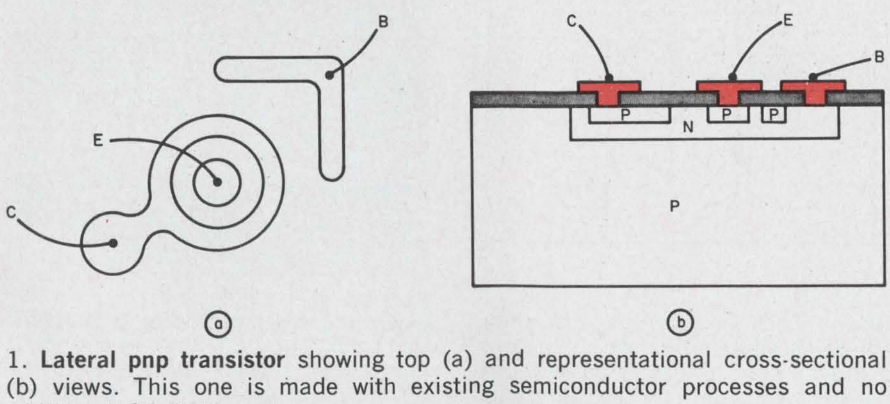
A few papers also took note of recent work on complementary unipolar pairs. One described a Westinghouse 32-bit memory prototype that uses complementary metal-oxide-silicon field-effect transistors (MOS-FETs). Even after a 5000-hour life test at 150°C, the devices (Fig. 2) were found to be stable. Gate threshold voltages are 3.8 V for the n-channel MOS-FET and 6.4 V for the p-channel device.

Fairchild stirred interest with a discussion of the relative merits of double-diffused, pinched-base, MOS and thin-film resistors. The conclusion was that for high resistance (25 kΩ /square) and high resistance-to-capacitance (50 kΩ/pF/mil^2) ratios, the MOS resistor is the optimum choice because of its high reproducibility and low temperature coefficient. A circuit that combines MOS resistors with bipolars was constructed with good results. One particular advantage of this method is that MOS resistors can be changed in value by varying their gate supply voltage. Thus, the power-speed trade-off of the circuit can be optimized to fit over-all system requirements.

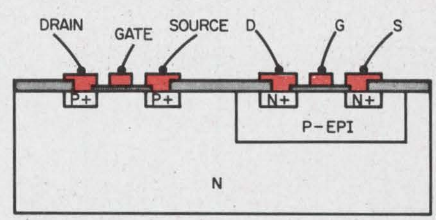
Devices become smaller yet

As device size dwindles, severe limits are imposed on present process technology.

Npn silicon transistors with an f_T of 7 GHz in which the emitter stripe width was 1 micron and the base thickness less than 0.15 micron were reported by Bell Telephone Laboratories. In the account it was stressed that a major fabrication



1. **Lateral pnp transistor** showing top (a) and representational cross-sectional (b) views. This one is made with existing semiconductor processes and no additional fabrication steps.



2. **P-channel (left) and n-channel (right) MOS-FETs** are fabricated on the same wafer. After grooves are etched into the substrate, p-type silicon is epitaxially grown over the entire surface. Lapping and polishing are followed by two diffusions to form the respective drains and sources.

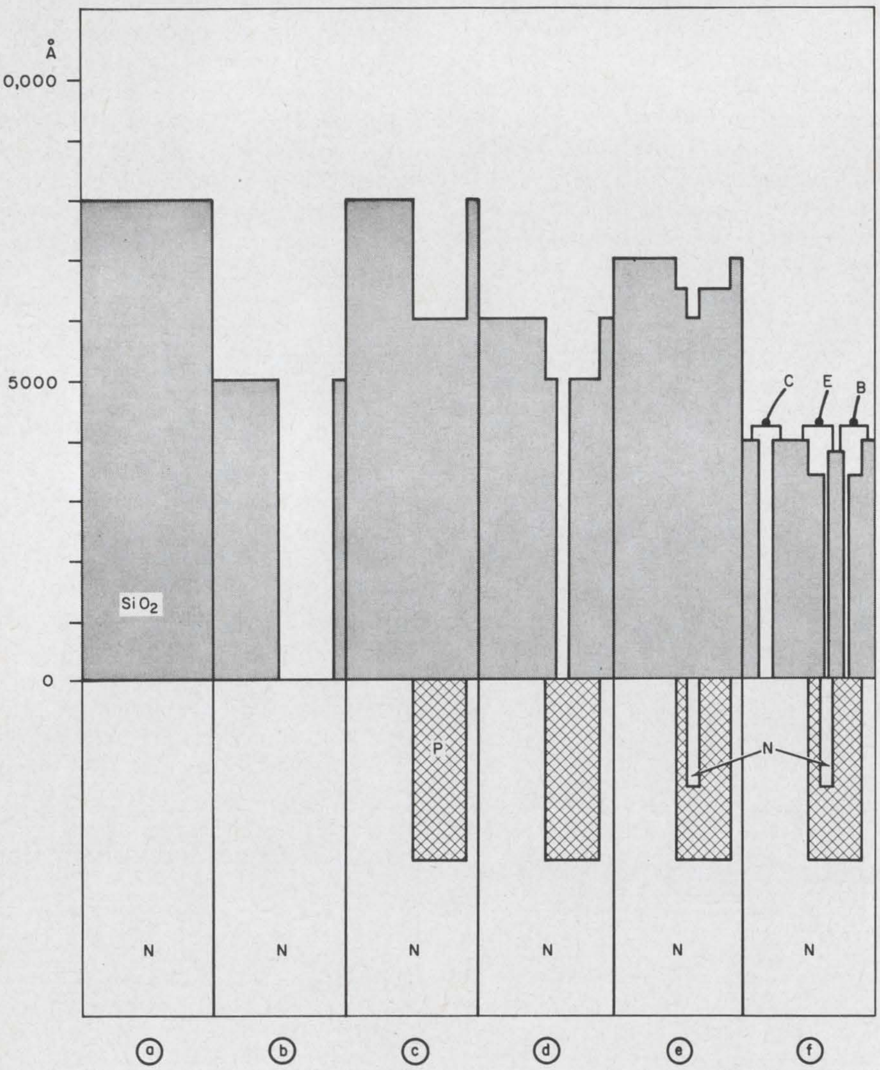
(**better ICs,** *continued*)

problem was the inadequate resolution of the photoresist (KTFR). This was partly due to the creation of standing-wave patterns by light reflecting from the silicon surface. It was overcome by depositing a thin metal layer beneath the photoresist to absorb the light energy.

Meanwhile, scientists at Westinghouse propose to eliminate the photoresist completely. They have found that electron bombardment of thermally grown silicon dioxide increases the etching rate of silicon dioxide by a factor of three. Ten transistors were fabricated on a 1/4-in. silicon chip. The n-type silicon substrate, coated with silicon dioxide, was exposed to a flood-type electron gun through a set of simple metal masks. The process, shown in Fig. 3, resulted in transistors with a β spread of 20 to 100 (not optimized).

Other Westinghouse researchers have used electron beams to expose the photoresist. Small-geometry transistors were formed with emitter contact areas no larger than 1 micron by 1 micron. This work eliminates the use of photomasks and yet does not depend on complex optical-mechanical systems.

Ion bombardment of silicon, as described by Hughes Research Laboratories, simplifies fabrication of MOS devices. The process calls for growing the SiO_2 insulation, depositing a metalization layer over the entire surface, and then etching away the source and drain areas to expose the silicon to the ion bombardment. After bombardment, the source and drain contacts are deposited. The resulting devices exhibit extremely low gate-to-drain capacitances, since the gates do not overlap the diffused regions.



3. **Electron bombardment of silicon dioxide** eliminates photoresist. The steps are (a) grow oxide layer over substrate; (b) cover with base mask (metal), bombard and etch; (c) diffuse-in base and regrow insulation; (d) cover with emitter mask, bombard and etch; (e) diffuse-in emitter and regrow insulation; (f) cover with metalization mask, bombard, etch, and metalize.

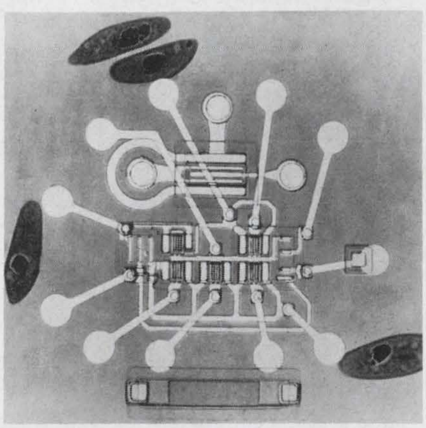
Circuits are faster and faster

Few circuits were discussed. Most of them were not at a production stage, but they do indicate future possibilities. For example, a logic gate with switching speeds in excess of 400 picoseconds was reported on by IBM Components. The circuit (see photo), uses regular junction isolation, small geometries and two-level metalization. Important in this work is the fact that the transistors themselves have cutoff frequencies of 7.15 GHz when I_C = 20 mA and V_{CB} = 2.0 volts. Little more than a year ago, discrete transistors in the laboratory had barely attained such characteristics.

High-frequency transistors in integrated circuits seemed to be the order of the day. Philco-Ford reported on complex arrays that use 3-GHz transistors in the basic cell. Each cell consists of two 3-input ECL gates. The gates have a propagation speed of 0.4 ns with average power dissipation of 60 mW.

New isolation methods take a bow

Among the various new isolation techniques are Fairchild's Mesa (glass), Motorola's Epic-G (glass), and Texas Instruments' ceramic dielectric isolation. All of them may lead to the virtual elimination of the parasitic problems associated with junction-isolated devices (see



Paramecia, single-celled animals, dwarf the small-geometry transistors that make up this high-speed logic circuit with a switching speed of 400 ps, that was developed by IBM Components Div. researchers.

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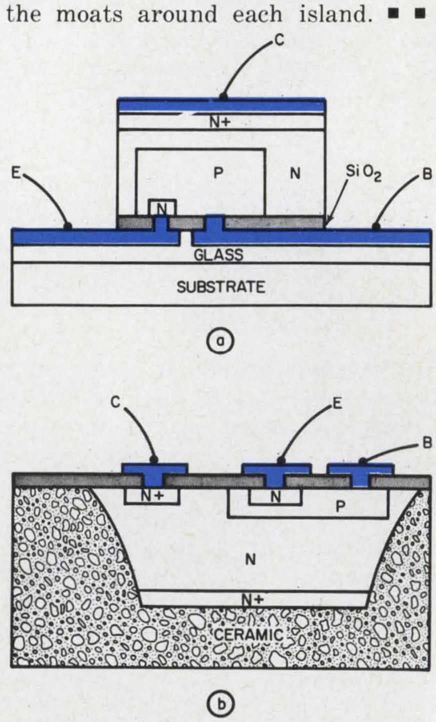
(**better ICs,** *continued*)

"Better isolation boosts IC performance," ED 21, Sept. 13, 1966, pp. 17-23).

In the Mesa process, a completed wafer and a compatible substrate material sandwich a thin, high-purity glass layer. The back of the wafer is coated with photoresist, masked, exposed, and etched. Isolating moats are etched in the silicon down to the interconnecting metalization and the glass. The result (Fig. 4a) is a series of active-device islands. These are electrically interconnected and are mounted face-down on a glass layer that is supported by the substrate. Contacts can be made down on the original metalization or, for the collector, directly to the back of the chip. This produces a lower V_{SAT} and collector resistance. An additional advantage is the increased thermal dissipation due to the conductive paths along the top and bottom surfaces of the devices.

In the TI (Fig. 4b) and Epic-G processes, the completed wafers are first etched to form islands of active devices and then a layer of dielectric material—ceramic for TI and glass for Motorola—is used to fill the moats around each island. ■ ■



4. **Mesa isolated device** (a) is shown with its collector contact on top, while the ceramic dielectric isolated device (b) uses the more standard collector connection. Actually, each can be interchanged as circuit needs dictate.

Mighty SCEPTRE analyzes any circuit

A computer program for automatic analysis of simulated circuits is disclosed at NEREM.

Roger Kenneth Field
News Editor

Two years ago Bill Bohan and three colleagues at IBM set out to create an extremely flexible computer program for the automatic analysis of circuits. It was to analyze transient responses and steady-state operation of any circuit precisely; yet it was to require absolutely no knowledge of programing on the part of its user. Last month they delivered the program to their customer, the Air Force Weapons Laboratory. Next month it will be made available to the engineering community.

The program, called SCEPTRE (Systems for Circuit Evaluation and Prediction of Transient Radiation Effects), uses an ordinary language, not Fortran and not a complicated machine-code. In using SCEPTRE, the designer does not have to know the design equations of the circuit that he wishes to analyze; he simply chooses a circuit configuration, and inserts arbitrary component values. The computer, presently an IBM 7094, then writes the design equations for the circuit and solves them.

Its output can be presented as either a tabular listing of data or a graph made by a plotter. The output can be any variable versus time, or even any variable as a function of any other variable.

A simple input tells all

Thus SCEPTRE's input could be nothing more complicated than a schematic with assigned component values. Yet its output could be the circuit's gain, the power dissipated in any of its elements, the transfer function of the circuit, or almost anything the designer can define. Of course, like other programs, it can determine the voltage across, or current through any element. In each case the user simply defines the parameter that he wants, such as V_{in}/V_{out}, and then the program automatically calculates it.

Says Bohan: "This could be quite useful, for instance, in analyzing an inverter circuit under an intense pulse of radiation. Here, the leakage current, i_{pp}, depends on the reverse bias of a particular transistor. If that current is analyzed simply as a function of time, the circuit appears to saturate for roughly 200 ns. But if the current, i_{pp}, is a function of both time and voltage, it barely saturates at all and then it promptly tails off. This cannot be done in the programs that preceded SCEPTRE."

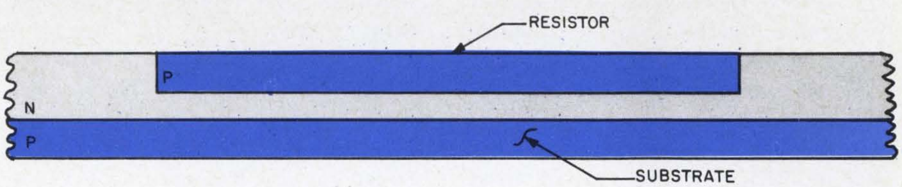
Active components from passive

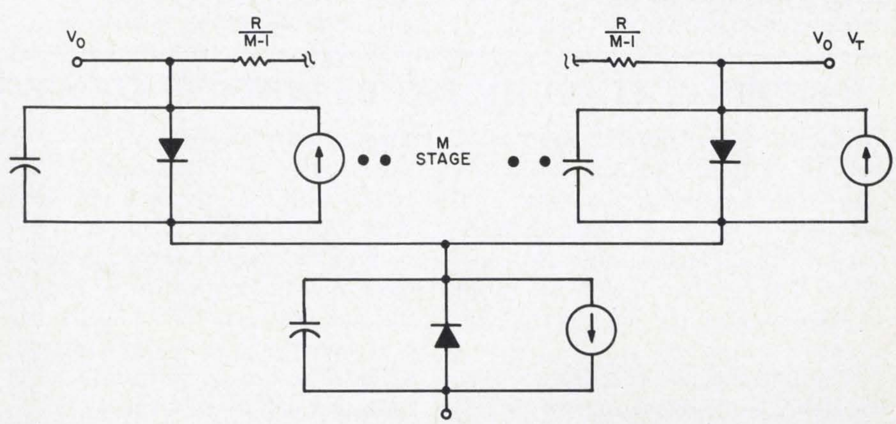
However, SCEPTRE doesn't do everything. It directly accepts only resistors, capacitors, inductors, mutual inductors, and current and voltage sources. Transistors, diodes, vacuum tubes and all other active components must be specified by equivalent circuits made of the components that the program will accept. The program will, however, store for instant use equivalent circuit models, which can be altered or replaced at will. Thus SCEPTRE can never become obsolete simply because somebody decides on a better equivalent circuit model for a transistor.

No dead models

In many other circuit-analysis programs, such as CIRCUS (by Boeing) and NET-1 (Los Alamos), fixed-topology equivalent circuit models for transistors, diodes (and in CIRCUS, for four-layered devices) were built into the program. In those programs the user might direct the computer to insert the model of transistor 2N7115 into the circuit. The computer then instantly calls up its model of that transistor, but such a model always makes a number of simplifying assumptions. And these models are an integral part of those programs, and, as such, they are exceedingly hard to change.

In SCEPTRE, model-making is





SCEPTRE can precisely simulate an integrated circuit resistor. The diffused resistor (above) is represented by M stages (below) of simulated diodes. Each contains a resistor, capacitor, diode and current source.

(**SCEPTRE,** *continued*)

left to the user, but once he makes a model he can store it and retrieve it at will. And he can update it to match actual improvements in the devices or he can refine the model to suit his particular problem. The models are defined according to the same rules that define the program. They allow an arbitrary configuration and the user controls it. This could be enormously useful in integrated circuits where the user might want to define and store a model of an entire monolithic chip.

According to Bohan, SCEPTRE's creators have eliminated virtually all restrictions on the circuit configuration. For example, in SCEPTRE's predecessor, PREDICT, every current or voltage source had to have an associated element either in series or shunt. In NET-1, nonlinearities must take place within the equivalent circuit model. These restrictions do not exist in SCEPTRE. On the contrary, it allows a variety of source dependencies: the user can make a current or voltage source linearly dependent on the current through, or voltage across, a resistor somewhere else in the circuit. This allows the circuit designer to use the small-signal family of equivalent circuits, such as the h- or y-parameter equivalent circuits. "The earlier programs handled these with something called a computational delay. But that method introduced inaccuracies, inaccuracies that were often catastrophic, into the answer," says Bohan. SCEPTRE is free of these inaccuracies. He also noted that SCEPTRE can digest the Linvill model equivalent circuit.

These source dependencies can also make analysis of logic circuits swift and clean. For example, the computer can be instructed to stop when V_1 exceeds two volts and V_2 exceeds five volts. Alternatively, it can stop when either V_1 exceeds two volts or V_2 exceeds five volts.

Fortran helps

Although the SCEPTRE user need not know machine codes and special computer languages, the more knowledgeable user can create his own subprograms to be used in conjunction with the main program, if he is versed in Fortran. This could be handy, says Bohan, for the analysis of otherwise awkward problems. For example, suppose a train of pulses is to be analyzed:

"Each pulse in the pulse train can be characterized by a set of parameters," Bohan comments. "The voltage source can be entered in a subprogram, which is written in Fortran. Let's say you wish to analyze the circuit's response to pulses of various widths. Rather than rerun your program at each of a number of pulse widths, you can simply make the pulse width a variable in the subprogram. One uninterrupted run then yields information about the effects of a broad range of pulse widths."

Easy as child's play

SCEPTRE embodies a number of features that make it extremely easy to use:

- It accepts inputs in a variety of forms (tables, graphs, charts, etc.).
- Elements can have arbitrary names (i.e.; a resistor can be labelled R_1, R_A, R_{in}, etc . . .).
- Component values can be specified in a variety of forms (i.e.; 10a, E1a, 2x5a, etc . . .).
- The user can select any system of units.
- Frequently used equations can be couched in a set of dummy variables and used by simply calling out these variables.
- The program contains a "diode" defined by the standard diode equation: $j = i_s(e^{\theta V}-1)$. To use it, the diode is merely called up, given a name, a value of the saturation current, i_s, and a value of θ.
- SCEPTRE automatically calculates the initial conditions for its user.

SCEPTRE will be available for the IBM 7094 around January 1, 1967, to users who get clearance from:

Lt. Gary Pritchard, WLRET
U.S. Air Force Weapons Lab
Kirtland Air Force Base
Albuquerque, N. M. 87118

After obtaining this permission, the tape and manuals can be obtained from:

Harry Mathers
IBM
Radiation Effects Department
Owego, N. Y. 13126

A version of SCEPTRE for the IBM 360 should be ready by the end of 1967.

Bill Bohan exudes confidence when he discusses SCEPTRE: "I feel certain that the next generation of circuit designers will use SCEPTRE and similar programs as routinely as present designers use slide rules. SCEPTRE can be a powerful tool in the hands of a good designer, but it still takes a good designer to get good circuits."

This program was described in detail recently at NEREM, Boston. The NEREM Record, a compilation of the conference papers, is available from its publisher, Ernest Witschi, Jr., Newton, Mass. ■ ■

Josephson effect measures physical constant

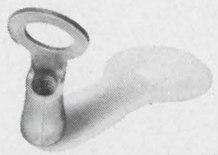
A group of scientists at the University of Pennsylvania, Philadelphia, are planning to use the Josephson effect* to measure accurately a fundamental physical constant. The constant is e/h, the ratio of the charge on an electron to Planck's constant.

The phenomenon that makes this measurement possible is an effect described by Brian Josephson to explain the action of currents through and voltages across hair-like gaps in superconductors.

Josephson, on the basis of theoretical considerations, predicted that, if two superconductors could be brought close enough together, a current could be made to flow across the gap between them. Under certain conditions a voltage appears across the gap and high-frequency radiation emanates from it.

This radiation, he predicted, would have a frequency precisely equal to $2eV/h$, where V is the measured voltage across the gap. Messrs. Langenberg, Parker and Taylor, working at the University's Laboratory for Research on the Structure of Matter, are using a Hewlett-Packard counter to measure the frequency, and a Julie potentiometer to measure the voltage. ■ ■

*See Donald N. Langenberg *et al.*, The Josephson Effects," *Scientific American*, CCXIV, No. 5 (May, 1966), pp. 30-39.



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ON READER-SERVICE CARD CIRCLE 14

The connector Thing

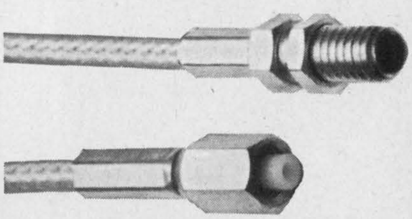
A periodical periodical designed, quite frankly, to further the sales of Microdot connectors and cables. Published entirely in the interest of profit.

WIN
a pot of gold!

Lepra/Cons Unite!

In celebration of the introduction of the highest density coax rack and panel and multi-pin connectors on the market today (the broadened Lepra/Con line), Microdot is awarding to five lucky winners (see contest rules below) five simulated gold pots (of the chamber variety) with your, repeat your, name emblazoned thereon. Perfect for desk top decoration.

First, let's talk Lepra/Con.



Through its stringent policy—"Never Look Back, They May Be Gaining On You"—Microdot has expanded its Lepra/Con line of ultraminiature connectors...tiny little coax jobs with an OD of only ⅛ inch and a mated length of only one inch.

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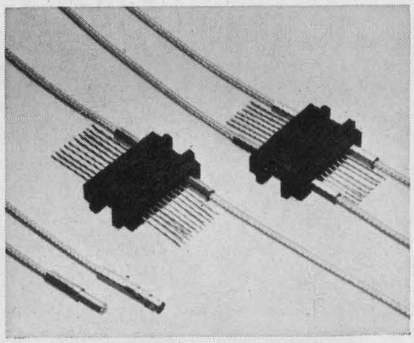
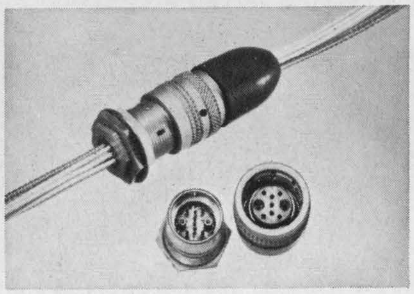
Now there's the Lepra/Con Twist/Con /say it fast fifty times) which combines all of the above advantages in a rack and panel coax connector.



Now there's the slide-on Lepra/Con for singular ease of installation.

And, of course, there is still the old Lepra/Con (if you can call six months old).



HOW TO WIN YOUR POT OF GOLD

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5. All entrants will win a free picture of our beloved Candy inscribed passionately and personally to you.

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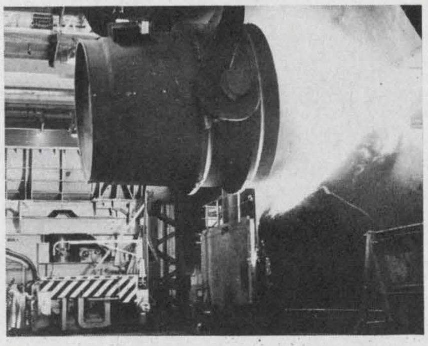
ON READER-SERVICE CARD CIRCLE 15

Defense spending leveling off



Washington Report

S. DAVID PURSGLOVE, WASHINGTON EDITOR

Survey confirms federal R&D trends

A National Science Foundation (NSF) survey of federal and some industrial spending and planning for research and development in Fiscal 1965-1967 has largely confirmed what was foreshadowed in the budget for Fiscal 1967. All the major trends predicted then have been proved correct. The big spenders on R&D will still be the Defense Department, NASA and the Atomic Energy Commission, though their funding is leveling off. Twenty-eight other agencies account for only 16 per cent of federal R&D funding, "but there is an underlying growth trend in the R&D activities of these 28 agencies," the survey says. Federal research and development emphasis is growing in the areas of health, transportation, environmental pollution control, development of natural resources and education technology, the survey says. The bulk of the nation's money on R&D comes from Washington (64%), but most of the work is performed outside the Government—63 per cent by industry, 16 per cent by educational and nonprofit institutions. This may be compared with 1956, when a third of the Government's research and development was done on its own facilities, and underlines the Government's increasing tendency to "contract out."

The NSF, itself a government agency, points out that though the amount of federal R&D performed by the Government has dwindled since the end of World War II, so too has industry's share of federal R&D dropped slightly from a 1956 high point of 80 per cent of all its extramural work. What the raw figures, however, do not show is that this year, for the first time, as industrial contracts partly replace the more traditional grants to colleges and universities, industry is becoming a major factor in several growing areas of research and development, such as air pollution control and education technology. Individual NSF officials rather than the survey itself back up statements by agency spokesmen to the effect that industry will be playing an ever greater role in the once small, university-oriented programs that are now destined to accelerate rapidly.

The demands of the war in Vietnam do not seem to be affecting the general pattern, but have had some effect on federal R&D programs. This has been confined mostly to the activities of the military and space agencies, where funds have been shifted from long-range or unessential projects or strategic-weapons development to programs of more immediate application to the needs of Vietnam. Though the war has also had its impact on the work of the 28 smaller agencies, this is much less clear from the survey.

The survey, which is based on the budget of last January, reflects fairly fully administrative actions since then, but does not take into account the effect of legislation by the last session of the Congress.

What follows Apollo keeps D. C. a-buzz

Almost every quarter in Washington, technical and nontechnical alike, is intrigued to know whether the Budget Bureau knows what NASA will do after Apollo. If it does, it is part of a very select group that includes only the topmost three officials of NASA, and the two highest executives of the Space Council, Vice President Hubert Humphrey and Council secretary Edward C. Welsh. According to the letter of Presidential order, the budgeters should know, but there is speculation that they might not, because NASA was specifically excluded from the order that requires all agencies to use the PPBS to help plan the budget that goes into effect next July.

The PPBS (Program Planning and Budgeting System) stemmed from Defense Secretary Robert McNamara's ideas on using advanced management concepts to plan ahead and determine the future of each agency. One aspect of this involves five-year advance forecasting. Each agency was by now to have prepared a draft budget and a five-year plan. Most of these were due at the Budget Bureau weeks ago, and unless excused, NASA should have had to include its post-Apollo plans. Normally talkative officials are silent on whether NASA has even sent in a Fiscal 1968 budget, let alone a five-year plan.

However, there seems to be a major effort under way to prepare industry and NASA personnel—already practically flocking from the agency—for a jolt. Welsh has recently been saying—after first stating that he is not discussing a formal post-Apollo program—that the major emphasis on space after 1970 will be on the application of satellites to weather observation and communications. He repeatedly points out that Apollo will not involve merely a single trip to the moon and then nothing more. His obvious urgency in making the point leads many to feel that he is trying to soften the impact of a drastic cutback in manned space programs and an anticipated announcement that the U. S. will not undertake in the near future any gigantic R&D programs oriented to deeper space exploration.

The other fact that is seen as an effort to cushion bad news is the Administration's "peaceful engagement with the East" concept. This envisions replacement of shooting wars by heavy and formal competition in technological areas. The arena of contest most often cited is that of applying satellites to weather observation and control, navigation, and to agricultural, conservation and educational uses. NASA funding and programs have been shrinking, and the pressures of Vietnam indicate to most observers, including many NASA officials, that this trend will continue.

Congress gets R&D guidelines

The Congressional committees with authority over research and development programs have now been given a fair idea of what direction Congress should be taking in funding and in stimulating new programs. The guidelines, contained in a report by a key Capitol Hill committee, generally urge action in those areas which the NSF's survey show to be already on the upswing, such as air and water pollution, health, transportation and education technology. The report comes from the House Science and Astronautics Committee's subcommittee on science, research and development under the chairmanship of Emilio Q. Daddario (D-Conn.). The report would also have the downward trend noticeable in some areas reversed, by having more funds allotted for information systems development and the use of cybernetics. The emphasis throughout, moreover, is on increased participation in R&D by industry and more liberal spending by industry for R&D.

For the past two years members of most of the committees involved with R&D have felt that Congress itself should be generating programs and should have more to say in guiding the nation's technological activities, rather than merely rubber-stamping the Administration's initiatives or withholding funds. Some new national commissions with some measure of real authority have been set up that are answerable to Congress as well as to the White House. The National Science Foundation is itself due for an overhaul at the behest of Congress, as are several other agencies concerned with health and education. Organization of a large technical staff to give Congress professional guidance is in the works.

A data-collection and -compiling system to help Congress to evaluate R&D programs, spot technological gaps and predict technology change will be authorized within two years.

Daddario's subcommittee has been the inspiration for most of these innovations and its reports are respected by both sides on Capitol Hill. It has issued exhaustive analyses of fiscal trends in federal research and development, the geographical distribution of R&D monies, almost all aspects of aeronautics, air and water pollution, and technology's role in reshaping the nation. Now, after three years' study, the subcommittee has brought out this report listing 12 areas where Congress should be more active. Many of these areas heavily involve the electronic industry and will require creative thinking by electronic designers.

The 12 areas, listed "without attempting to ascribe priorities" are: strengthening information management, providing new sources of energy, application of cybernetics, protecting the natural environment, stimulating transportation innovations, diminishing urban congestion, enhancing adequate housing, improving food production and distribution, alleviating crime, upgrading the quality of education, protecting the nation's health, and fostering industrial R&D.

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Gunn oscillators power modular phased arrays

Gunn-effect oscillators appear to be the key to making inexpensive, small, efficient phased arrays. Conversely, the need for good phased arrays speeds up the development of reliable, medium-power bulk oscillators. It also gives impetus to the integration of the Gunn oscillator into ICs by a monolithic deposition process.

Motorola Government Electronics Div. (formerly known as Military Electronics Div.) in Scottsdale, Ariz., is conducting a study of phased arrays, where each antenna is powered by a Gunn-effect oscillator. Engineers plan to come up with a 1-in^3 module that contains the printed circuit antenna and front end, including the oscillator, mixer, phase control and IF amplifiers, as shown in the figure.

A master oscillator, that controls the stability of each module by phase-locking the Gunn oscillators, is external to the module.

The advantages of this design approach may be evaluated from both the system and the component point of view, according to project-engineer James A. Higgs.

From the system angle, the bulk device is a low-power one; it can be phase-locked for stability with very weak signals (40 dB below the actual signal level), says Higgs.

The device is very convenient, Higgs continues, because it is easy to modulate, small, inexpensive and can provide the necessary power.

Research faces many problems

Research and development work at Motorola mainly concentrates on the bulk oscillator. "We want to get out 10 watts from it," says Higgs. "Now we are around 1 watt." The efficiency needs to be improved, too. Observed levels range from 2% to 20%, while predictions are around 30%, according to Higgs.

However, there are more fundamental problems to be solved before large-scale production can start, according to Tony Kallas, project leader of Gunn-effect research work at Motorola. The research effort centers on three major areas:

- Determine the influence of the external circuitry.
- Devise good mounting methods for the ohmic contacts for high-power and cw operations.
- Learn how to specify the gallium arsenide material so that it will provide good oscillators everytime. Now it is largely a matter of luck.

"The first two points pose less difficulties," said Kallas, "than the last." He describes their line of attack on the latter as an attempt to find a group of measurable parameters and relate them to the performance of the material.

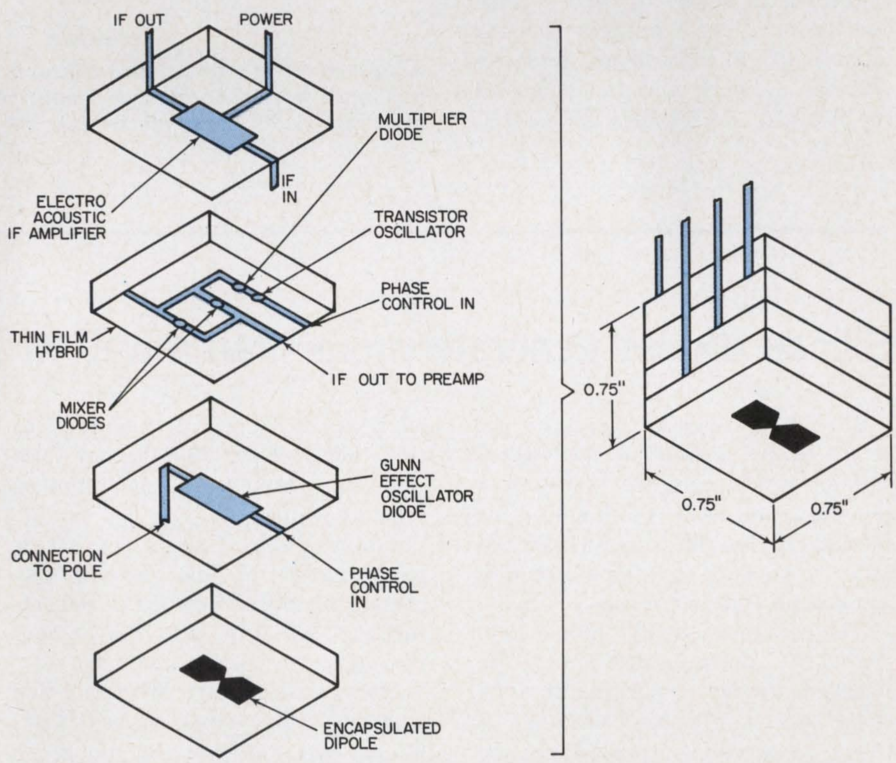
There are some temperature problems too, mainly because the material has a negative temperature coefficient, according to Kallas. High-current densities at the projected power levels will require effective heat sinks.

"It will take at least another year before these questions are answered in a reliable and fully satisfactory way," concluded Kallas.

IC Gunn-effect devices?

The suitability of gallium arsenide to monolithic processes also plays an important role in the research efforts.

Texas Instruments, Inc., is already investigating monolithic versions of the Gunn-effect oscillator. At the present they are trying to find out whether or not the oscillator can be formed with the monolithic process, according to Larry Levieux, press relations, TI. ■ ■



Phased-array module is built by a thin-film hybrid method. The phase control is provided by an external master oscillator.

Function generator diffused on a single chip

A function generator can now be deposited on a single chip by means of standard planar integrated-circuit fabrication techniques, according to P. Post, Norden Div., United Aircraft Corp., Norwalk, Conn.

Semiconductor manufacturers have developed an expertise in fabricating components which they only rarely use to make unusual configurations such as this arbitrary function generator. Yet everything in semiconductor life is not necessarily composed of resistors, diodes, transistors and capacitors. The shape is the secret.

The geometry of the working surface, controlled during manufacture by a computer, determines just which one of a variety of functions the chip will generate.

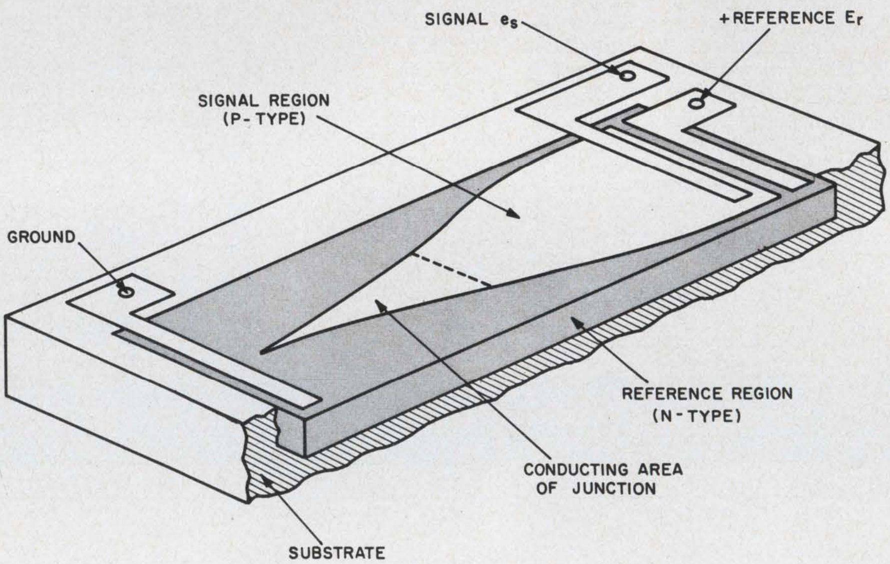
The device can be made to generate log-arithmic, sinusoidal and square-law functions, and even completely arbitrary functions. Thus it could serve as a fixed operator in an analog computer.

The generator consists of two passive elements: a fixed resistor and a nonlinear resistor. Fabricated on a single chip of silicon, they are connected in series to form a voltage divider. The nonlinear resistor is actually a continuous diode-resistance network and the shape of the network determines its electrical characteristic.

The generator's output is a function of both a reference current and a signal current. A reference voltage, $+E_v$, on an evaporated metal strip in ohmic contact with a thick n-doped substrate, maintains a uniform reference electric field in that substrate. If the instantaneous voltage, C_s, is zero, the pn junction, between the signal region and the reference region, is back-biased and n current flows to ground. If C_s exceeds $+E_v$, the whole device conducts much like a large-area diode.

If, however, the value of C_s is between $+E_v$ and zero, the signal current flows along the p-doped resistive (shaped) surface. But as this p-doped surface narrows, and the current density increases in proportion to this narrowing, the signal current spreads down into the n-doped region and on to ground. Thus, the active length of the shaped resistor is a function of the signal.

Used in conjunction with an operational amplifier having a differential input, the unit can impose its particular function on any analog signal impressed on its input. ■ ■



A tapered resistor of p-doped silicon is the heart of this function generator. This nonlinear resistor's effective length varies as an inherent function of the applied signal. Its shape determines the response of the generator.

Silicon diodes generate more than a watt at 12 GHz

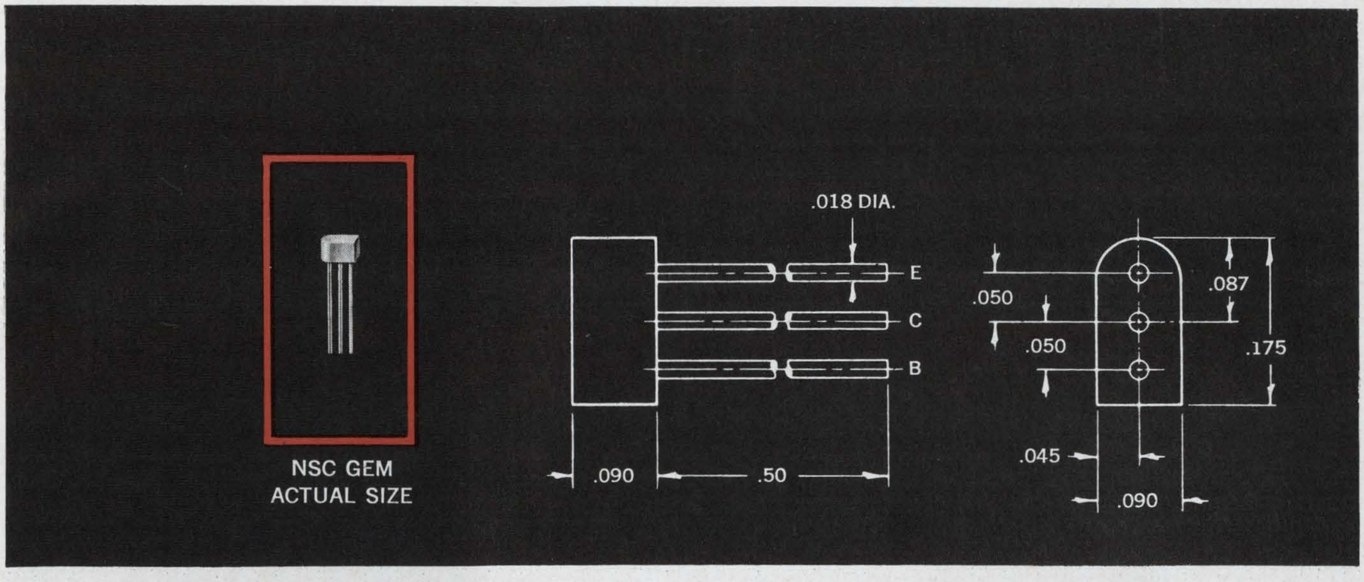
Silicon diodes that generate 1.1 watts of cw power at 12 GHz—said to be the highest cw power reported at this frequency for semiconductor microwave oscillators—have been developed at Bell Telephone Laboratories.

The continuous-wave power generated by these experimental pn junction diodes, according to BTL scientist Dr. Toshio Misawa, is twice as great as previously reported at 12 GHz for silicon pn junction diodes. The 8 per cent efficiency achieved at this frequency is about 2 per cent higher than that of previous silicon diodes, Misawa said.

The scientist credits the better performance of the devices primarily to improvements in mounting and bonding, and closer control of processing techniques.

More specifically, Misawa cited a major improvemnt in heat flow, which was achieved by mounting the diodes upside down in their metal housings—a complete departure from conventional diode-mounting practices. This upside-down arrangement places the pn junction closer to the metal mount, thus reducing thermal resistance between the junction and the metal.

Better device efficiency was achieved by controlling the impurities or doping profile of the semiconductor and by reducing the n-type region of the diode to the minimum necessary thickness. This cuts the diodes' resistance. ■ ■



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Laser replaces umbilical cord in spacecraft

Time-sharing lasers take the place of wires for carrying data to and from spacecraft during launching.

Maria Dekany
Technical Editor

"Five, four, three. . . . Stop countdown. The umbilical cord did not disconnect. . . . Launching will be postponed till the disconnect mechanism is repaired."

You may not have to hear this again. IBM Federal Systems Div. has designed and tested a laser system that can take the place of umbilical cords used for communications, telemetry and data transmission during space launches. It will not replace wires for prime powers, fuels and oxygen, but these leads are usually disconnected at a relatively early stage of a countdown.

The tests, completed a couple of weeks ago, proved the feasibility and practicability of the design, says Dwight Divine, senior associate engineer for IBM at Cape Kennedy.

According to him, the advantages of optical systems over conventional hardware are:

- No disconnect problems.
- Totally isolated grounds. Electrically shifting grounds in wire systems may introduce errors.
- Ease of use in space launches. Thick bundles of cables may upset the stability of a launching platform in space.

System works without tracker

The 0.9-μ two-way communication system, linking the launch umbilical tower and the space vehicle, uses 12 gallium arsenide injection laser diodes at room temperature as transmitters: four at the tower and eight in the vehicle. The receiving systems consist of focusing lenses, silicon photodetector diodes, amplifiers and demultiplexing circuitry.

The system offers wide-angular view of the field and has a range up to 1000 ft. At the launching tower, two lasers provide a short-range (10 to 60 ft) link with ±3 ft horizontal and ±1 ft vertical view. Two more lasers are used for the long-range link, with the same angular coverage from 60 up to 1000 ft. A similar technique is applied in the vehicle, except that four lasers are used in a time-sharing mode in each link, explains Divine. The two optical paths are separated by 3 ft.

This approach eliminates the need for tracking and cuts the cost considerably, compared with other optical communication systems, according to Divine.

Transmission to the vehicle is performed by pulse-code modulation. From the vehicle, pulse-position modulation is used. "The type and amount of data require different modulating schemes," says Devine. "Much more information is collected from the vehicle and ppm can handle higher average data than pcm. For example, we can transmit 41 analog signals, a voice channel and 47 discrete on-off type signals from the vehicle. To the vehicle, we have a voice channel, a pcm channel and some on-off type information. Since the pcm channel has the highest data rate, we choose the pcm scheme."

The pcm system can transmit 44 thousand pulses per second with two diodes. The ppm system can handle 90 thousand pulses per second, with four diodes in a time-sharing mode. These data rates were observed when the diodes operated at power levels from 0.2 to 0.5 volt and at room temperature.

Tests show small error rates

The system was tested twice over a range of 28 ft for 1.6 hours of continuous operation. The total bit error rates were 3.7×10^{-8} and 2.7×10^{-8}.

The system was also tested in a simulated foggy environment. A CO_2 fire extinguisher was used to fog up the transmitting windows and the path. However, the error rate remained unchanged. "It worked like a charm," comments Divine.

Speed of data transmission and output power are the areas where improvements will have to be made to make the system fully competitive with wire types, Divine adds.

Higher data rates can be achieved by either using more lasers in a time-sharing mode or by cooling the lasers down to cryogenic temperatures, he states. He points out that cryogenic cooling is more economical and also reduces the size and weight of the system by cutting back the number of lasers needed.

Since demonstration of the feasibility model did not require higher data rates, no tests were performed with cooled diodes.

The range, limited by the available peak power at room temperature, can also be extended by cryogenic cooling, according to Divine.

Receiver uses Si diodes

Both long- and short-range transmitters can be picked up by the same receiver, since the optical paths are fairly close together, Divine notes. Only the focusing lenses are different: for the long-range link, a 5-in.-diameter one is used; for the short-range, a 1.5-in. is sufficient. The photodetector is a back-biased silicon diode, followed by a 3.5-MHz video amplifier and a threshold detecting circuit.

When asked about avalanche silicon diodes* as detectors, Divine points out that the project was started before the avalanche effect became generally known. "We are interested in it," he says, "but the state of the art has not advanced far enough to make the change imminent." He feels that their production is a little uncertain at the present. However, if the production problem is overcome "it looks like the case of getting something for nothing," he concludes.

NASA is reported to be studying the test results and actual applications will depend on the outcome of its evaluation. ■ ■

*See "Solid state competes with lasers . . .," ELECTRONIC DESIGN, XIV, No. 22 (Sept. 27, 1966), p. 63

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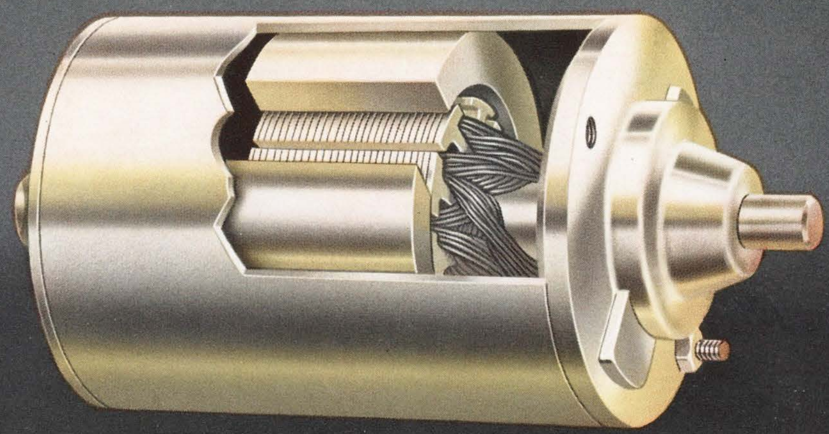

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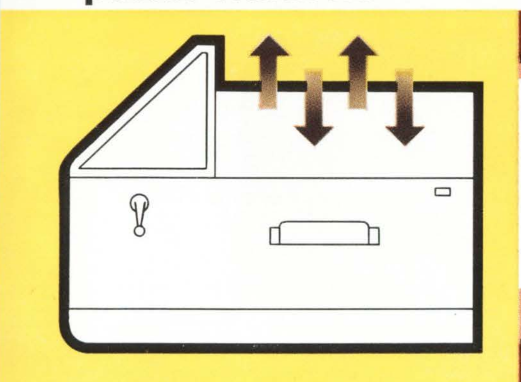

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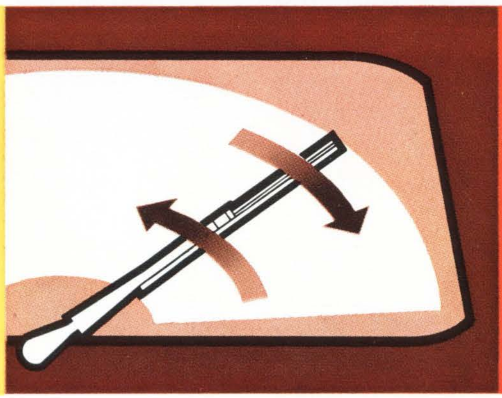

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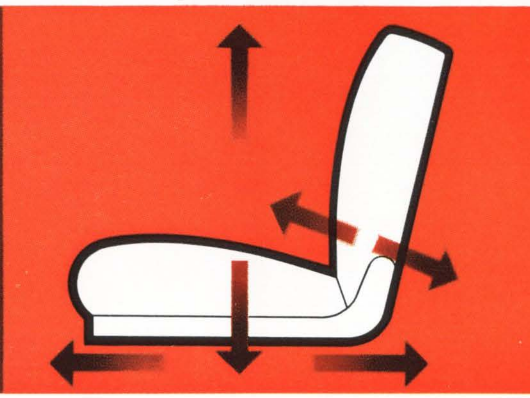

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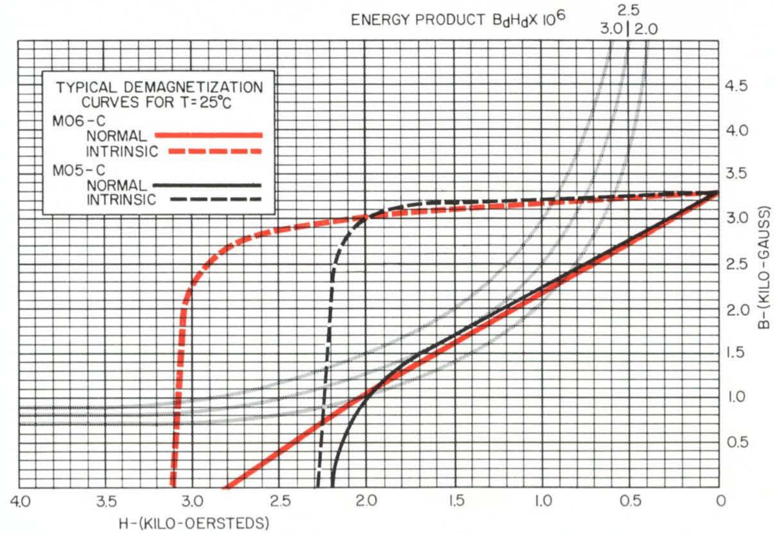
Properties of typical Allen-Bradley ceramic permanent magnets



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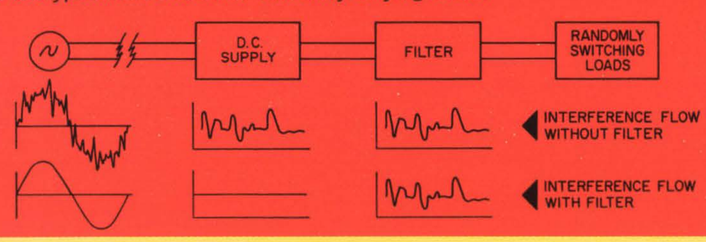
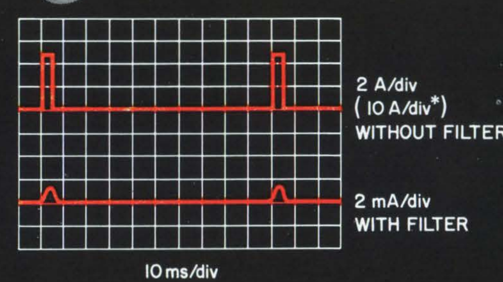
Allen-Bradley active filters can provide as much as a 50 to 1 reduction in size and a corresponding reduction in weight over conventional passive elements.

The diagram below and performance curve at right illustrate how Allen-Bradley *active* filters prevent current fluctuations in the power distribution system above 10Hz (3Hz*), developed by pulse modulated communications equipment, such as teletypewriters and other randomly varying loads.





Typical example of A-B Active Filter performance

Directly as the result of some new ideas applied to the field of ElectroMagnetic Compatibility, Allen-Bradley has been able to produce a new *active* low pass filter that provides an attenuation of greater than 60 db over the range of 10Hz (3Hz*) to 100KHz. The maximum dc component of the load current is 5 amperes.

The primary purpose of this filter in the above application is to prevent impulses generated by rapid load fluctuations, which may be carrying information of a confidential nature, from being reflected back through the power supply and into the power distribution system.

These new filters are designed to satisfy specific requirements. For instance, power line filters are under development for 60Hz and 400Hz power frequencies. Here, a sharp pass band is afforded the power frequency while greatly attenuating all other frequencies.

Allen-Bradley active filters produce a far greater attenuation of unwanted signals than is possible with a filter composed of conventional passive elements, occupying the same volume. By using the A-B *active* filter, a size reduction of 50 to 1 is attained, together with corresponding savings in weight. These filters employ solid-state circuitry. No external power source is required other than that supplying the power to the load. In addition, complete inrush and short circuit protection is provided.

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Improved mechanical filters compete with crystal and LC

For 20 years the mechanical filter has offered the circuit designer a small, rugged frequency selector that has been relatively temperature-stable. But insertion losses, often running upwards of 20 dB, have prevented the mechanical filter from seriously challenging either the inexpensive LC filter or the highly selective crystal filter.

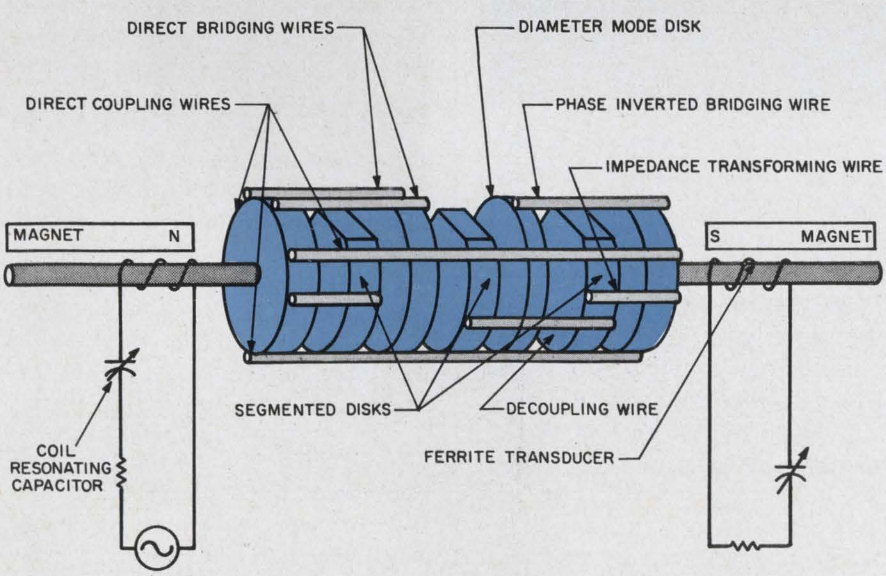
Recently, however, new nickel-alloy disks have reduced the mechanical filters insertion losses to less than 15 dB for simple filters and as low as 2.5 dB for multiple element units, according to William Carnes, Collins Radio Co., Newport Beach, Calif. And these rugged devices can maintain a temperature stability of better than one part per million per degree centigrade at 455 kHz over a 100-degree range.

Operating up to one MHz, the filters are particularly useful in citizens' band receivers and transmitters and many single-sideband applications. The mechanical filters have a higher *Q* than comparable LC filters and are often cheaper and more rugged than crystal filters.

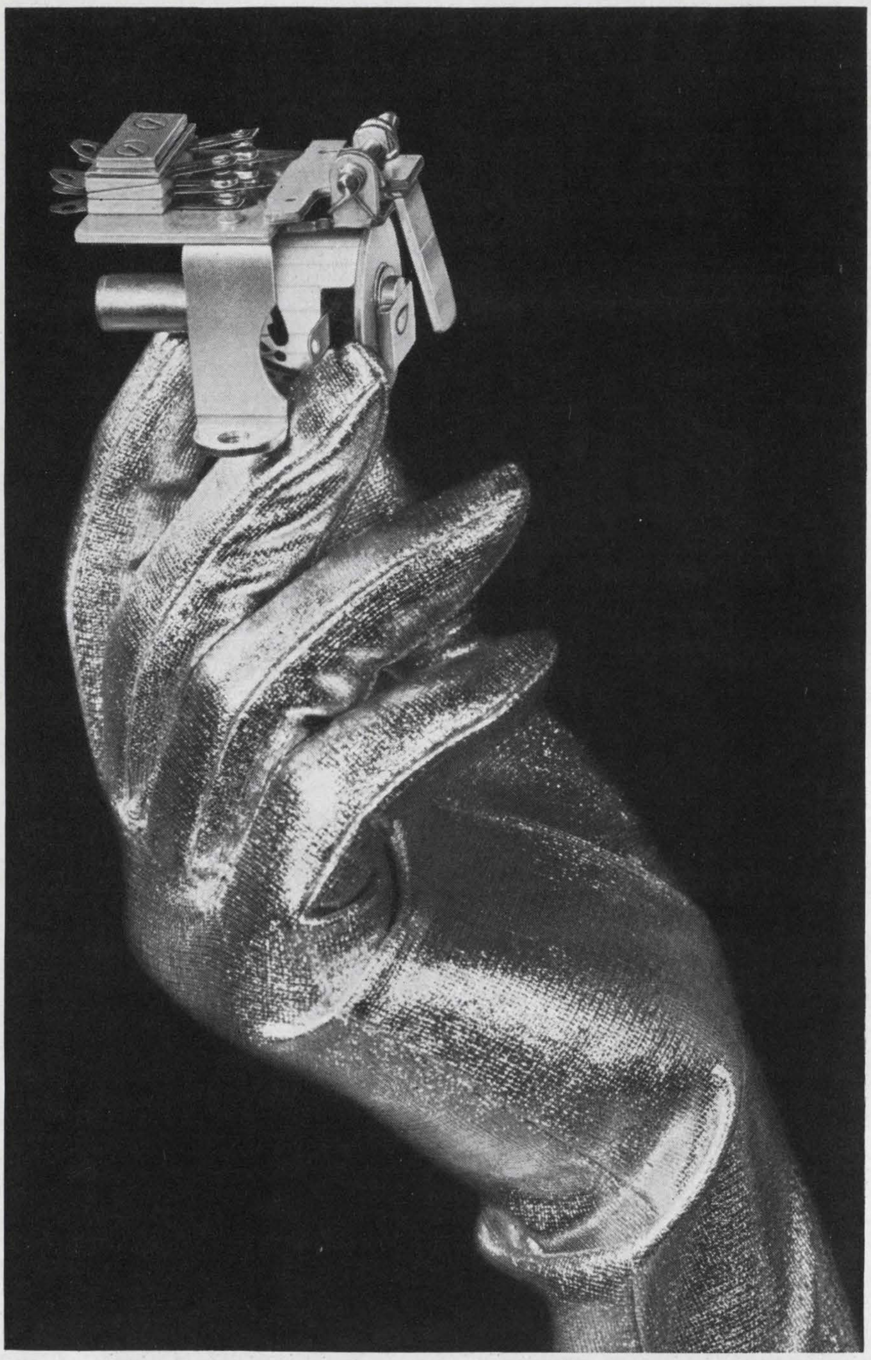
This is how the devices work: The mechanical energy produced by the signal in a magnetically biased ferrite core travels through a series of metal alloy disks. Variations in the number and shapes of the disks and in the lengths and locations of the connecting rods determine the frequency response. At the other end of the filter, another ferrite core surrounded by magnetic flux converts the filtered mechanical motion back into an electrical signal.

Although a mechanical filter can have as few as two thick metal disks, the more sophisticated pass-band, side-band and stop-band filters can contain from four to seven. In the seven-disk stop band illustrated below, the insertion loss with ferrite cores is merely 2.5 dB with a pass-band ripple of ±0.15 dB at 78 kHz. (With ordinary nickel-steel cores the insertion loss is 8 dB.)

Though the seven-element filters with ferrite-core transducers are, quite naturally, more expensive than less complex types, Collins reports very good yields in production. This, it says, is due to the simplicity and stability of the metal and ferrite machined parts. And apparently the price edge enjoyed by the LC filters does not deter sales: "I show designers 50-cent LC filters," says Carnes, "and I tell them they're going to pay $12 for the mechanical version. And they do." ■ ■



An insertion loss of only 2.5 dB can be attained with this ferrite-transducer seven-disk mechanical filter. The segmented disks reduce the amplitude of spurious responses. Thus, unwanted resonances are not propagated through the filter by either the circular or the segmented disks.



LETTERS

More research needed into UFO phenomena

Sir:

I noted with interest your comments on the UFO puzzle in the August 16 issue ["The UFO puzzle: time for a technical evaluation," ED 19, p. 63], and further data on ball lightning investigations in the issue of Sept. 13 [ED 21, p 14].

The theory of Philip J. Klass and the work of Drs. Uman and Moruzzi may well make a useful contribution to this field of investigation by eliminating one more natural source of UFO phenomena. However, I think it is unlikely to provide a universal explanation of some of the unusual sightings reported by many reliable witnesses. Reports of large metallic objects resting on the ground, which have subsequently taken off, leaving a depression in the ground and scorched grass, cannot very well be reconciled with ball lightning.

A very persistent phenomenon, which could be regarded as a giant form of ball lightning, has been reported by many observers in the USA and in France. This takes the form of a large glowing object usually found at night on or near a roadway. The effect of this object on an automobile is to extinguish the lights, cut out the engine, and blank out the car radio. The occupants sometimes report a tingling or paralyzing feeling. What we would like our theoretical physicists to explain is what sort of field would produce these effects, and how would it be generated by ball lightning.

I have recently helped to investigate the sighting of an unusual object, seen at night in the area of Reading and Oxford [England] this summer. It took the form of a cluster of points of light which moved rapidly across the sky together. The individual lights moved about relative to one another in a curious jerky manner. All observers were convinced that is was not an aircraft (no sound), a satellite (moving too fast) or a meteorite.

(continued on p. 38)

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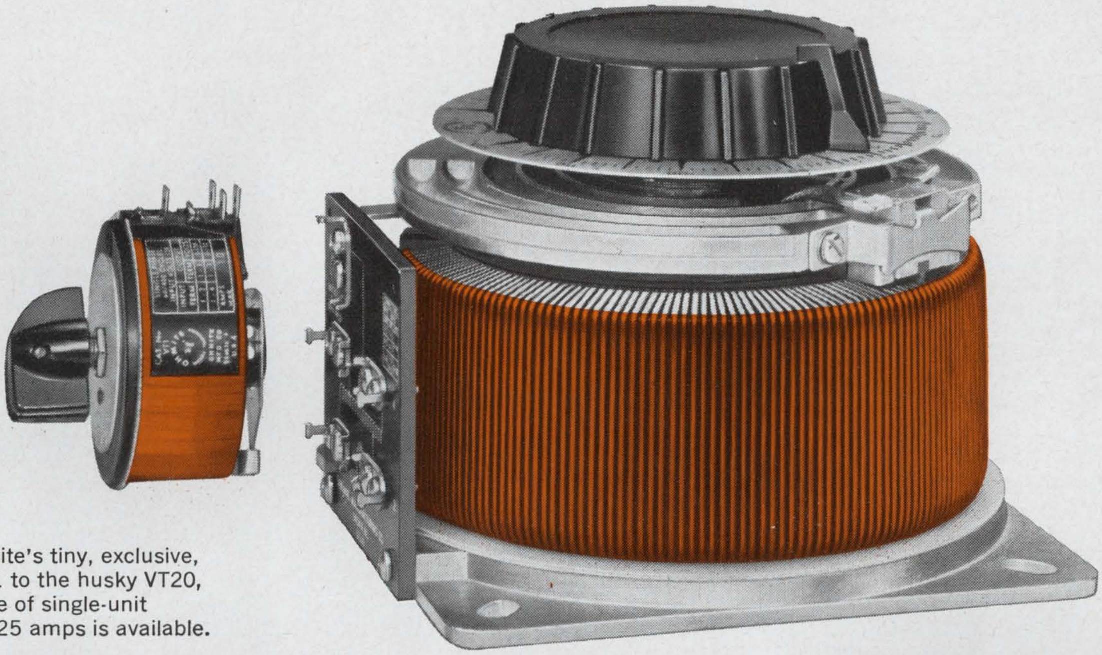

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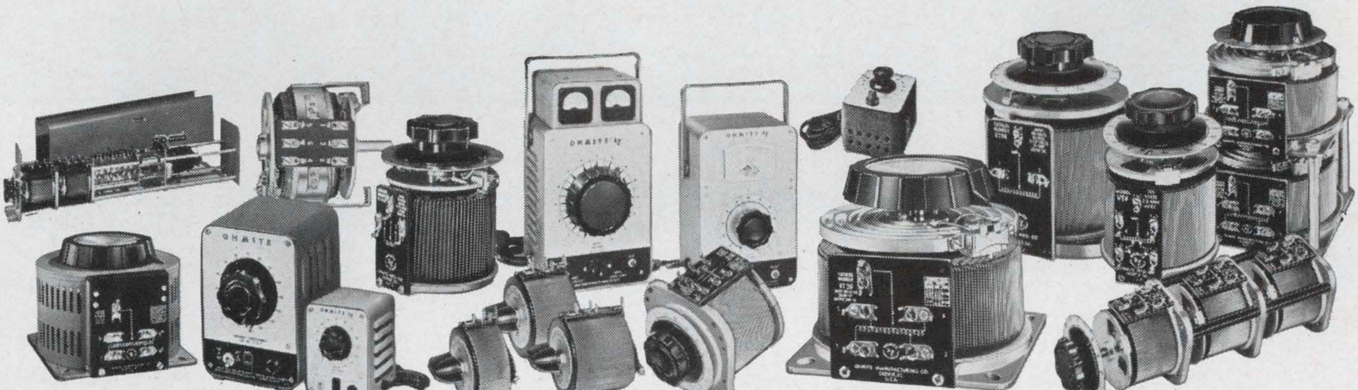

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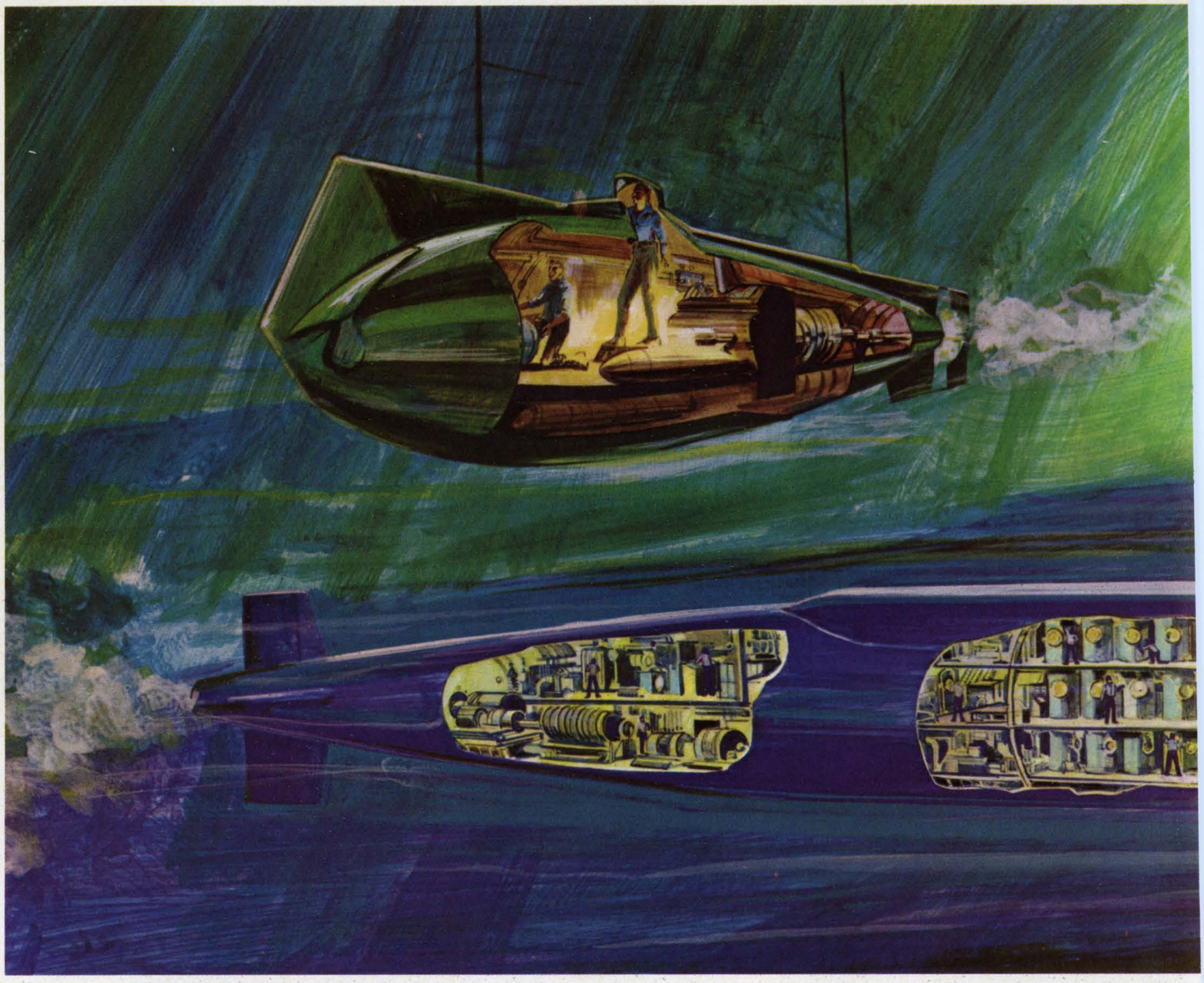

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ON READER-SERVICE CARD CIRCLE 26

LETTERS

(continued from p. 34)

The same, or similar, object was seen in different places at different times over a period of days, ruling out the meteorite explanation. One observer was an amateur astronomer, and has never seen anything like it before.

I think that very much more investigation is needed and scientists have spent too long with their heads in buckets of sand. We need more practical efforts like those of Drs. Uman and Moruzzi, but on a much greater scale. I suspect that spectroscopic tests are only just beginning to scratch at the problem.

G. Elliott

Director
Elliott Electronics
Reading
England

More on the great Mho, recognized at last

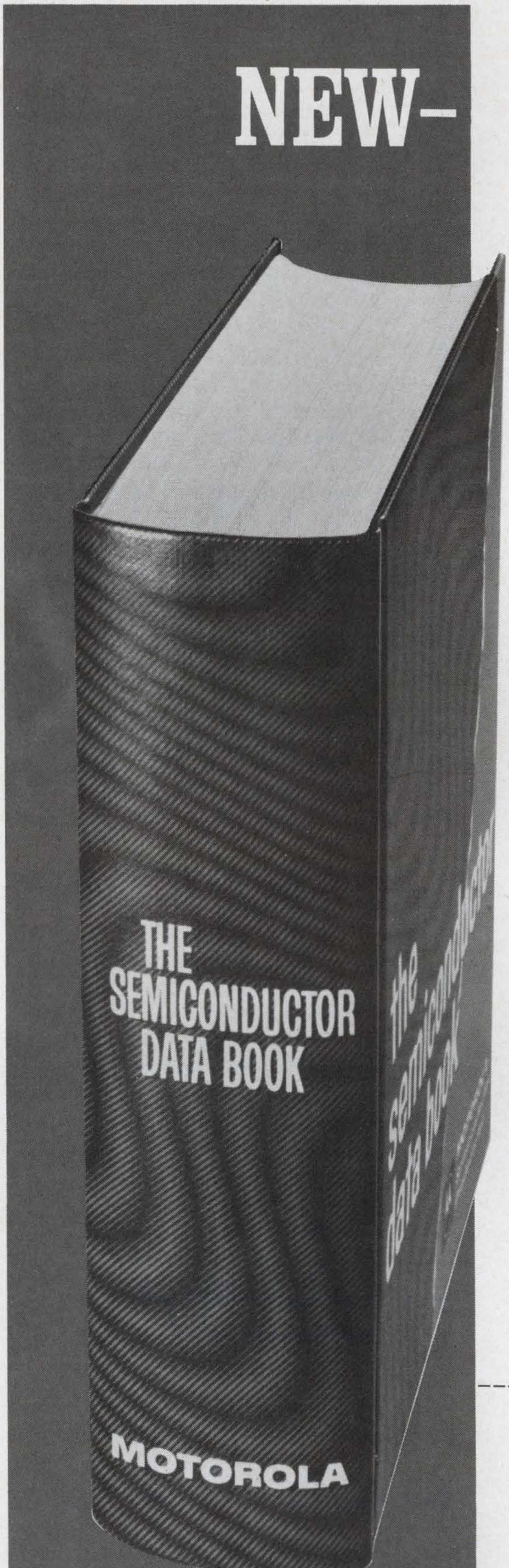
Sir:

I was very pleased to find that another reader knows of the eminent Mho Wang Fu (Roger T. Stevens, ED 22, Sept. 27, 1966, pp. 40 & 42). As Mr. Stevens pointed out, the career of this distinguished Chinese philosopher is virtually unknown in the West today.

Mr. Stevens also neglected to mention, undoubtedly through an oversight, that Mho formulated the laws known today to the engineering profession as Murphy's Laws (or Finagle's Laws). These resulted from Mho's battery experiments with a shorting bar across the electrodes. Crudely translated, Mho's Law comes out as: "Watch it, men, I think the infernal thing is going to burn up again." In the time since 1161 B.C., naturally there have been many chances for engineers to refine and expand this basic law.

I concur heartily in the protest against this unseemly drive to eliminate the sole remembrance of this great philosopher and experimenter by dropping his name as the unit of conductance. Can't the siemens be reserved for the unit of conductor

(continued on p. 40)



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(continued from p. 38)

area, eliminating the circular mil, for example?

Eli Silverman

Consulting Engineer
Hempstead, L. I., N. Y.

Biology inspires fluidic design

Sir:

Your interesting article on fluidics, which appeared in the Aug. 30 issue of ELECTRONIC DESIGN [ED 20, pp. 17-21], has prompted me to jot down a few ideas which I have not seen in print and which may be relevant to the subject.

With the present emphasis on fluidics, it appears strange—to me, at least—that the analogy has not been drawn between man-made fluidics and natural fluidic systems, such as the vascular system of animals. From such an analogy much could be learned and exploited: for one thing, new models—both mathematical and functional—of the vascular system could be elaborated; and second, new and useful hardware directly based on biological models might be created. This note is primarily concerned with the second of these two alternatives.

The basic fluidic circuit is that of the bistable amplifier illustrated in Fig. 2 of your article [p. 18]. The major difference between natural and man-made fluidics is that the latter are rigid-walled structures. By contrast, the walls in the former are free to respond to a variety of stimuli by either contracting or expanding. This property can thus channel flow selectively from partially "obstructed" channels to unobstructed, or even actively opened, channels. This suggests that flexible-walled models of a bistable amplifier could be made out of compressible plastic Y-shaped pieces interconnected by conventional plastic tubing. Compression at the branches of the junction could be achieved by a variety of mechanical means, such as electrically activated solenoids, or by control tubes wrapped around the arms of the junction in such a way that fluid flow in the control tube will constrict the walls of the main channel. Among the attractive features of such a scheme is cost, since the major components of the system could be made with cheap plastics by conventional molding and extrusion techniques. Another attraction is that linear as well as nonlinear characteristics are achievable; hence analog as well as digital operation appears feasible.

A device similar to the turbulence amplifier in your Fig. 4 [p. 21], but not dependent on changes from laminar to turbulent flow, can be made with collapsible-wall fluidics. In this case, the inlet orifice of the output tube would be contractile and changes in its diameter would control the output flow.

Pursuing the analogy between living and nonliving systems still further, one could create a fluidic diode, employing the same principle as venous valves, which permit blood flow in one direction only.

Still another useful analogy would permit control of fluidics by use of phenomena similar to clotting, which by formation of an obstructing plug allows blood flow to be diverted to uninjured channels. A properly chosen circulating fluid could be caused to interact with a suitable coagulant at given branches, forming a plug and causing diversion through other branches. For some susceptible liquids (i.e., heat-labile) this coagulation could be produced by localized heating.

R. M. Zilberstein

Sharon, Mass.

Critic replies to critic on war and peace

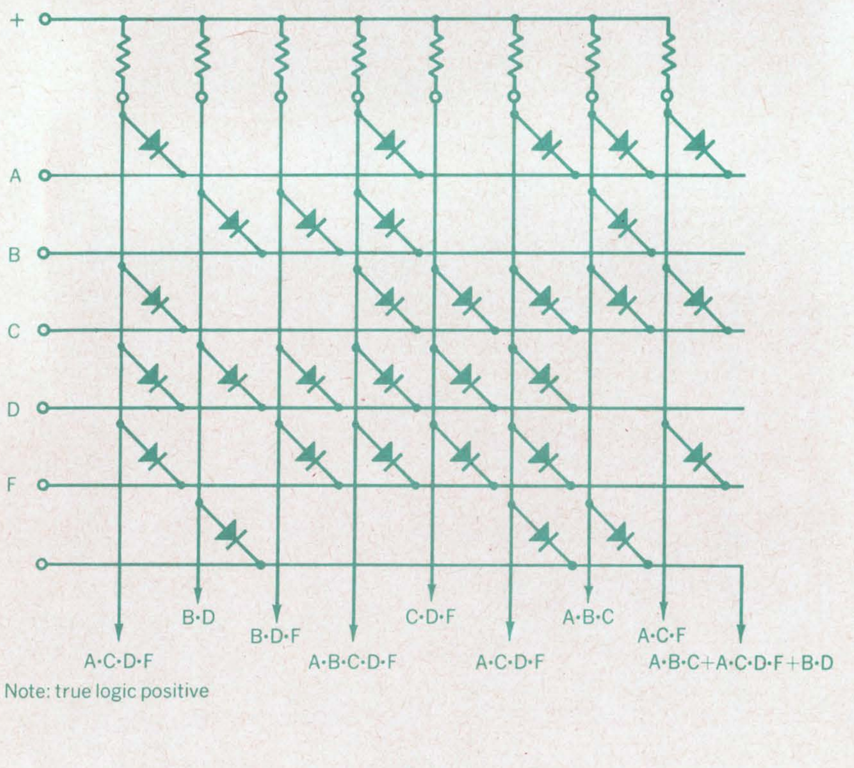
Sir:

Donald Davidson criticized me [ED 21, Sept. 13, 1966, pp. 42-44] for defending hecklers during an anti-Vietnam-war march who were dubbed "neo-Nazis" in an ED editorial.

I have been in two shooting wars so far, and while I did not see the incident referred to in the editorial and am willing to concede that the hecklers were neo-Nazis, I cannot

(continued on p. 44)

State of the monolithic art



Note: true logic positive

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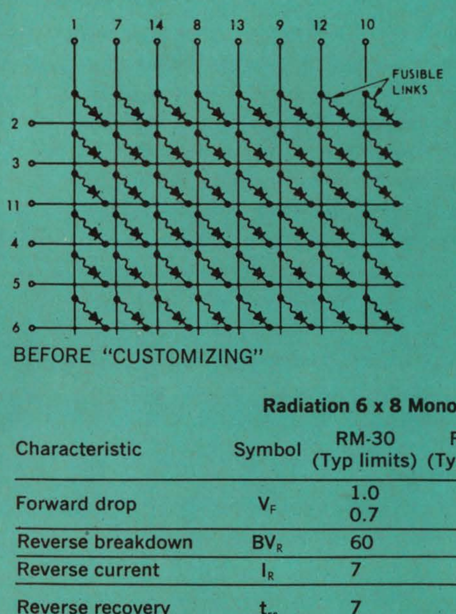

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Reverse breakdown	BV_R	60	60	50	V	$I_R = 100\ \mu A$
Reverse current	I_R	7	25	70	nA	$V_R = 25$ V
Reverse recovery	t_{rr}	7	11	30	ns	$I_F = 10$ mA to $I_R = 10$ mA
Crosspoint capacitance	C_{cp}	1.9	1.9	2.0	pf	$V_R = 5$ V; f = 1 MHz
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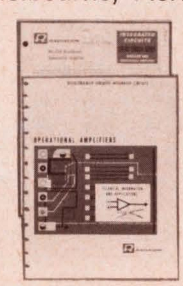

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(continued from p. 40)

condemn their actions in this instance.

When you were in the service, Mr. Davidson, were there any groups trying to undermine your positions and possibly get you killed? And if there were, what did you think of them? Why weren't the Nazis in the service? Why aren't the marchers? "Practice what you preach" indeed works both ways, Mr. Davidson.

We are at war. If you feel that you cannot help your country, don't hinder it. The hecklers may not have been very commendable types, but what were the marchers?

Paul Doerr
San Francisco Bay Naval Shipyard
Vallejo, Calif.

Power supplies are complete V and I sources

Sir:

As one involved in the specification of dc power supplies and the generation of meaningful specifications about them, I should appreciate the opportunity to reply to reader Kestenbaum's letter in your Sept. 12 issue [ED 21, p. 34].

Mr. Kestenbaum's complaint is that modern series-regulated power supplies will not sustain overloads, even momentary ones, as their self-protecting circuits invariably act to limit overload current. He describes power supplies made and rated this way as "highly unrealistic" in terms of his particular application (involving audio or pulse loads).

The term power supply is an unfortunate misnomer, as it tends to imply a *power* capability in some users' minds, an implication which is perhaps derivative from a simpler era, when power supplies were limited fundamentally by thermal considerations. Then it was possible to speak of a "power-limited" circuit for which peak values and duty cycle were subordinate to average and rms numbers.

Modern series-regulated supplies, on the other hand, are *voltage* and *current* sources in the complete sense of the word. No longer are mere thermal conditions the sole limiting factor in output ratings. The supplies are designed for, and deliver, certain specific maxima in terms of both voltage and current. These characteristics require manufacturers to specify and describe their product in terms of the absolute values of voltage and current, defining, thus, an operating region or area on the volt/ampere plane.

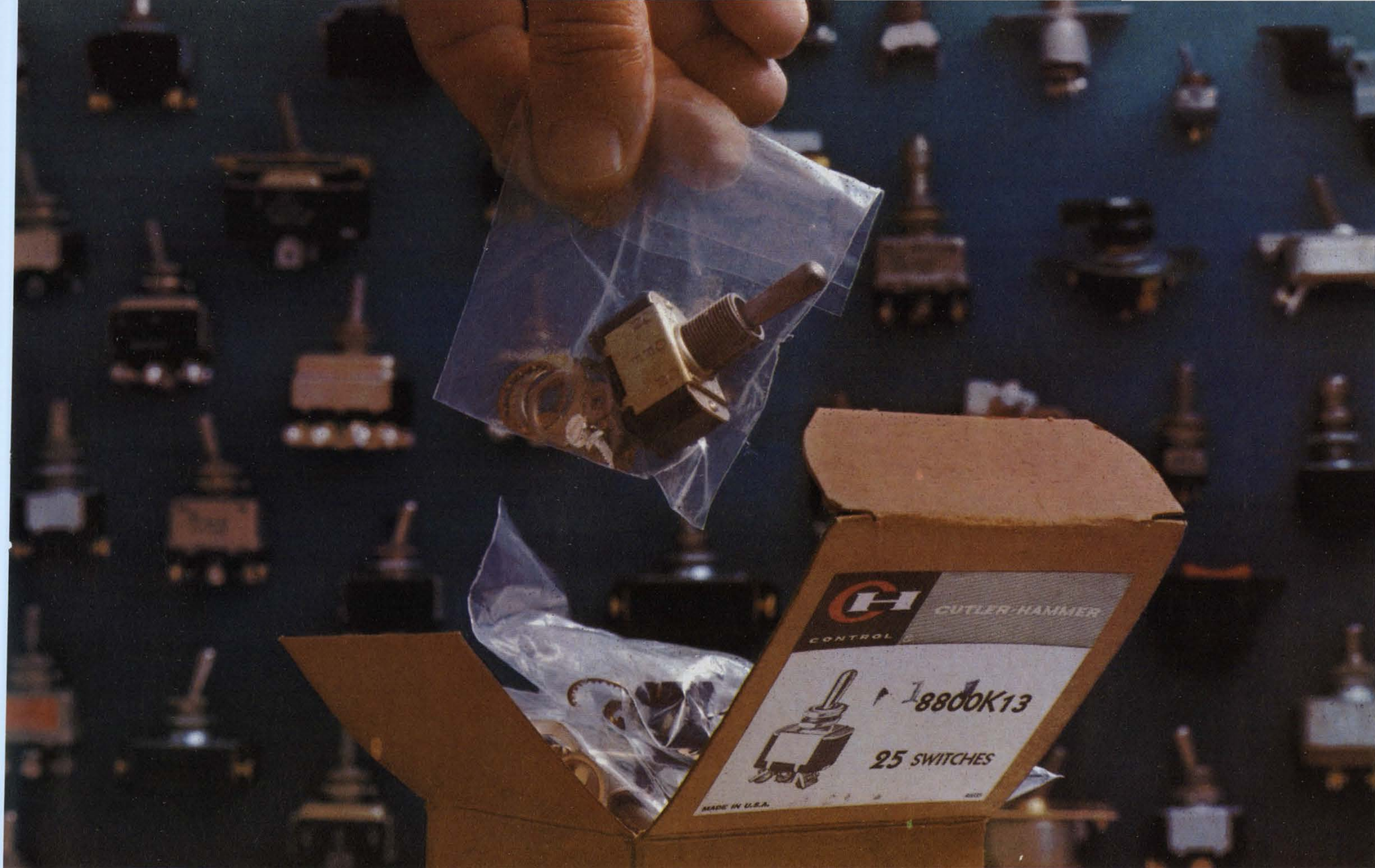
Far from being "unrealistic" or failing to give the user a true appraisal of the unit in the user's circuit, such ratings are entirely real, referring to easily duplicated test conditions and specified in easily measured maximum volts and amperes. Of course, they do force the user to re-evaluate his circuit requirements in terms of absolute (peak) volts and amperes, and do not permit the sort of time-averaging which describes a 300-volt, 10-ampere pulsed load as "300 volts at 10 milliamperes." This latter specification is the unrealistic one. . . . Properly stated, peak and average values of an ac load should be given, together with a duty cycle and waveform. Whatever the description, a series-regulated power supply must always be rated for the peak load conditions. It matters not that a particular load draws only 10 amperes for a very short time, only once a year (a minuscule average); its power supply must be rated to deliver the 10 amperes or the circuit will be starved, and will not perform properly.

A proper understanding of the equipment ratings, the units, terms, and methods, is essential to the application of such equipment in an engineering sense. Your magazine is to be commended for furthering that vital understanding.

Paul Birman
Sales Engineer
Kepco, Inc.
Flushing, N. Y.

Accuracy is our policy

In "Try the hybrid-pi," ED 21, Sept. 13, 1966, pp. 66-68, author Robert Mammano points out that the test equipment input capacity, C_o, in Fig. 2, p. 67, should read 7.5 pF, not 2.0 pF as printed.



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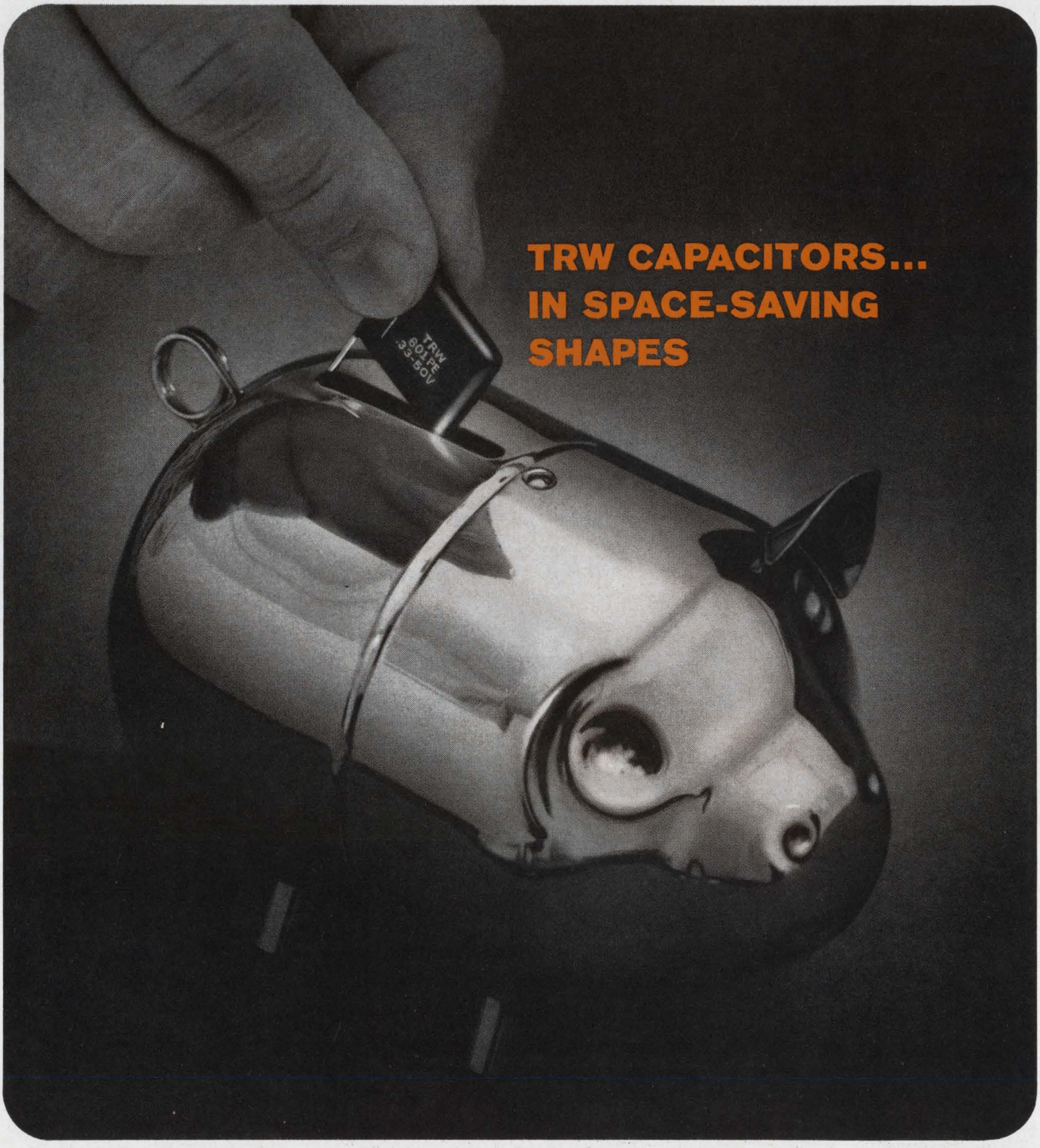

14-60

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EDITORIAL

Saga of a systems man — or meetings, shmeetings

Dr. Perry Asymptote, Chief Systems Scientist for Analysis and Reanalysis, Inc., was preparing his briefcase for his 17th technical meeting of the year.

The renowned systems specialist was heading this time for the Poconos—"Vacationland of Pennsylvania," the flyer said. "Too warm for skiing and too cold for fishing at this time of the year," Dr. A. mused, but at least he would get to bend an elbow with some old friends. Memories of meetings in Las Vegas, Miami, Paris and Disneyland waltzed through his mind.

(Are resort locations truly necessary for the exchange of ideas? Or do they offer, instead, a number of interfering distractions?)

Then, as Dr. A. shuffled through his morning's mail, he spotted a curious letter. It read:

> "All Government agencies are seeking ways of reducing expenditures in order to relieve pressures on the economy, while giving strong support to our efforts in Vietnam. To that end the Air Force is deferring or eliminating all conferences or meetings which are not of immediate necessity. I have, therefore, decided to postpone the Congress on . . . ."

Signed by an Air Force general, the letter went on to explain that the papers scheduled for the meeting would be published and delivered to all who had been invited.

(It's really true. The letter was sent out Oct. 31—the most efficient time-saver for meetings attendance we've heard of yet.)

The sudden turn of events meant that Dr. A. would have to sit in the home plant, pursuing some sort of activity for the next three weeks—until the next conference was scheduled.

Just then, a junior systems man, looking a bit sheepish, appeared at the office door.

"Sorry to bother you, Dr. Asymptote. I know you've been busily traveling to important conferences, but do you remember that design problem I mentioned as you were rushing to catch a plane six months ago? Well, we're still stuck . . . "

Dr. A. realized that this time there was no escape. He pushed a pile of analyses, reanalyses and memoranda aside and invited the young engineer to sit down. In a few minutes he was enmeshed in a difficult technical quandary—and found that his problem-solving apparatus had become distinctly rusty.

On the following Thursday afternoon, Dr. A. went through his meetings schedule and crossed out over half the entries. For the next few days he plunged deeper and deeper into the problem.

"It hurts," he mumbled, "But the Air Force was right."

ROBERT HAAVIND

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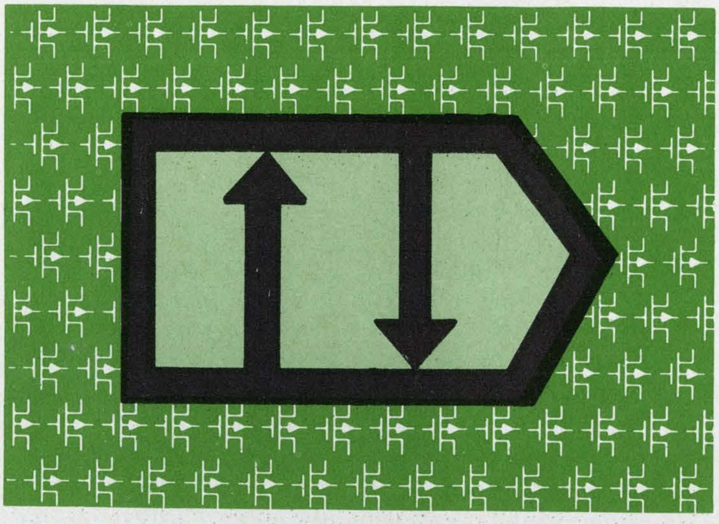
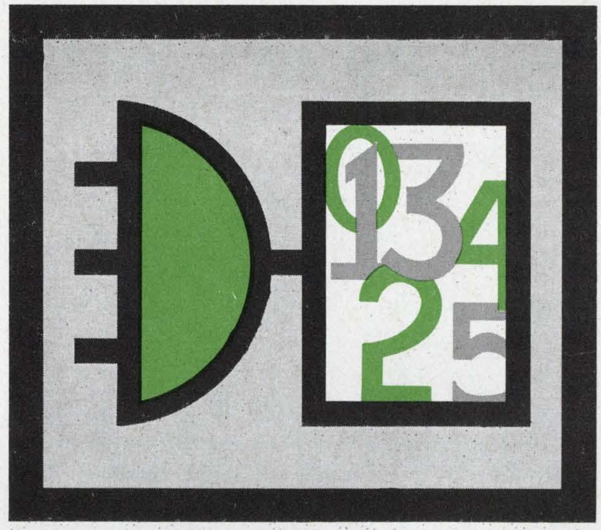
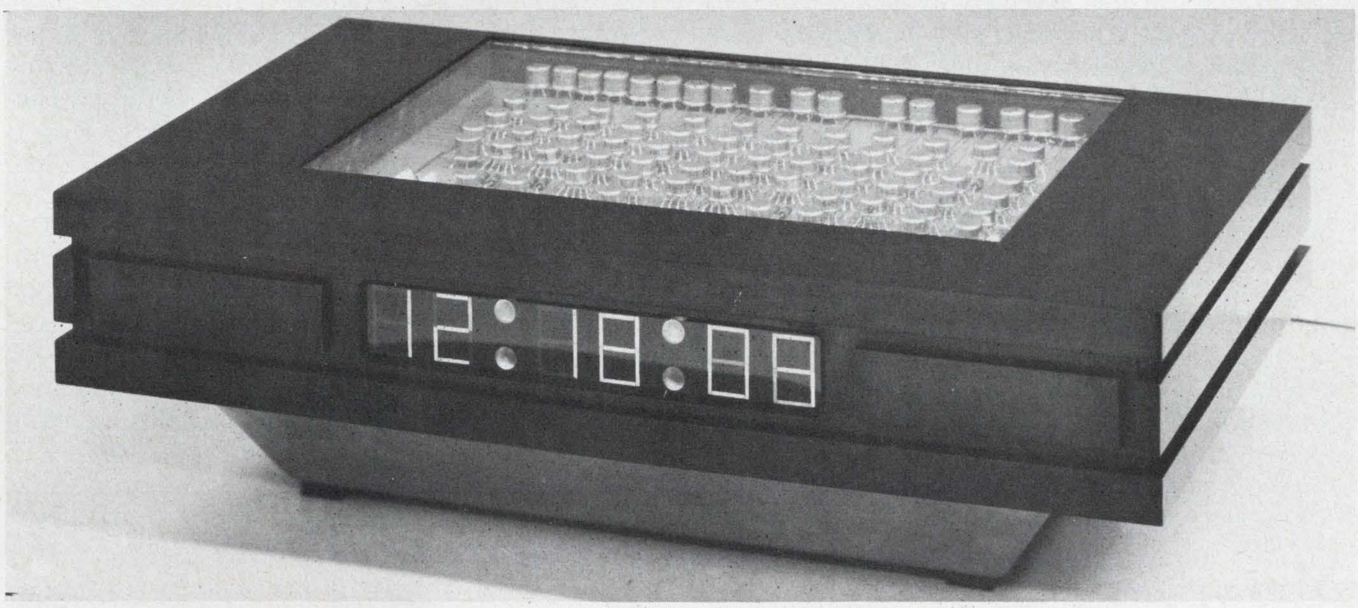
Technology



FETs function with low-level logic, so bridging the 'driver gap' in analog signal switching. Page 50



Karnaugh map eases Boolean equations and helps simplify logic design. Page 64



A digital clock built with integrated circuits and a 1-MHz crystal-controlled oscillator will develop signals that have an accuracy better than one part per 100 millions. Page 70

Also in this section:

ICs end the 'driver gap' in FET analog signal switching. These circuit designs permit the use of junction and MOS devices as switches with low-level logic.

From the time they were first introduced, junction field-effect transistors (J-FETs) and metal-oxide semiconductor types (MOS-FETs) have always been excellent for analog signal switching.* But they could never be used directly with low-level logic circuits, because of the relatively large voltages (both positive and negative) required for their control.

Now the problem can be solved. Several integrated circuits have been developed to bridge this "driver gap." These circuits, available commercially, can amplify low-level signals and also shift levels. The considerations that went into their design should prove useful in selecting the right circuit. They also would apply to discrete-circuit design.

The circuits can be used in any application where good isolation of the switched signal from the driving source is required. For example:

- Sequential switching (commutation) of many signals into a single output.
- Analog-to-digital converters.

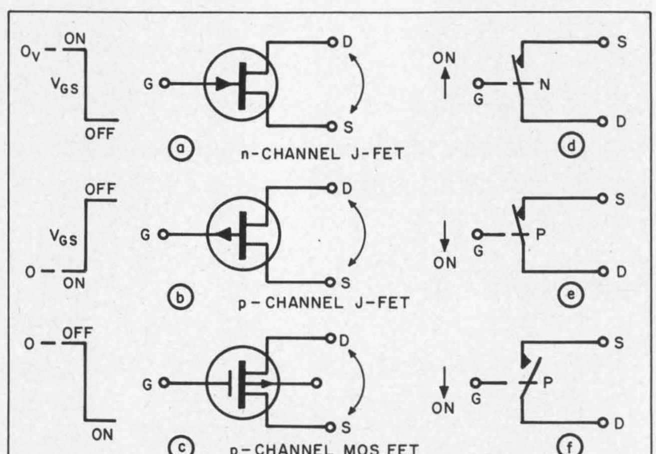
Starting with a step-by-step description of J-FET and MOS-FET fundamentals as switches, let us consider input-output driver circuit requirements and how to integrate the J-FET-and MOS-FET analog switches and drivers.

FETs are switches

Figure 1 shows three types of FETs as they are commonly used for analog switching. Figures 1a and b are n-channel and p-channel junction-FETs (J-FETs), respectively. Figure 1c is a p-channel MOS-FET. Each can be used to perform a single-pole, single-throw switch function. Figures 1d, e and f show the functional symbols used in this article to represent the three FETs in Figs. 1a, b and c. The n- and p-channel J-FETs are normally ON switches; hence their symbols are shown with the contacts closed. The p-channel MOS-FET is normally an OFF switch; its symbol has open contacts.

Also indicated in Fig. 1 is the gate voltage V_G polarity needed to turn the switch OFF or ON. For example, an n-channel J-FET is turned ON when V_{GS} swings positive with respect to the OFF gate voltage. This fact may be indicated in the switch symbol by placing an arrow pointing upward at control terminal G. Following this new sign convention, both p-channel FET switch symbols have downward pointing arrows at terminal G, to indicate that the ON gate voltage level is negative with respect to the OFF voltage.

The FET source and drain terminals are internally connected by the channel. When the FET is ON, the channel conducts current in either direction between them. Therefore the analog signal can be fed into either the drain or source and taken out of the opposite terminal. Since the FET is usually symmetrical, the drain and source terminals may be interchanged without affecting



1. **J-FETs as switches** (a, b,) are normally closed (d and e) while MOS-FETs (c) are open (f). The arrows are used to indicate the gate voltage polarity required to turn the switch ON, positive-up, negative-down.

*See ELECTRONIC DESIGN issues 12, 13, 14, 15, all Vol. 14, 1966.

Arthur D. Evans, Vice President, Engineering Manager, Siliconix, Inc., Sunnyvale, Calif.

performance. For the purpose of this discussion, let us assume that the analog input signal is connected to the source terminal, designated the analog input terminal; thus the drain becomes the output terminal.

Know your n's and p's

Channel conduction, or channel resistance, is a function of gate-to-channel voltage (V_{GS}). The graphs in Fig. 2 show channel conduction $1/r_{ds}$ vs voltage V_{GS} for the three FET types. Note that, for both p- and n-type J-FETs, the conduction is high (switch is ON) with zero gate voltage. When the gate is made negative for the n-channel, or positive for the p-channel, conduction decreases to approximately zero for a gate voltage equal to pinch-off V_p. The n-channel J-FET requires a gate-to-channel voltage more negative than V_P to hold if OFF. For example, assume the analog signal at the source is $+5$ volts and the drain is -3 volts. If $V_P = -8$ volts, the gate voltage must be equal to or more negative than -11 volts to hold the J-FET switch OFF. For similar analog signal conditions ($+5$ and -3), a p-channel J-FET with $V_P = +8$ volts would need a gate voltage equal to or greater than $+13$ volts to hold it OFF.

The operation of the p-channel MOS-FET differs a little from that of the p-channel J-FET. As shown in Fig. 2, the conduction of the MOS-FET channel is approximately zero in the absence of a gate voltage—that is, the device is normally OFF. When the gate is made more negative than threshold voltage V_{th}, with respect to either source or drain terminal, the channel begins to conduct. Again, if we assume the same analog signals as above ($+5$ and -3 V) and assume $V_{th} = -6$ volts, the gate voltage should be more positive than -1 volt to hold the switch OFF.

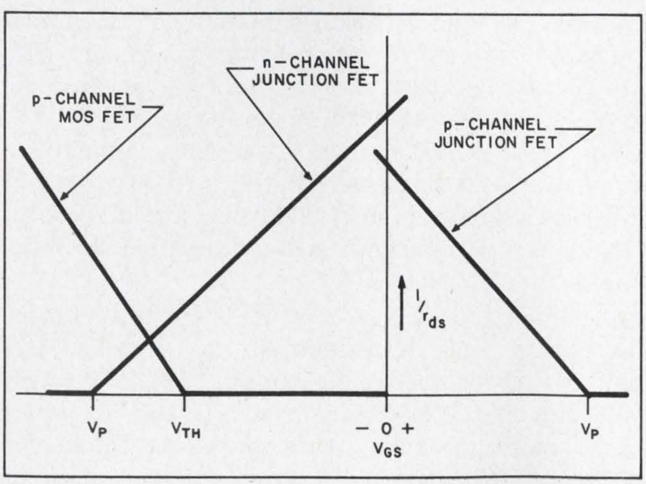
When switched ON, FET source and drain terminals are approximately at equal potential. In addition, with J-FETs the gate-to-channel voltage (V_{GS}) should be approximately zero. Although a forward-biased gate will produce higher channel conduction, it also may result in excessive current being forced into the channel and hence into the analog signal path from the gate control circuit. This may be permissible, if the analog signal disturbance is very small, but usually it should be avoided.

For the p-channel MOS-FET, gate voltage should be much more negative than V_{th} to obtain high channel conduction. A typical value of ON gate voltage for the MOS is -15 volts plus the most negative analog signal to be switched. If the analog signal is expected to swing down to -5 volts, then a gate drive voltage of -20 V should be provided to turn the switch ON. If the analog signal is expected to swing up to $+5$ volts and the MOS has a V_{th} (minimum) of -3 volts, then the gate voltage must go up at least $+2$ volts to turn the switch OFF.

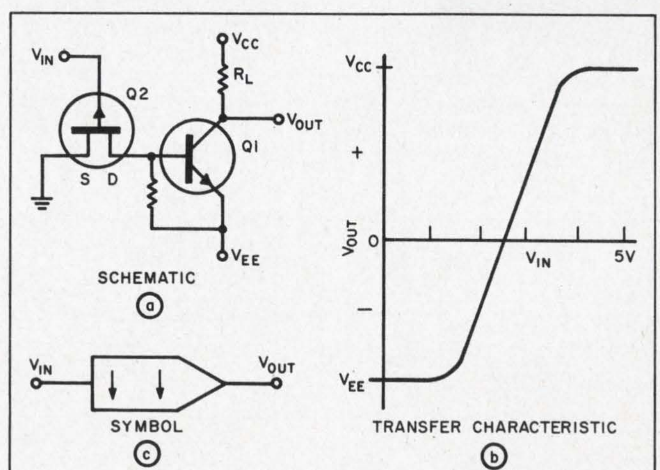
Drivers amplify and shift levels

In many applications the gate control signals originate in low-level logic stages with outputs of less than 5 volts. The foregoing examples indicate that gate control signals of 10 to 30 volts are needed to turn FET switches OFF and ON; hence an amplifier is needed. Also, the logic signal is usually referenced to ground (logic 0) and swings positive (logic 1), whereas the analog-switch gate may need to swing from -20 volts to $+10$ volts. Thus the gate driver must provide both amplification and level-shifting functions. For flexibility, the output reference level (0) should be fairly independent of the driver input reference level.

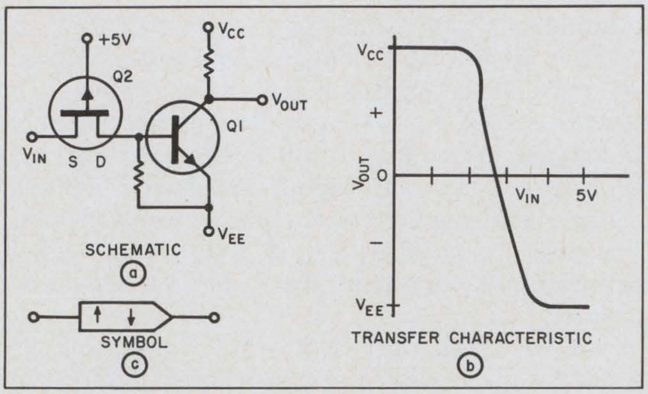
The driver circuit in Fig. 3a accomplishes these



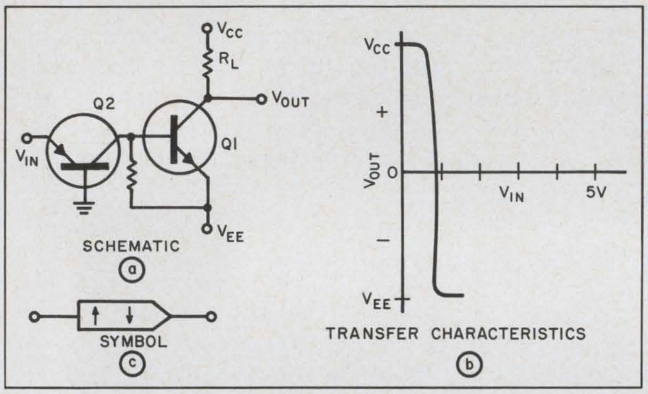
2. **J-FET channel conduction** vs gate voltage is easy to remember: n-channel (negative V_{GS}) = OFF; p-channel (positive V_{GS}) = OFF; for MOS-FETs this is reversed. All voltages are from gate to channel.



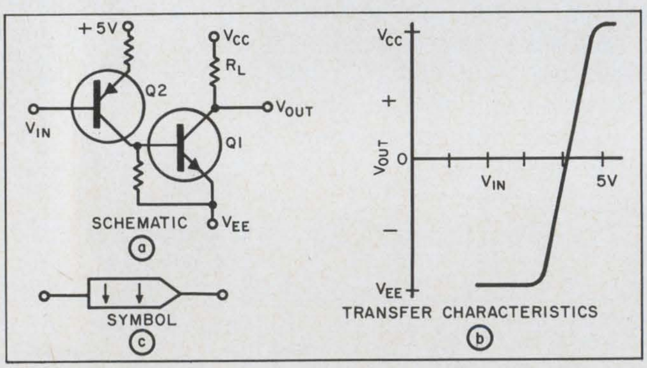
3. **One J-FET and one transistor** (a) amplify and shift levels (b) in response to a low-level input. Note the new logic symbol (c), with the arrows of Fig. 1 used to indicate the signal polarities when the driver is ON.



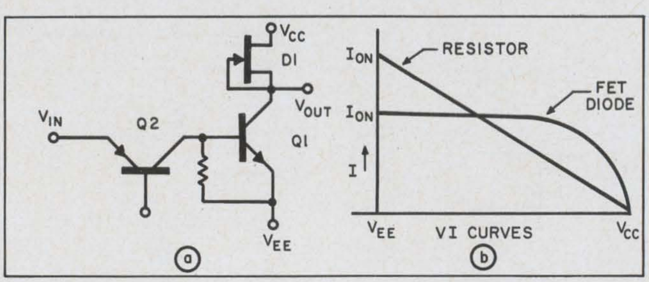
4. **Invert function** of circuit of Fig. 3 results if the input leads are rearranged.



5. **A two-transistor driver** (a) can accept even lower inputs (b) than the circuit of Fig. 4. A pnp transistor, Q2, shifts the levels.



6. **Invert function** of circuit of Fig. 5 results through additions of a resistor and rearrangement of the input. The function is the same as that of Fig. 3.



7. **Replacing R_L** in the circuit of Fig. 6 with a FET diode (a) results in ON power saving (b). Note that since the areas under the two curves are about the same, the switching time is not affected.

goals. Fig. 3b shows the transfer characteristics of this driver. When input FET Q2 is ON ($V_{IN}=0$), the output stage Q1 is saturated and the output voltage is approximately V_{EE}. As V_{IN} is made positive, the channel conduction of Q2 begins to decrease, and Q1 begins to come out of saturation. Further increase in V_{IN} results in turning OFF both Q2 and Q1. V_{OUT} then rises to V_{CC}. For this driver, a logic 0 at the input turns the driver ON. In the ON condition the output is low as indicated by the new symbols defined below.

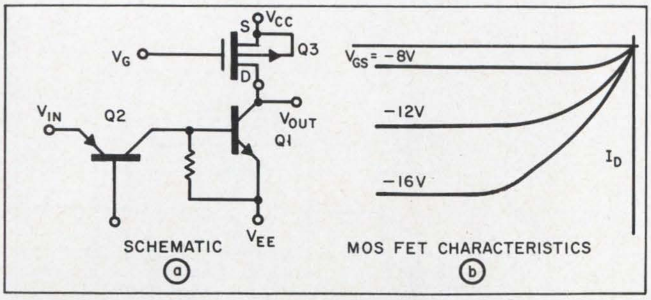
A symbol, shown in Fig. 3c, has been devised to represent the analog gate driver function. The arrows at the input and output sides indicate the voltage condition at the terminals when the driver is ON. When Q2 in Fig. 3a is ON, the output voltage is down (to V_{EE}); therefore the output arrow in the symbol points down. For the output to be ON, the input V_{IN} must be at logic 0 (down); hence the input arrow also points down.

The circuit of Fig. 4a is the same as Fig. 3a, except the source of Q2 is the input terminal and the gate is referenced to the logic voltage supply, +5 V. In this case a logic 0 at the input turns the output OFF, and a logic 1 (+5 V) turns the output ON. Fig. 4b shows the transfer characteristic and Fig. 4c the symbol for this driver. Note that the input arrow points up. This circuit has an invert function, in addition to amplifying and level-shifting.

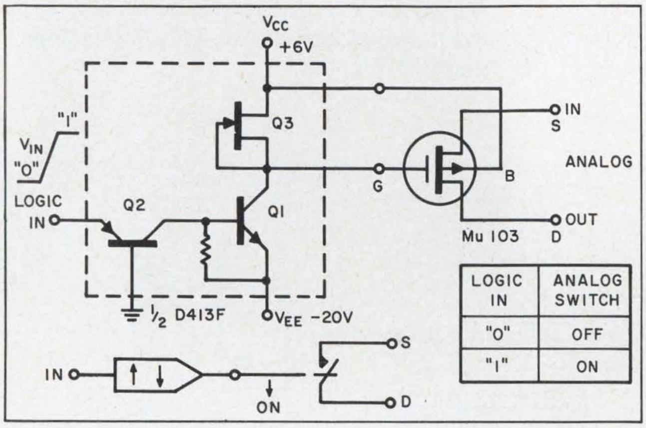
The circuit of Fig. 5a has a function similar to that of 4a. However, as indicated by its transfer characteristic, it will switch with a lower input voltage. A pnp transistor Q2 provides the level-shifting function. Fig. 6a shows that a noninvert function can be achieved by interchanging the input and reference voltage terminals. In this case a current limiting resistor has been added to the emitter of Q2. Fig. 6b shows the transfer characteristic and Fig. 6c the symbol for this driver.

The external load on an analog-gate driver is usually light and consists primarily of the capacitance of the gate or gates being driven. The R_L values in Figs. 3, 4, 5 and 6 will be determined, in part, by the required switching speed. As the value of R_L is made smaller, the gate capacitance can be charged up faster and the turn-off time will decrease. Since this also results in an increase in ON power, a trade-off is now possible between speed and ON power.

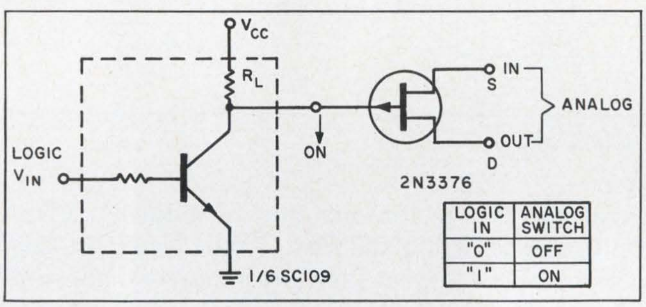
As shown in Fig. 7a, a FET current-limiter diode may replace resistor R_L to decrease ON power without decreasing speed. Diode D1 has a volt-amp characteristic, as shown in Fig. 7b. Since areas under the two curves are about equal, the turn-off time (capacitor charging time) is about the same. The FET diode, however, limits the ON power to about 60% of that resulting when the resistor is used. In Fig. 8a, the MOS-FET Q3 is



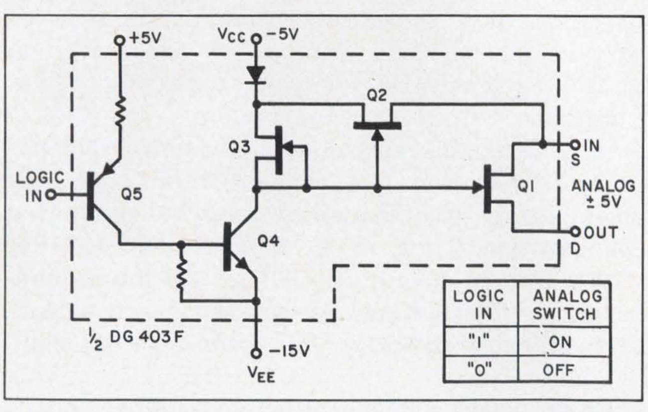
8. **Output current can be "pulled up"** if R_L of the circuit of Fig. 6 is replaced with MOS-FET (a). Note the effect of V_{GS} on the current for a given V_{ds}(b).



9. **Integrated driver** can provide −20 V to operate the MOS-FET analog switch. The power consumption is minimum when the switch is OFF.



10. **Low-level analog signals** can be switched with a single transistor integrated driver and a J-FET. Analog signals exceeding 0.5 V cannot be handled by the switch.



11. **An integrated driver-FET switch** dissipates minimum power in the ON condition.

used for the output "pull-up." With this addition, the gate of Q3 is available to set the pull-up current level. Fig 8b shows the output characteristics of the MOS-FET as a function of V_G.

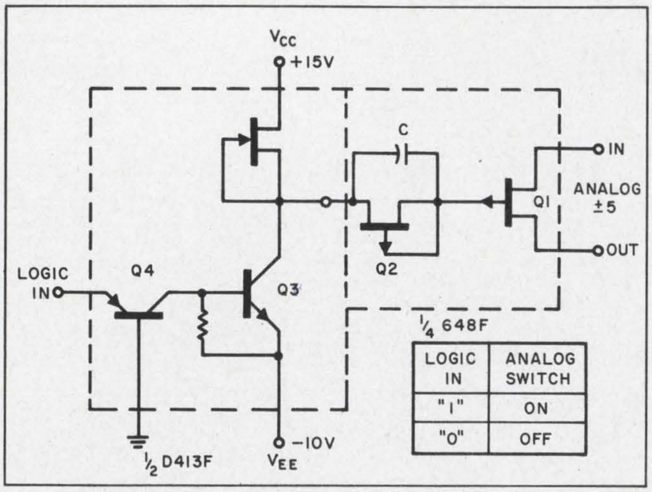
Any of the foregoing driver circuits can be used to control a p-channel MOS-FET switch. Fig. 9 presents the schematic and symbol for a typical integrated driver and switch. To turn the switch ON, the driver must pull the switch gate down to −20 V. The switch is held ON over the full analog signal range of ±5 V. When the driver is OFF, pull-up FET Q3 clamps the switch gate to +6 V (V_{CC}), which holds the switch OFF over the full analog signal range. In the ON condition, switch conduction varies with analog voltage, because channel conduction is a function of gate-channel voltage (see Fig. 2). In most cases this modulation of channel conduction by the analog voltage is not serious.

A simple integrated driver and J-FET switch are shown in Fig. 10. The advantages of the circuit, other than simplicity, are that dissipation in the OFF condition is very low, and the required gate voltage swing is only slightly greater than V_P. Though the analog voltage range in the ON condition is limited, this circuit is excellent for switching low-level signals. In the ON condition, the FET gate is held at about 0.2 volt. If either source or drain is allowed to become more than a few tenths of a volt positive with respect to the gate, gate-current flow will decrease gate isolation and disrupt switching action. As a result, analog signals of greater than 0.3 to 0.5 V cannot be handled by this circuit.

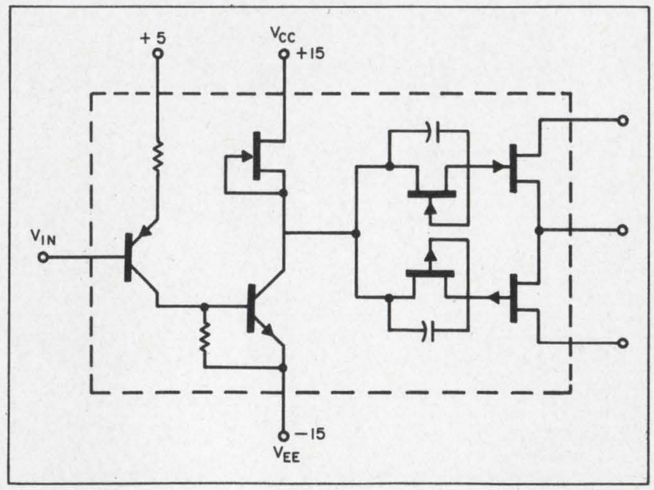
In the circuit of Fig. 11, the gate of the n-channel J-FET switch Q1 is clamped to its source in the ON condition and clamped to −15 V in the OFF condition. The voltages used in this illustration assume that: (1) $V_P \leqq -10$ volts for all the FETs, and (2) the analog signal is ±5 volts. This circuit functions as follows:

If Q4 is ON, the gate of Q1 is clamped to −15 volts, and switch Q1 is turned OFF. FET Q2 is also turned OFF, disconnecting the driver circuit from the analog switch source. To turn the analog switch ON, Q4 is turned OFF. With Q4 OFF, the voltage drop across Q3 is reduced to zero, thus permitting Q2 to turn ON. With Q2 ON and zero drop across Q3, V_{GS} of Q1 is zero; therefore Q1 is ON. Note that this circuit uses minimum power when the switch is ON. The circuits of Figs. 9 and 10 use minimum power when the analog switches are OFF

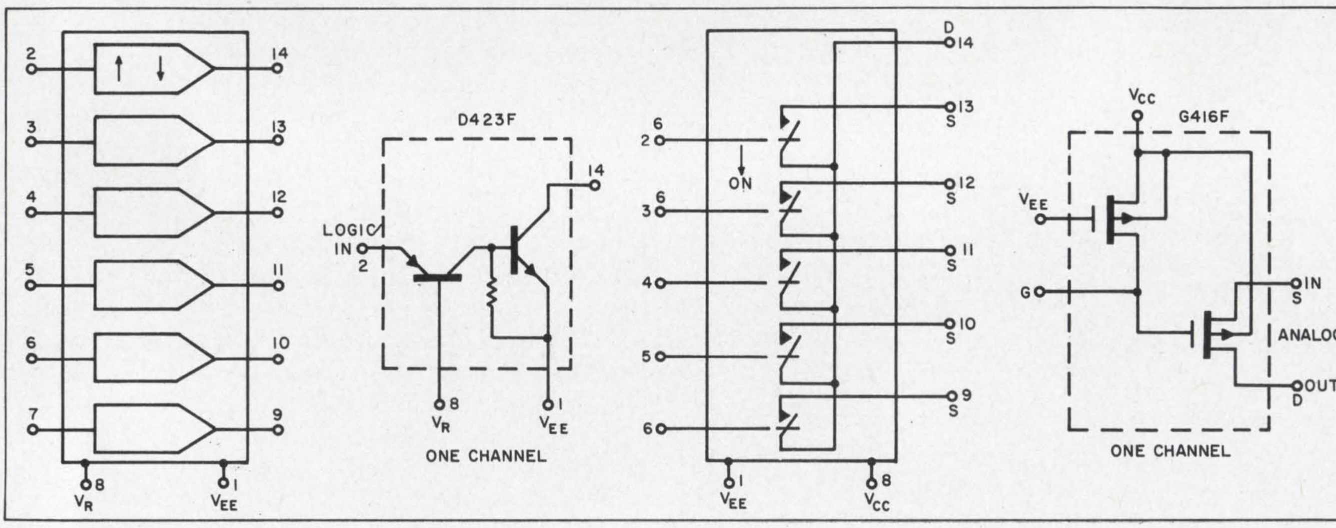
In Fig. 12, when Q3 is OFF, Q1 is OFF because its gate is at +15 volts. When Q3 is ON, V_{GS} of Q1 becomes negative, and the gate pulls a certain amount of current from the analog input terminal. The amount of current is limited to the saturation current of FET diode Q2. For this switch the saturation current is limited to 6 μA. Fig.



12. **Only 6 μA** of current are drawn from the analog input terminal when the switch is ON.



13. **An SPDT switch** results with addition of three components to the circuit of Fig. 12.



14. **Six drivers and five gates** are packaged separately in 14-lead flat packs.

13 is similar to Fig. 12, with an n-channel switch added to provide a SPDT switch function. The n-channel and p-channel J-FET switches should have comparable V_P.

How to integrate

Many of the driver and gate circuits discussed above are suitable for integration onto a single chip. In fact some of the drivers are so simple that as many as six may be placed in a single package. Though integrated drivers can be built with both J-FETs and bipolar transistors on a common substrate, the same circuits with FETs and bipolars on separate chips are more economical. For example, the circuit of Fig. 7a may be separated into two parts: pull-up FET D1 on one chip and the rest of the circuit on another. A pair of drivers may be packaged in a single 14-lead flat-pack or in a 12-lead TO-5.

The driver and gate circuit of Fig. 9 (with a MOS-FET substituted for Q3) may also be separated into two parts: one chip includes all MOS-FETs and the other the rest of the circuit. In this case, a pair of drivers plus gates may be packaged in a single 14-lead flat-pack or in a 12-lead TO-5. An alternate approach is to package six drivers, less the pull-up FETs Q3, in a single 14-lead flat-pack. Five MOS analog switches plus the five pull-up FETs are mounted in another flat-pack (Fig. 14). This arrangement increases the number of circuits per package. The use of one driver to control several MOS switches results in fewer packages.

In general, the exact circuit packaging depends on the application. Cost considerations also play an important part in determining the packaging configuration. Thus, if one designs a multiplexer with a large number of inputs, the maximum number of circuits per package is desirable to reduce the number of packages. For example, a 25-channel multiplexer has been constructed utilizing only eight flat-packs of the type shown in Fig. 14, i.e., six-gate and two-driver packages. ■ ■

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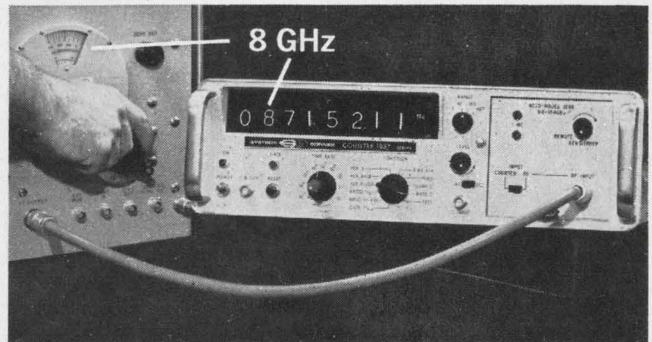

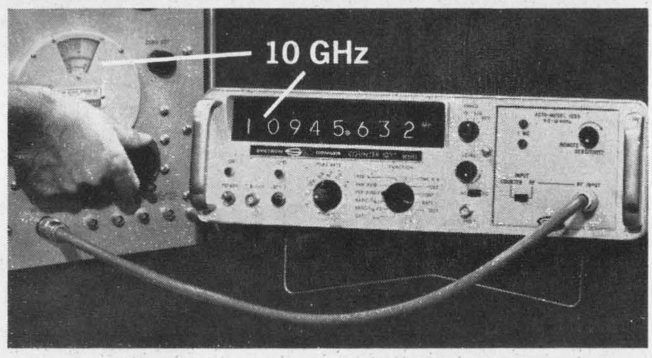

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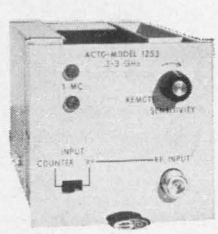

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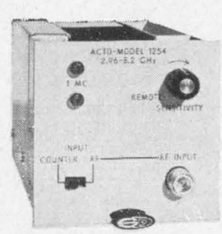

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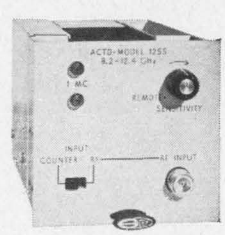
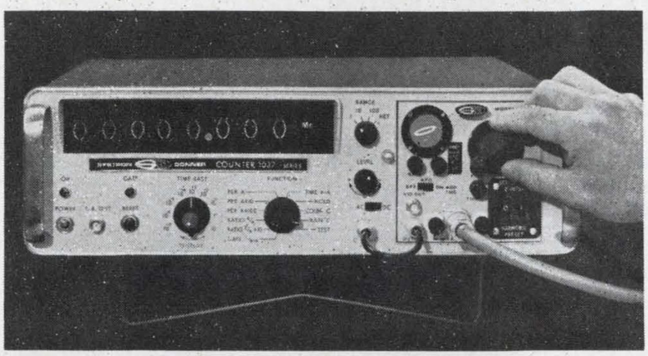


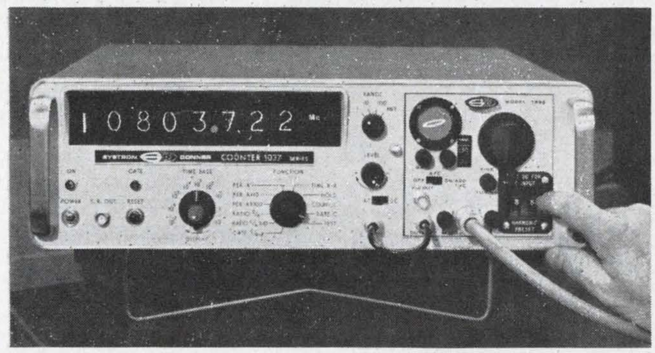
ACTO, 8 to 12.4 GHz, $1,975

# of microwave frequency measurement.

Simple 2-step readings to 15 GHz with one transfer oscillator plug-in



1. Tune transfer oscillator until a zero beat—any zero beat—appears on the built-in scope. The transfer oscillator is now phase-locked to the input.



2. Adjust harmonic preset until the reading appears. Notice the counter reads "10,803.722 Mc," an actual microwave frequency presented with counter accuracy.

Transfer oscillator plug-in gives you the enormous range from dc to 15 GHz in a single cabinet plus the ability to measure pulsed rf, FM center frequency and FM deviation.

The harmonic preset on the Systron-Donner transfer oscillator eliminates all need to calculate the harmonic number if you have even a rough idea of the frequency of the signal—as is nearly always the case. In the example above the frequency was known to be about 10.8 GHz. The following readings appeared as the harmonic preset was increased:

Harmonic preset number	Reading
84	10,676.634 Mc (Far too low)
85	10,803.722 Mc (Obviously correct)
86	10,928,860 Mc (Far too high)

The center reading was obviously the correct indication—located quickly, unambiguously and without calculation.

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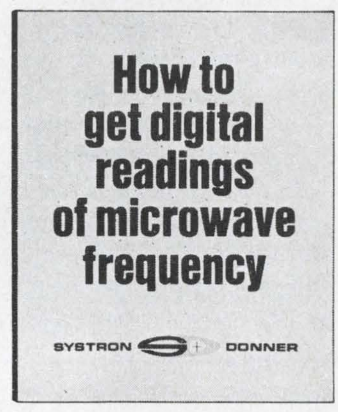

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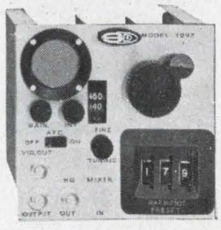
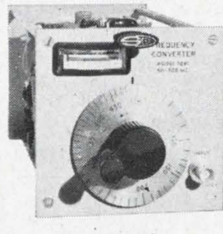


Transfer oscillator 50 MHz to 26 GHz with external mixers, $1,550



50 to 500 MHz het frequency extender, $550

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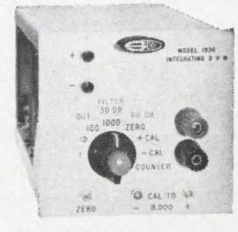

Integrating DVM, $575

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Tackle delay-line circuits graphically.

These plots, tailored to frequency-modulated radars relate critical parameters.

The interpretation of signals and the design of delay-line circuits for frequency-modulated radars can be performed rapidly with the aid of the two graphs presented here. The graphs are tailored to systems with linearly modulated FM pulses, where the frequency changes linearly with time. Similar curves may easily be prepared for other systems.

The actual circuit, shown in Fig. 1, illustrates the operating principle of a typical system: The instantaneous phase of the IF input signal from the receiver is compared with the phase of the same signal, displaced in time by a delay of ΔT, which is determined by the delay line. The resulting interference pattern causes the output to vary as a function of frequency, with nulls appearing at frequencies differing by $1/(2\Delta T)$ cycles. The delay may be as large as the pulse repetition rate of the radar. In general, a larger delay makes the discriminator more sensitive to frequency changes, provided that the input and delayed signal overlaps.

For example, a 1-μs delay line stores 30 cycles of a 30-MHz signal, 31 cycles of a 31-MHz signal, and so on. The phase difference between the input and the output of the delay line therefore varies by 360 degrees for each megahertz change of the input frequency. The minima and the maxima of the output alternate at every 180 degrees. Similarly, a 2-μs line would cause the output to repeat every half megahertz.

David Cohen, Consultant, Data Systems, and **Richard L. Heimer,** Engineer, Space Systems Div., Cutler-Hammer Airborne Instruments Laboratory, Deer Park, L. I., N. Y.

Other major components of the discriminator include a limiting amplifier to remove amplitude variations, a separate amplitude detector, and a Schmitt circuit to provide synchronization with an oscilloscope and to operate the IF switch, which removes limiter noise when the signal is not present.

The output of the phase detector and the pulse envelope from the amplitude detector appear in Fig. 2. The actual circuit includes a delay line with a 10-μs delay and an oscilloscope with a 5-μs/division trace speed. The input pulse width is 30 μs. The photograph shows that, with linear FM, 10 uniformly spaced beat cycles are generated during the latter 20 μs of each 30-μs input pulse.

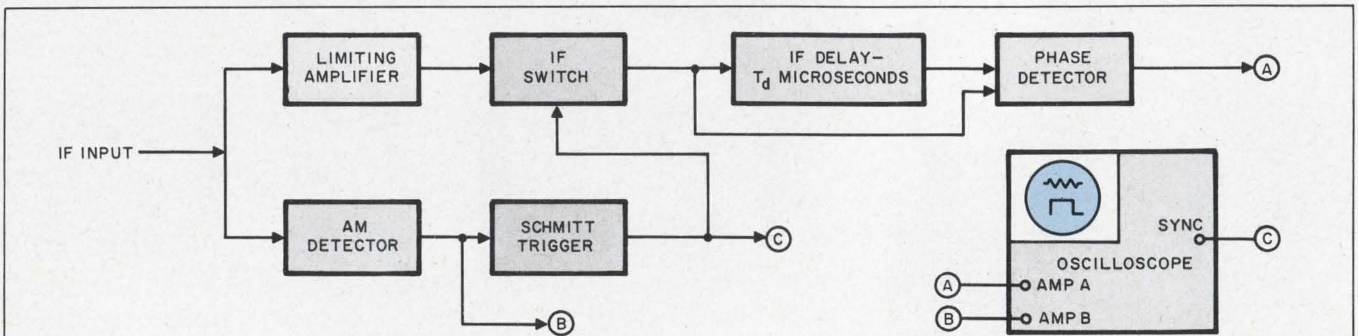
With these values, the designer can use the graphs to analyze the output or to redesign the system.

The graphs relate beat frequency, FM rate, frequency deviation, and time-bandwidth product to the number of beat cycles, pulse width and delay time. They are based on the following mathematical expressions:

Beat frequency $(f_b) = N/(T_p - T_d)$; (1)

FM rate $(R) = N/[(T_p - T_d)T_d] = f_b/T_d$; (2)

Deviation $(f_d) = NT_p/[(T_p - T_d)T_d] = RT_p$; (3)



1. **A frequency discriminator** is used to analyze the characteristics of linearly modulated FM pulses of frequency-modulated radars. Graphs simplify the interpretation of its output and the needed design changes.

$$\text{Time-bandwidth product } (\beta_T) = NT_p^2/[(T_p-T_d)T_d] = RT_p^2 = f_b T_p^2/T_d; \quad (4)$$

where N=beat cycles, T_p=input pulse width, and T_d=delay time.

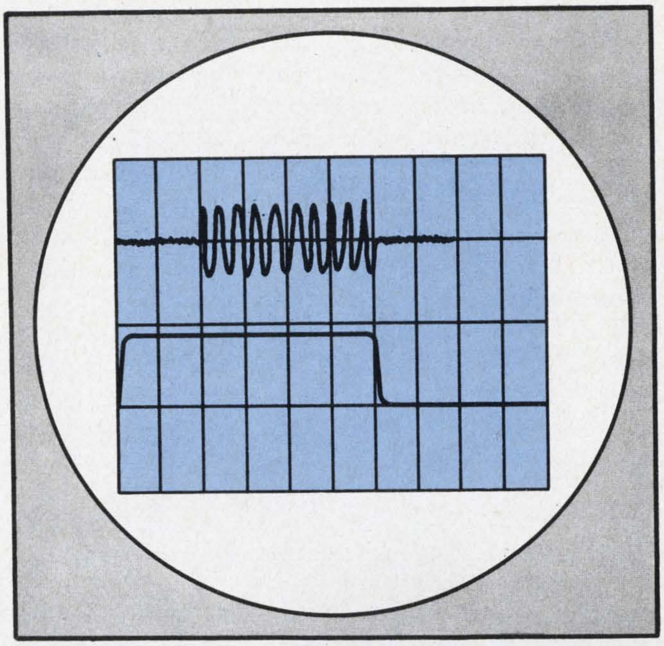
Of course, it is possible to devise short cuts even with the mathematical approach. For example, the beat frequency may be deduced from the oscilloscope traces by taking the reciprocal of the time of one cycle of the beat signal. In the long run, however, the alignment diagram (Fig. 3) and the four-dimensional chart (Fig. 4) considerably simplify analysis and design.

Graphs complement each other functionally

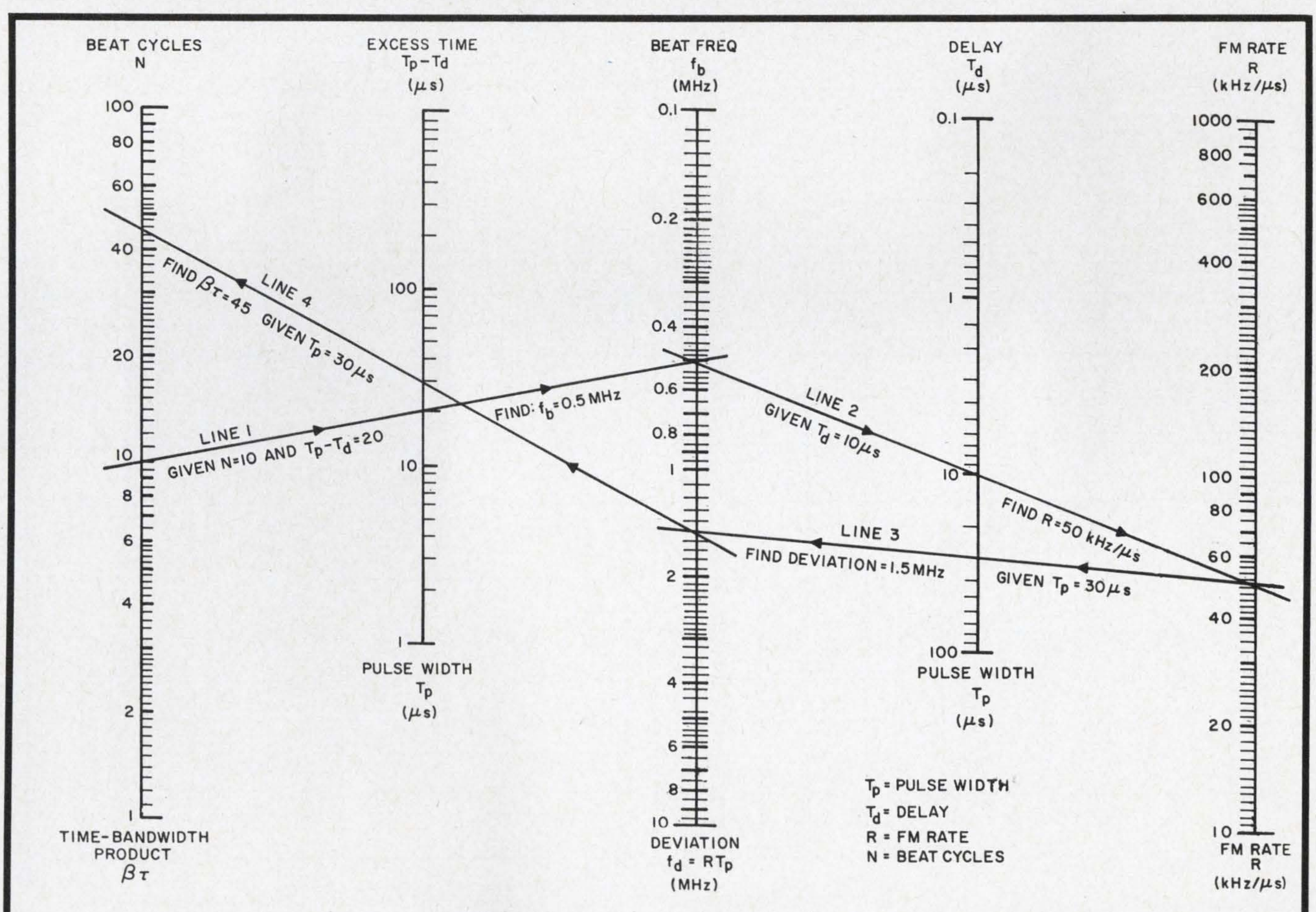
The alignment diagram will, with a little practice, provide relatively accurate answers. However, it gives no insight into the consequences of any change of the initial conditions. The four-dimensional chart overcomes this by allowing curves to be drawn.

To illustrate the use of the alignment diagram, consider the previous example, where $N=10$, $T_d = 10\ \mu s$, $T_P = 30\ \mu s$.

Align $N=10$ on the N scale with $T_p-T_d=20\ \mu s$ on the T_p-T_d scale, and read off $f_b=0.5$ MHz on



2. **Typical display of a discriminator** shown in Fig. 1. The lower trace is the pulse envelope from the amplitude detector, the upper trace is the output of the phase detector. The delay line has a 10-μs delay, therefore, the beat cycles do not start for 10 μs. (Each division on the horizontal scale represents 5 μs.) The 30-μs input pulse yields 10 uniformly spaced beat cycles.

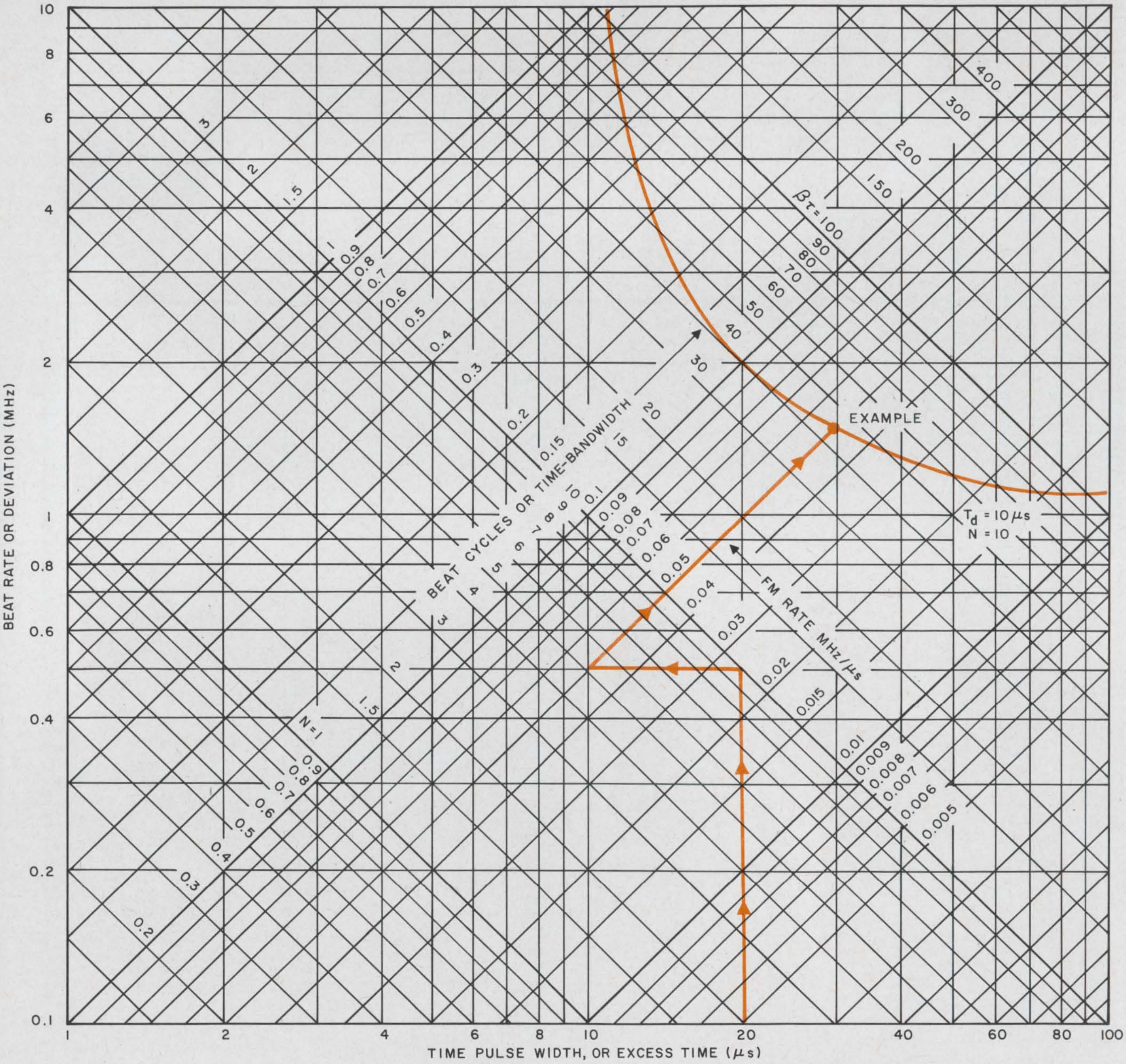


3. **Alignment chart** provides rapid solutions for the values of the beat frequency, FM rate, deviation and time-bandwidth product once the performance of the circuit has been specified.

the beat frequency scale. Align this result with $T_d = 10$, and find $R = 50$ kHz/μs on the FM-rate scale at the right. Now, referring to the lower scale labels, line up this result with the right-hand pulse-width scale, marking $T_p = 30$ μs, and note that deviation $f_d = 1.5$ MHz. Finally, project a straight line from this result through $T_p = 30$ μs on the left-hand pulse-width scale to the $\beta\tau$ scale at the left, and observe that the time-bandwidth product is 45.

The same results are obtained with the four-dimensional chart of Fig. 4. In the example, the excess time of 20 μs intersects with 10 beat cycles at a beat rate of 0.5 MHz. This beat rate intersects with the delay time of 10 μs at an FM rate of 0.05 MHz per μs. Extending this FM rate to a pulse width of 30 μs yields a point on the graph that contains the over-all pulse parameters including the total deviation, 1.5 MHz, and the time-bandwidth product of 45.

By varying the pulse width, a locus of pulse parameters yielding 10 beat cycles with a 10-μs delay line can be drawn. Curves of varying pulse widths or delay times or beats may be similarly drawn, holding the remaining two parameters constant. In fact, any one of the seven variables involved may be plotted with any two others held constant, and the necessary curves may thus be obtained for the solution of any particular design problem. ■ ■



4. **Four-dimensional chart** permits the evaluation of changes in the design parameters or in the initial conditions. For example, the variation of the pulse width results in a curve (color) which is the locus of all points having 10 beat cycles with a 10-μs delay line. Any one of the seven variables may also be plotted.

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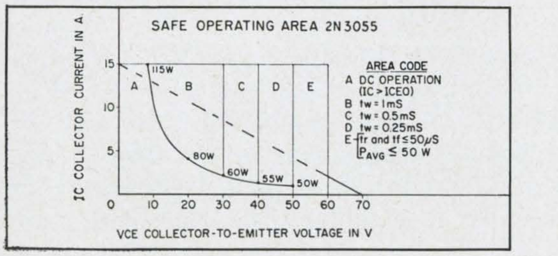

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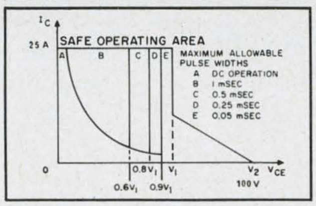

TYPE NUMBER	IcMAX A	V_1 V	V_2 V	Ppeak W	ΘJ-C °C/W
2N514B	25	45	70	1750	0.5
2N677C, 2N678C, 2N1031C, 2N1032C	25	60	80	2000	0.8
2N1120	15	35	60	900	0.5
2N1136B-2N1138B	10	50	80	800	1.2
2N1146C, 2N1147C	20	45	70	1400	0.8
2N1166A, 2N1167A	25	45	75	1875	0.8
2N1365	6	70	100	600	0.8

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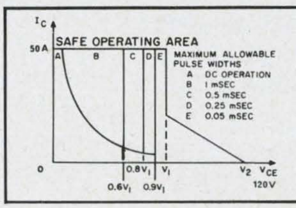

TYPE NUMBER	Ic Max. A	V_1 V	V_2 V
2N2284, 2N2469	3	70	110
2N1073B, 2N2290	10	70	110
2N1430	10	80	120
2N1653, 2N2287	25	60	100
2N2638	25	80	120
2N2359	50	50	90

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Take the easy road to logic design. Use the Karnaugh map to help minimize logic equations. Here's an example of its use in counter design.

The Karnaugh map offers an easier and more positive way of minimizing logic equations than Boolean algebra. Because there is usually more than one solution to a Boolean equation, experience and intuition are usually necessary to obtain as simple a solution as possible. On the other hand, the Karnaugh map clearly shows the minimum equation required.

To see how this approach can be used to handle a practical design problem, the Karnaugh map will be used to determine the simplest Set and Reset equations for each flip-flop of a synchronous binary-coded decimal counter (Fig. 1).

The first step in the design is to determine the code that will be used for the decimal counter. A four-flip-flop counter can result in 16 possible code combinations. Any ten of these combinations could be used; let us select the first ten.

The code in the table shows the state of each changes or "ripples" at every count. Cross-coupling the outputs Q and $\overline{Q}$ (*1* and *0*) of flip-flop A, shown in Fig. 1, to its Set and Reset inputs will cause it to "toggle," or change states, for each clock pulse.

In a *synchronous* counter, the clock pulse is tied in parallel to all flip-flops of the counter, so that the clock pulse is applied to all flip-flops simultaneously. Gating at the Set and Reset inputs is required to ensure that the flip-flop will change state only at the time or count shown in the table. This is done to improve the counter's operating speed.

In a *ripple* counter, the speed is limited by the propagation delay through all four flip-flops.

Design one flip-flop at a time

Set/reset for flip-flop A : The first step is to set flip-flop A of the decade counter. The equation is: Set $A = \overline{A}$ (or $A = 0$) on the Karnaugh map (see the map labeled "Set A"). The two columns enclosed are adjacent when the map is folded into a cylinder.

Note that A will be set by the next clock pulse when the counter is at states (in order of DCBA) *0000, 0010, 0100, 0110, 1000, 1010, 1100*, and *1110*.

C. J. Grandmaison, Manager, Semiconductor Applications Engineering, Sprague Electric, Worcester, Mass.

However, states ten through fifteen cannot occur, and thus are "don't-care" conditions. Place a *1* in all squares where A is set, and X in every "don't-care" square. Enclose as large an even-numbered group of adjacent *1* squares as possible. "Don't-cares" are "wild" like jokers in a pack of cards and may be included wherever advantageous (See map above). There are eight squares that can be so enclosed.

The logic equation for the Set input to flip-flop A is determined by using only the letters that do not change state for any square in the enclosure. $A = 0$ is the only bit that satisfies this requirement. B is both *0* and *1* within the enclosure, as are C and D. They are not required as inputs to control the Set input of flip-flop A, because they can be in any state and flip-flop A will still be set when it should. Thus, the Set A will be true when $\overline{A}$ output is coupled to the Set input of flip-flop A.

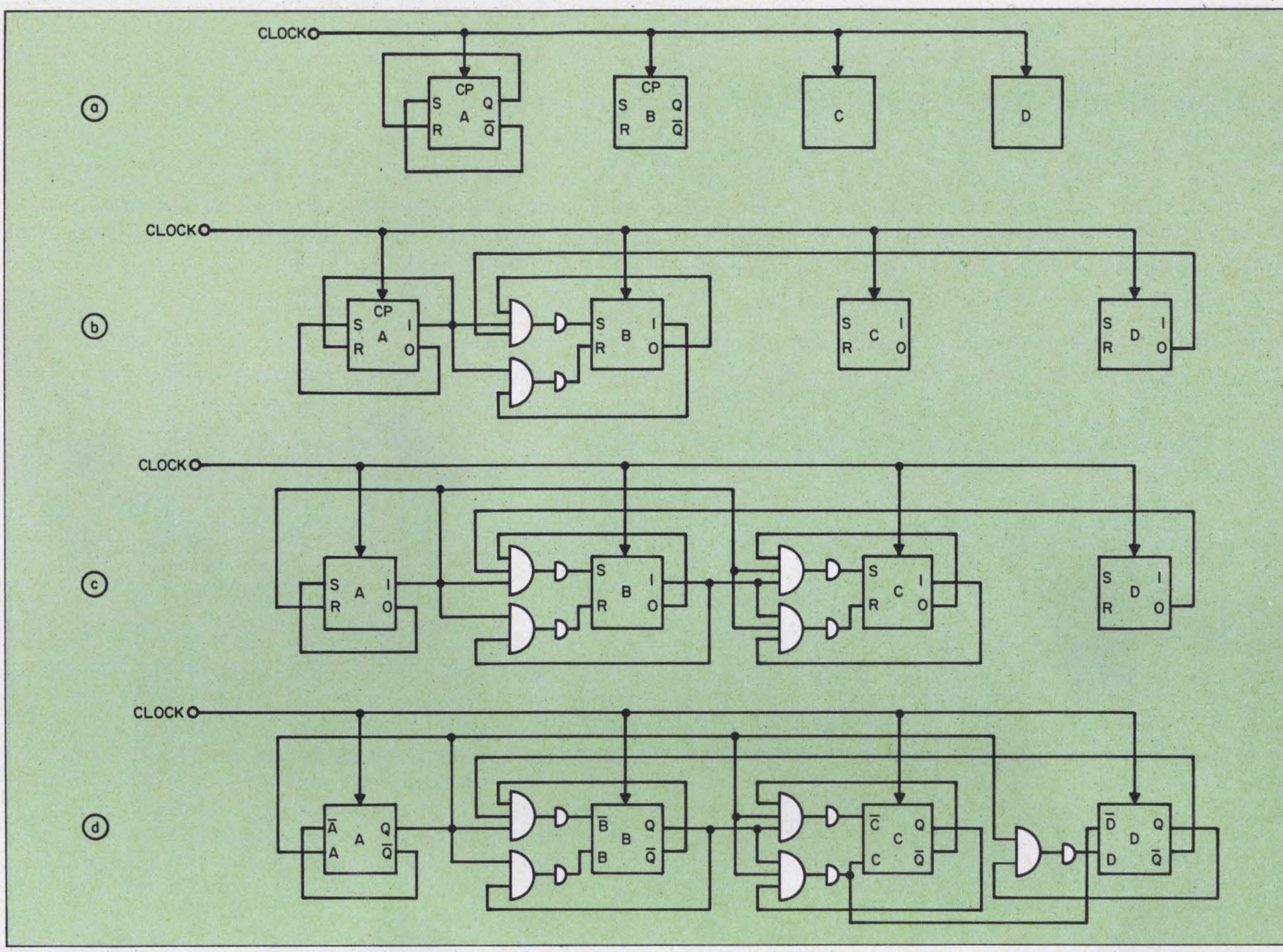
A must now be reset (See map labeled "Reset A"). The equation for this condition is: Reset $= A$ (or $A = 1$).

Flip-flop A becomes reset, or "*0*", whenever the following states of the BCD counter occur: *0001, 0011, 0101, 0111, 1001, 1011, 1101*, and *1111*. As in the previous instance, "don't-care" states are *1010* through *1111*. Enter the *1*'s and X's on the Karnaugh map and the result will be the equation for resetting A. Because $A = 1$ is the only condition that is constant in the grouping, it is the only bit needed to ensure the resetting of A.

Here the Q output is also called A and the $\overline{Q}$ is called $\overline{A}$. In a synchronous counter, the clock is simultaneously coupled to all flip-flops.

Set/reset for flip-flop B: Now the Set equations for flip-flop B can be obtained. From the code chart, we see that B is set when the following counter states are present: *0001, 0101, 1001*, and *1101*. Because *1101* (13) and *1010* (10) are greater than nine, we must not allow B to be set after count *1001* if we wish to ensure that only 10 different counter states will occur. Thus, *1001* must not be allowed to set B, as it would have in a binary counter (see table). The Karnaugh map for this condition is labeled "Set B." Only 2 squares may be enclosed. It is of no value to enclose the 4 squares of "don't cares," which are shown dotted. The two *1*'s enclosed are adjacent when the map is folded.

It is also of no added value to enclose the *1* and



1. **Karnaugh maps simplify BCD counter design** by eliminating the need for manual simplification of Boolean equations. The design proceeds step-by-step by obtaining the individual Set/Reset equations for flip-flops A, B, C and D in that order, as shown in (a) (b) (c) and (d) respectively. The completed design appears in (d).

SET A

SET A	A	0	1	1	0
	B	0	0	1	1
DC					
00		1			1
10		1		X	X
11		X	X	X	X
01		1			1

RESET A

RESET A	A	0	1	1	0
	B	0	0	1	1
DC					
00			1	1	
10			1	X	X
11		X	X	X	X
01			1	1	

SET B

SET B	A	0	1	1	0
	B	0	0	1	1
DC					
00			1		
10				X	X
11		X	X	X	X
01			1		

RESET B

RESET B	A	0	1	1	0
	B	0	0	1	1
DC					
00				1	
10				X	X
11		X	X	X	X
01				1	

adjacent *X*, because the enclosure shown already includes all the *1*'s necessary to reset *B*. The equation takes the form:

$$\text{Set } B = A\ \overline{B}\ \overline{D}.$$

From the table, the clock pulse will reset flip-flop *B* in order to decade-count when the counter is at *0011* and *0111*.
The equation is:

$$\text{Reset } B = A\ B$$

The BCD counter form is now as shown in Fig. 1b. The gates shown utilize negative NAND logic. It is necessary to invert the gate output so that the proper voltage will be present at the Set or Reset inputs. Ground potential is required to

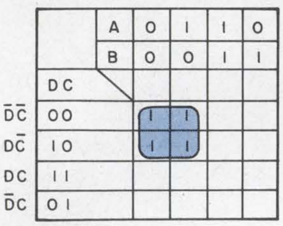
POSSIBLE COUNTER STATES

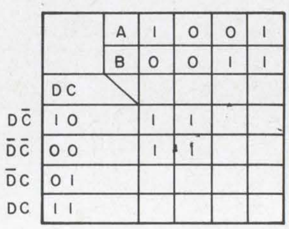
DIGIT	FLIP–FLOP D C B A	
0	0000	TEN COMBINATIONS FOR OUTPUT FROM FOUR FLIP-FLOPS
1	0001	
2	0010	
3	0011	
4	0100	
5	0101	
6	0110	
7	0111	
8	1000	
9	1001	
10	1010	THESE CODES WILL NOT BE ALLOWED TO OCCUR AT ANYTIME
11	1011	
12	1100	
13	1101	
14	1110	
15	1111	

How to use the Karnaugh map

Rules for applying Karnaugh maps in solving and minimizing Boolean equations and logic are:

1. Only one bit is allowed to change in each adjacent column or row heading.
2. The outside squares are assumed to be adjacent as in a cylinder or globe. All four corner squares are adjacent; i.e., the matrix could have been shown in either of the forms below. (*1* is the true state, and *0* is the false or "not" state.)



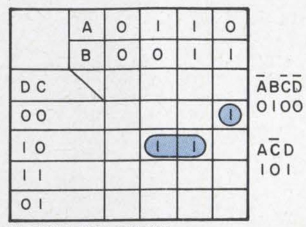


3. Logic minimization is possible when there is a symmetrical grouping of 2, 4, 8, or 16 squares that have a *1* or an *X* marked in them. The enclosing of a group of squares allows the writing of an equation that is composed of flip-flop states (such as *A*, *B*, *C* or *D*) which remain constant within the enclosure. In the example shown above, the four upper left squares have *1* marked in them. The enclosure is square and groups the four squares. Note that the *B* and the *C* states are consistently *0*. The Boolean expression $\overline{B}\,\overline{C}$ (i.e., not-*B* and not-*C*) is shown on the Karnaugh map.

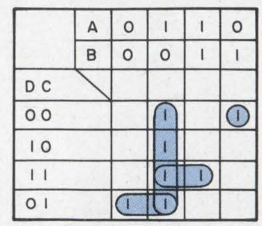
NOTE: Marking each of the squares that have $\overline{B}, \overline{C}$ ($B=0$, $C=0$) in common will result in the Karnaugh map shown above. Only rectangular enclosures are allowed. L or T shapes are not valid as a whole; that is, the equation must be written for each leg. The larger the square or rectangular enclosure, the more simple the equation becomes.

In the following example, there is a *1* in the squares where the equation $A\overline{C}D+\overline{A}B\overline{CD}$ is satisfied. To satisfy the equations: $A=1$, $\overline{A}=0$. Then $A\overline{C}D$ will be true for *1X01* (in order of *ABCD*), where *X* indicates that *B* can be either *0* or *1*; hence it is not needed in the equation. Therefore, on the Karnaugh map, mark *1* in squares where $A=1$, but only where the squares are also in line with $\overline{C}D$ (where $C=0$ and $D=1$) as shown in the circled squares upper right.

To finish the equation, write *1* in the square that has $\overline{A}B$ and $\overline{CD}$ in common. The resulting map is shown below.



IN EQUATION FORM:
$A\overline{C}D + \overline{A}B\overline{C}\overline{D}$



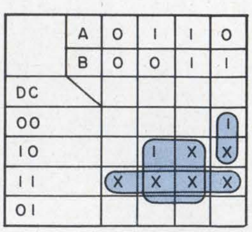
IN EQUATION FORM:
$A\overline{B} + ACD + \overline{B}C\overline{D} + \overline{A}B\overline{C}\overline{D}$

The equation for the Karnaugh map on the right could have been as complex as: $\overline{AB}C\overline{D}+A\overline{B}C\overline{D}+ A\overline{B}CD + A\overline{BC}D + A\overline{BCD} + ABCD + \overline{A}B\overline{CD}$. Note that the equation below the map will put a *1* in all required squares and is less complex.

Note that there are two places where a *1* is enclosed by more than one enclosure. Remember that the least complex equation will be found when the enclosed groups are symmetrical and still enclose as many *1* or *X* terms as possible. Terms that are enclosed in more than one group can be factored using Boolean algebra. For example:

$$A(\overline{B}+CD)+\overline{D}(\overline{B}C+\overline{A}B\overline{C})$$

4. A "don't-care" condition is said to exist when there are codes that do not occur, such as the last six codes in binary when a four-flip-flop decimal (10-count) counter is designed. A "don't-care" may be enclosed in a grouping as though it were a *1*. The "don't-care" is symbolized by an *X*.



Using the example given in Rule 3, the equation $A\overline{C}D+\overline{A}B\overline{CD}$ becomes $AD+\overline{A}B\overline{C}$.

Note that only groupings which also include *1*s are used in forming equations. Thus *CD* is not a useful equation.

SET C

SET C	A	0	1	1	0
	B	0	0	1	1
DC					
00				1	
10				X	X
11		X	X	X	X
01					

RESET C

RESET C	A	0	1	1	0
	B	0	0	1	1
DC					
00					
10				X	X
11		X	X	X	X
01				1	

RESET D

RESET D	A	0	1	1	0
	B	0	0	1	1
DC					
00					
10			1	X	X
11		X	X	X	X
01					

allow the Set or Reset inputs to operate.

Set/reset for flip-flops C and D: To detemine the Set equation for flip-flop *C*, note that *C* is set only at count *0011*. The Karnaugh map, "Set C," is shown below:

Therefore:

$$\text{Set } C = A\,B\,\overline{C}$$

Reset *C* occurs at count *0111*, so the equation is: Reset $C = A\ B\ C$ and the map is shown labeled "Reset C."

Note that on each map, the "don't care" conditions (10 through 15) are marked *X*.

The binary-coded decimal counter is now as shown in Fig. 1c:

Checking over the counter code table shows that the setting of flip-flop *D* occurs only at *0111*, which is the same time that flip-flop *C* is reset. This means that the gate output for resetting *C* can also be used to set *D*.

Therefore:

$$\text{Set } D = A\ B\ C$$

Reset *D* occurs at count *1001* only. The equation is:

Reset $D = A\ D$ and the map is labeled "Reset *D*."

The counter is now completely designed.

For the binary-coded decimal counter, some decoding matrices and other simple logic forms, the equations may be converted directly from the table of code combinations merely by inspection. Nevertheless, this exercise in the conversion from codes to equations to logic should help the reader to understand the process of digital design. Using the three basic steps—code-equation-logic—we can now design and solve other logic problems from beginning to end. We could count to any selected number, simply by writing the equations for setting and resetting and then implementing the equations with logic circuits. ■ ■

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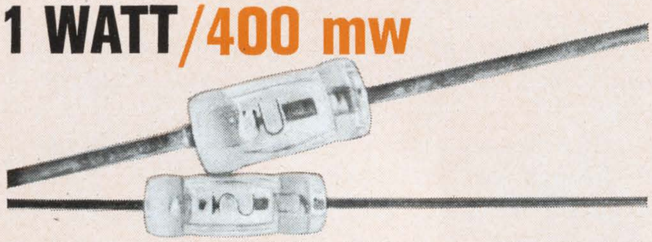

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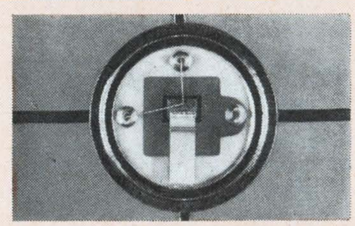

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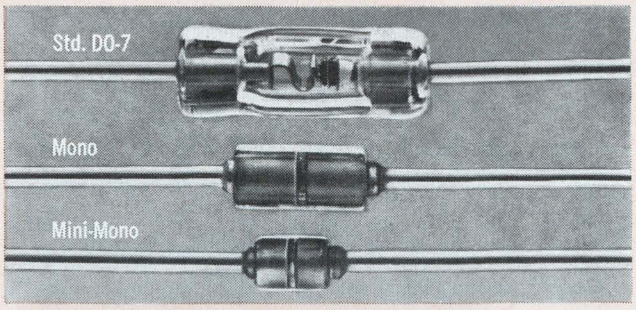
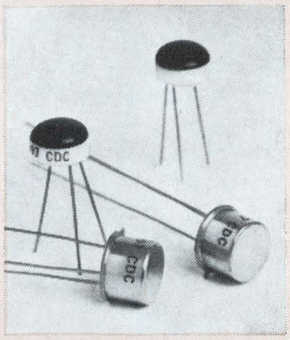


CDC's subminiature dual stud hermetic glass packaged unit is an extremely sophisticated device. Considerable dimensional and electrical flexibility exists. Units are available in O.D.'s from .060 to .100 and overall lengths from .090 to .265. Electrically, the range is from 1N457 to 1N3600.

DEVICE	STANDARD D07		MONO-DIODE EQUIVALENT		MINI-MONO EQUIVALENT	
	1-99	100-999	1-99	100-999	1-99	100-999
JAN 1N914	$ .35	$ .24	$ .40	$ .27	$ .70	$ .57
JAN 1N916	.52	.35	.65	.43	.95	.73

EPOXY/METAL CAN
TRANSISTOR



With CDC the chip's the thing! Only the package changes. CDC uses the same stringent process controls in manufacturing dice for epoxy transistors as are used for all military and high reliability metal packaged devices.

METAL CAN TRANSISTOR			EPOXY EQUIVALENT			
Device	1-99	100-999	Device	1-99	100-999	1000
JAN 2N697	$1.00	$ .67	CS 697	$ .60	$ .40	$ .28
JAN 2N1613	1.50	1.00	CS 1613	.70	.47	.30

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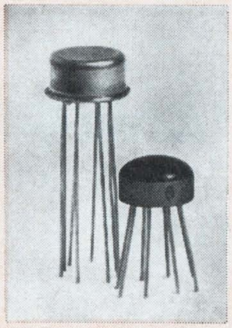
Model 9522 tests *all* DC E&I characteristics for any 2 to 14 lead integrated circuit. It is a solid state, short circuit protected device. It measures from 0-30V and from 1nA to 100mA. Also, it is adaptable for measuring switching characteristics. Has four 0 to ±15V power supplies with vernier control and two fixed 24V power supplies. Small, compact, easy to carry. Weighs a mere 25 lbs. Immediate delivery. $995.00.

RTL
Mono Circuit



Continental Device Corporation's RTL family of monolithic circuits is really an extension of CDC's proven ability in the manufacture of hi-rel volume components. And when it comes to prices, CDC wins the game.

OPERATING RANGE:		
	−55°C to +125°C	To-5 metal can
	0 to +100°C	To-5 metal can
	+15°C to +55°C	Epoxy equivalent

DEVICE	PART NO.	PACKAGE	1-99	100-999	1,000
Buffer	CMC219001	Epoxy TO-5	$ .80	$ .54	$ .36
Dual 2-Input Gate	CMC219141	Epoxy TO-5	.80	.54	.36
JK Flip-Flop	CMC219231	Epoxy TO-5	1.50	1.00	.67

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ON READER-SERVICE CARD CIRCLE 41

Precision digital clock uses ICs and a crystal oscillator to develop signals that are accurate to 10 parts in a billion.

An ordinary alarm clock that can be bought for less than $5 has an accuracy level of about one part in 1000. A fine watch, costing $100 or more, may be accurate to one part in a million. But for the engineer who has everything, there is an even more accurate timing device: a digital clock built with integrated circuits (Fig. 1).

Though it costs considerably more than other timepieces, it achieves an accuracy that exceeds one part in 10^8.

A 1-MHz crystal-controlled oscillator serves as the basic timing source. At this relatively high frequency, crystals achieve a greater degree of stability and accuracy then at lower frequencies. The oscillator output is coupled directly to the first stage of a series of six decade counters. These counters divide the 1-MHz timing signal by one million. The resulting one-hertz signal is the basic reference for all further timing in the clock.

System is iterative by nature

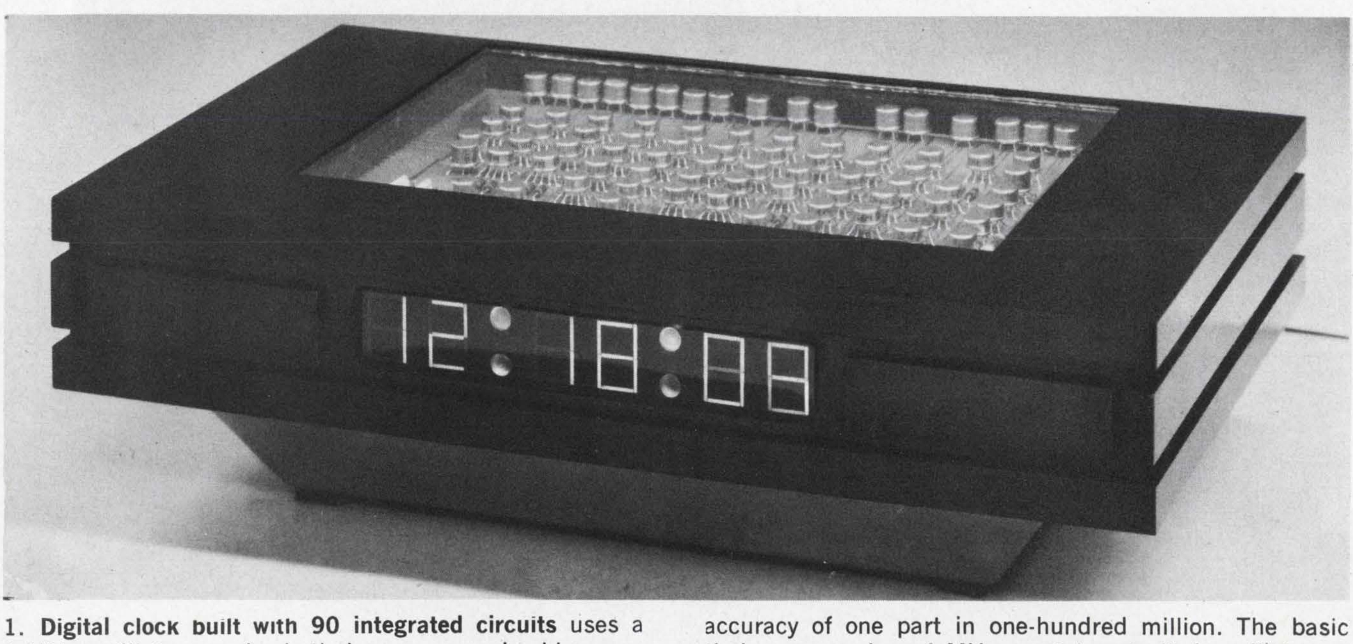
A general block diagram of the clock is shown in Fig. 2. Notice the iterative nature of much of the circuitry; i.e., the logic circuits for seconds, minutes and hours are all alike, as are the circuits for tens of seconds and tens of minutes. As it results in simpler circuitry, the clock follows the traditional United States method of keeping time and recycles to 01:00:00 o'clock at 12:59:59 o'clock plus one second. The Continental method, going from 0 hours to 24 hours, would require additional circuits in the last two stages.

Using an integrated decade counter drastically reduces the actual number of elements needed for implementation: Only six packages are needed to form the basic frequency divider network. The particular counter used (Fairchild CμL 958) is functionally shown in Fig. 3a; the relative position of the waveforms at the output appears in Fig. 3b. A positive transition occurs at output D as the count goes from nine to zero. Since this is the only positive transition at this terminal, this output can be coupled directly into the input of the next stage.

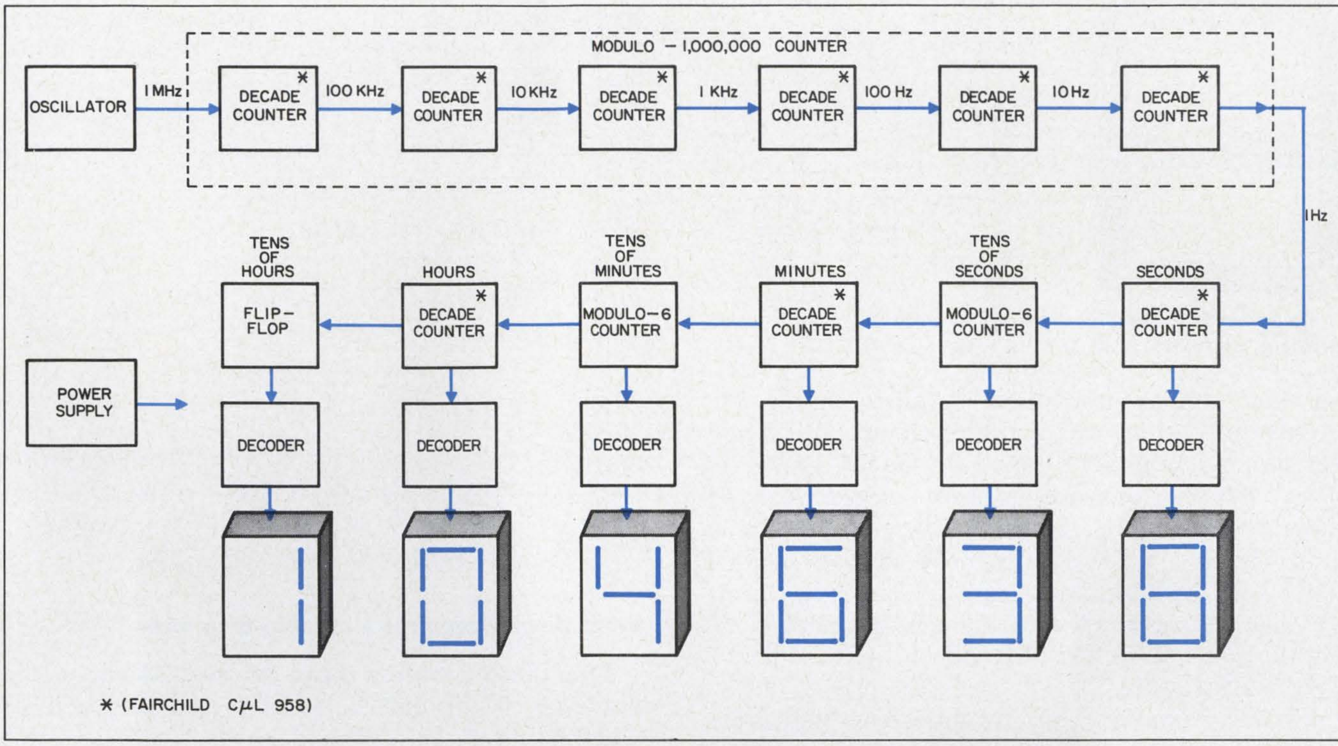
Because this counter provides a decimal output (through a binary code), it is also used as the units' counter circuit for seconds, minutes and hours.

To count tens of seconds and tens of minutes, a modulo-6 counter is required. The choice of possible circuitry for this is wide, so that selection

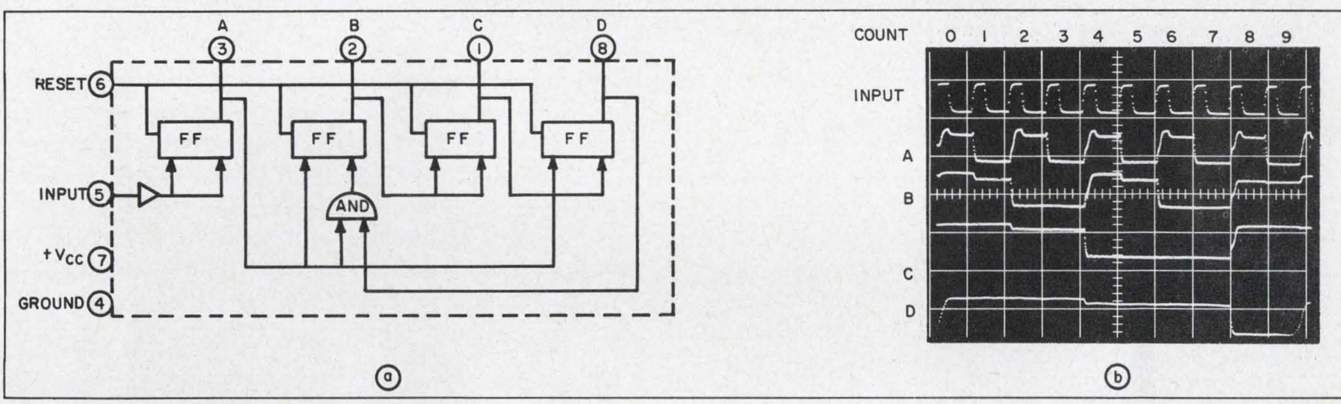
Jack Irwin and Robert Jensen, Applications Engineers, Fairchild Semiconductor, Mountain View, Calif.



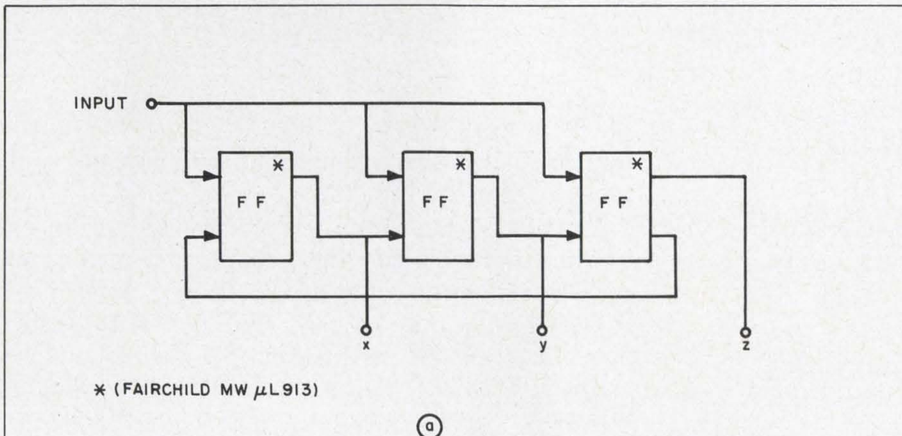
1. **Digital clock built with 90 integrated circuits** uses a 1-MHz oscillator as a basic timing source and achieves an accuracy of one part in one-hundred million. The basic timing source is a 1-MHz crystal-controlled oscillator.



2. **The four fundamental units of the clock** are the oscillator, counters, decoders and displays. Note the iterative nature of the count-decode-display combination for the seconds', minutes' and hours' sections.



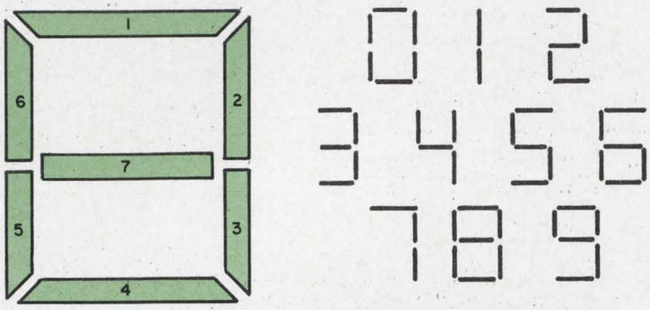
3. **Complete integrated decade counter** greatly reduces the component density; six of these make up the complete modulo- 1,000,000 counter. The functional diagram is shown in (a) and the output waveforms in (b).



COUNT	x y z	BINARY WEIGHT
0	0 0 0	0
1	1 0 0	1
2	1 1 0	3
3	1 1 1	7
4	0 1 1	6
5	0 0 1	4

(b)

4. **Modulo-6 counter uses three flip-flops** in a shift-mode arrangement (a). The truth table is shown in (b).



5. **Incandescent display has seven segments** and these form the numbers from zero to nine as shown.

becomes highly subjective. Because of its low power-dissipation rating, high fan-out, and ready availability, an RTL-type flip-flop (Fairchild MWμL 913) was used as the basic element for the modulo-6 counter. This counter, functionally shown in Fig. 4a, is a shift-mode counter, known also as a "walking clock" or "twisted-ring counter." The timing chart for this counter is given in Fig. 4b; on the sixth count, all outputs return to their initial state.

For the displays, six incandescent indicators were selected. Use of an incandescent display, as opposed to a gas-tube display, simplified the power supply design. This includes a direct connection to a set of rechargeable batteries so that stand-by power is available. The segmented indicator layout is illustrated in Fig. 5, along with the segmented display of the numerals 0 through 9.

Developing the logic for the units' decoders

The states of the units' counters are decoded as the counters progress through their cycles so that the appropriate indicator segments may be lit or extinguished. Since more segments are generally ON than OFF, the better method of indication is to extinguish superfluous lights rather than to illuminate needed lights. Note also that the numbers 6 could be represented with or without segment 1, and likewise the numbers 9, with or without segment 4; inclusion of these bars, however, lessens the amount of extinguishing that has to be done.

A set of logic equations, as a function of each segment, can be written for the numbers that have to be displayed. These take the form:

$$\overline{f_1}=(1+4+10+11+12+13+14+15),$$
$$\overline{f_2}=(5+6+10+11+12+13+14+15),$$
$$\overline{f_3}=(2+10+11+12+13+14+15),$$
$$\overline{f_4}=(1+4+7+10+11+12+13+14+15),$$
$$\overline{f_5}=(1+3+4+5+7+9+10+11+12+13+14+15),$$
$$\overline{f_6}=(1+2+3+7+10+11+12+13+14+15),$$
$$\overline{f_7}=(0+1+7+10+11+12+13+14+15).$$

The symbol for negation above (—), means extinction as opposed to ignition. Because all four binary variables are being dealt with, there is a possibility of sixteen states (0-15); but as the decade counter completes its cycle on the tenth count, states 10-15 will never occur and can thus be included as "don't cares" in our logic. The Boolean equations governing the decoding are:

$$\overline{f_1}=\overline{B}(A\cdot\overline{C}\cdot\overline{D}+\overline{A}\cdot C),$$
$$\overline{f_2}=C(A\cdot\overline{B}+\overline{A}\cdot B),$$
$$\overline{f_3}=(\overline{A}\cdot B\cdot\overline{C}),$$
$$\overline{f_4}=\overline{B}(A\cdot\overline{C}\cdot\overline{D}+\overline{A}\cdot C)+A\cdot B\cdot C,$$
$$\overline{f_5}=A+f_4,$$
$$\overline{f_6}=\overline{C}\cdot\overline{D}(A+B)+A\cdot B\cdot C,$$
$$\overline{f_7}=(\overline{B}\cdot\overline{C}\cdot\overline{D}+A\cdot B\cdot C).$$

These reduced equations can be implemented as shown in Fig. 6. Because certain logic combinations occur often, three new terms are created:

$$\overline{U}=A\cdot B\cdot C;\quad V=\overline{C}\cdot\overline{D};\quad \overline{W}=\overline{A}\cdot B.$$

Tens' display requires a modulo-6 counter

The tens' counters have to display only the numerals 0 through 5, so that the question of whether the 6 and 9 should have "bars" does not apply. It was consequently felt that in this case it was better to switch on the segment lights required than to extinguish those not required in the display indicator.

Figure 4b shows that the binary progression of the counter is actually: 0 - 1 - 3 - 7 - 6 - 4. Since it does not matter to the displays what the input to the decoder is, these values can represent the numbers 0 - 1 - 2 - 3 - 4 - 5, respectively. Only three variables are involved and thus eight distinct states are possible. Of these, the states 2 and 5 never occur, so they may appear as "don't cares" in our prime implicants. The functions governing the seven segments are as follows:

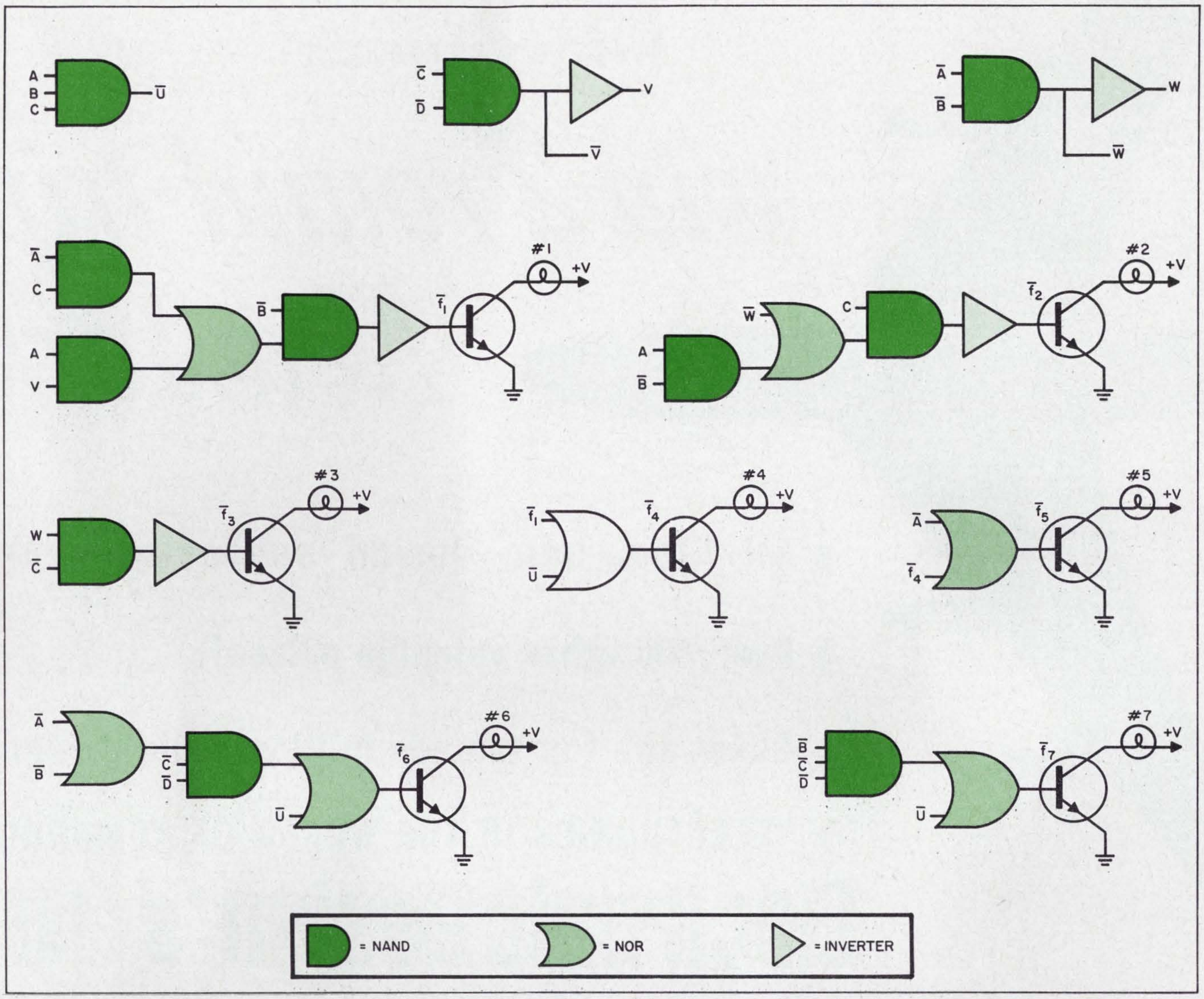
$$\overline{f_1}=(1+2+5+6),\qquad \overline{f_5}=(1+2+4+5+6+7),$$
$$\overline{f_2}=(2+5+6),\qquad \overline{f_6}=(1+2+3+5+7),$$
$$\overline{f_3}=(2+3+5),\qquad \overline{f_7}=(0+1+2+5).$$
$$\overline{f_4}=\overline{f_1},$$

When algebraically reduced, the equations become:

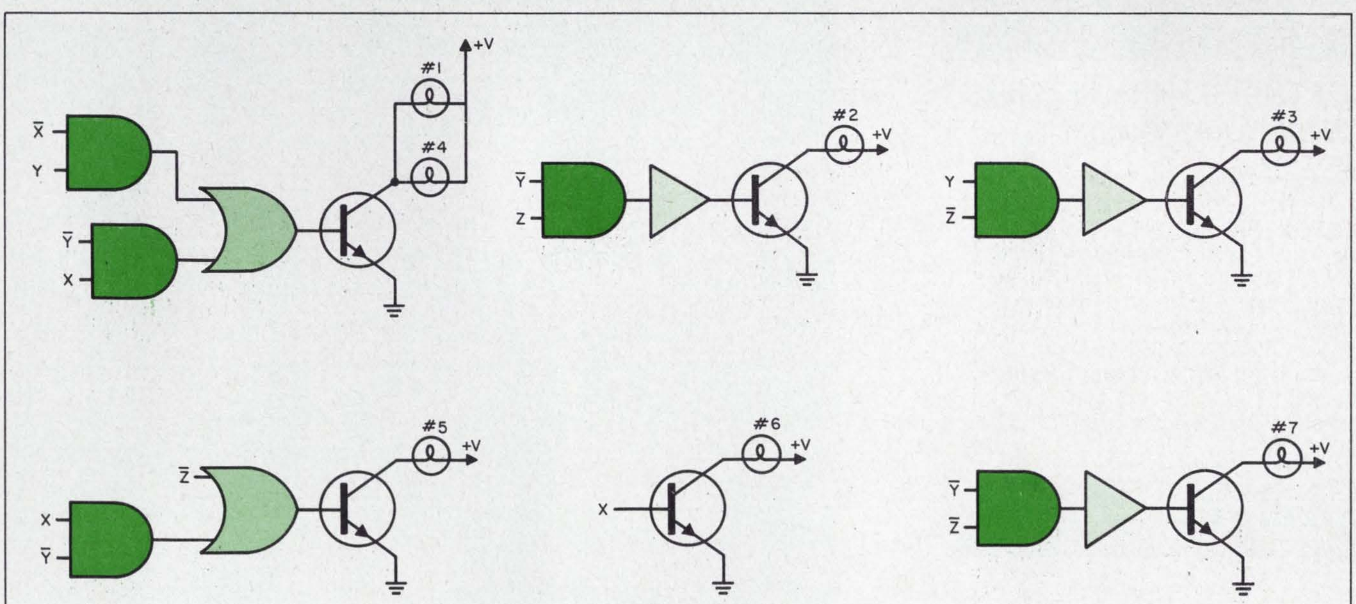
$$\overline{f_1}=\overline{X}\cdot Y+X\cdot\overline{Y},\qquad \overline{f_5}=\overline{Z}+X\cdot\overline{Y},$$
$$\overline{f_2}=\overline{Y}\cdot Z,\qquad \overline{f_6}=X,$$
$$\overline{f_3}=Y\cdot\overline{Z},\qquad \overline{f_7}=\overline{Y}\cdot\overline{Z}.$$
$$\overline{f_4}=\overline{f_1},$$

Implementing these equations yields the logic configuration in Fig. 7.

The hours' tens' circuit is a completely different circuit from the other tens' counters. Since a new cycle starts on the count of 12:59:59 + 1 second, a single flip-flop may be used. The hours' tens' flip flop is turned ON at 9:59:59 + 1 second and remains ON until the new cycle is started. During this time, segments 2 and 3 of the hours' tens' indicator are illuminated. At all other times this indicator is extinguished. ■ ■



6. **Decoding circuits for the units' sections.** The fact that certain combinations appear often makes it possible to achieve some simplification by creating sublogic, such as $\overline{U}$, V and $\overline{W}$. The functions (NAND, NOR, invert, etc.) are generally available from all integrated-circuit manufacturers.



7. **Decoding circuits for the tens' sections.** Some manufacturers offer multifunction integrated circuits, so that the circuits above can frequently be combined within one package.

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Not forgotten in the *"Top Ten"* contest, advertisers and their agencies may also enter. In addition to prizes of a **flight to Paris, color TV, and electronic timepiece,** the top 10 ads, and the winning advertiser's ad (if run January 4, 1967) will be re-run in the April 1st issue. Watch for the special *"Top Ten"* contest rules and entry blanks appearing January 4, 1967

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The "Spaceview" is an ideal timepiece for electronics engineers. Its clear-view dial reveals transistorized electronic circuit and tuning fork assembly. The tuning fork, advertising symbol and unique frequency standard of Accutron® timepieces, is the reason Bulova guarantees an in-use, on-the-wrist accuracy of within 60 seconds a month. (Retail value: $150.00.)

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This clothbound, 8½ x 11, 320-page, 1966 edition will be given free to 100 winners. "Microelectronic Design" offers a thorough overview of the field in six sections—has almost 90 outstanding articles compiled from the pages of *Electronic Design*. Edited by Howard Bierman. (Retail value: $11.50.)

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January 4 issue

"Top Ten" contest

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Entry blanks and complete contest rules will appear in the January 4th issue. Don't miss this opportunity to win one of the many valuable prizes shown at left. The first prize winner will receive round-trip tickets for two, between New York and Paris via Air France!

Try solid-state regulators for your high-voltage dc power requirements. You get big performance in a compact package.

Try designing your own solid-state high-voltage dc regulator the next time you require a long-life unit. Solid-state units in high-voltage applications have demonstrated useful lifetimes several times greater than that of vacuum-tube regulators. You can tailor your own regulator circuit quite easily with a step-by-step design procedure.

A typical regulator circuit providing a nominal output of 290 Vdc at loads of 50 to 600 mA is shown in Fig. 1. Regulation is better than ±0.5% with a 15% change in input voltage over a load variation of 50 to 600 mA.

The complete regulator consists of three major stages:

- *Series control element* (Fig. 2)—Essentially a two-element voltage divider network used to maintain the load voltage within desired limits. The input voltage is divided between V_{CE} of the series transistor and the load. The series element must be capable of adjusting its voltage drop, V_{CE}, to compensate for the change in input voltage. A similar condition exists when the input voltage is constant and a variable output is required. V_{CE} is defined as E_{in} less E_{out}.
- *Preregulator* (Fig. 3)—In regulator design it is common practice to return the base of the series element through a resistor to the positive side of the unregulated supply (Fig. 3a). In this case, ripple current from the unregulated supply is injected into the base of the series control element and amplified. This amplified ripple appears in the output and may be overcome by the use of a preregulator (Fig. 3b).

The preregulator consists of two resistors, *R1* and *R2*, and a Zener diode, *D1*. The Zener tends to keep a constant voltage across *R2* and therefore supplies a constant current, I_Z, to the collector of the sensing amplifier and to the base of the series element. The reference voltage of *D1* may be any value less than $E_{in}-E_{out}$ that will supply sufficient current to *Q2* and *Q3*.

- *Sensing amplifier* (Fig. 4)—The sensing element samples the output voltage, compares it with a reference voltage and produces an error signal that is proportional to the difference. The emitter-coupled differential amplifier is used as a sensing element because of its high sensitivity and good thermal stability.

The current through *R7* must supply the collector of *Q4* and the base current for the dc amplifier. Resistor *R8* is not critical, but should be almost the same value as *R7* in order to keep the differential amplifier balanced. With an understanding of the functional requirements of each regulator stage, the designer can now proceed with calculation of circuit values. Design of the regulator begins with the series control element (Fig. 2). In this particular circuit the DTS-413 transistor was chosen, but the same design approach could be taken with other devices, such as the DTS-423 or the 2N2580 series.

DTS-413 operating limits

Operating points	Input E_{in}	Input I_{in}	Output E_{out}	Output I_{out}	V_{CE}	I_E
1	min	max	max	max	min	max
2	min	min	max	min	min	min
3	max	max	min	max	max	max
4	max	min	min	min	max	min

Design series control element first

The area of operation for the series element can be defined by four points which can be plotted on the safe-operating-area curves (Fig. 5). The characteristics of each of these points are shown in the table above.

David E. Engel, Applications Engineer, Delco Radio Division, General Motors Corp., Kokomo, Ind.

Each of these four points has its particular limitations with respect to the operation of the transistor. Care must be taken that the maximum ratings of the transistor are not exceeded.

Point 1. V_{CE} is minimum and I_C is maximum. The point must not exceed the maximum allowable I_C. Sufficient base drive must be available to produce the desired I_C but the transistor must not be driven to saturation.

Point 2. V_{CE} is minimum and I_C is minimum. This point should not lie in the nonlinear saturated region.

Point 3. V_{CE} is maximum and I_C is maximum. This point must not exceed the maximum dc dissipation rating of the series transistor.

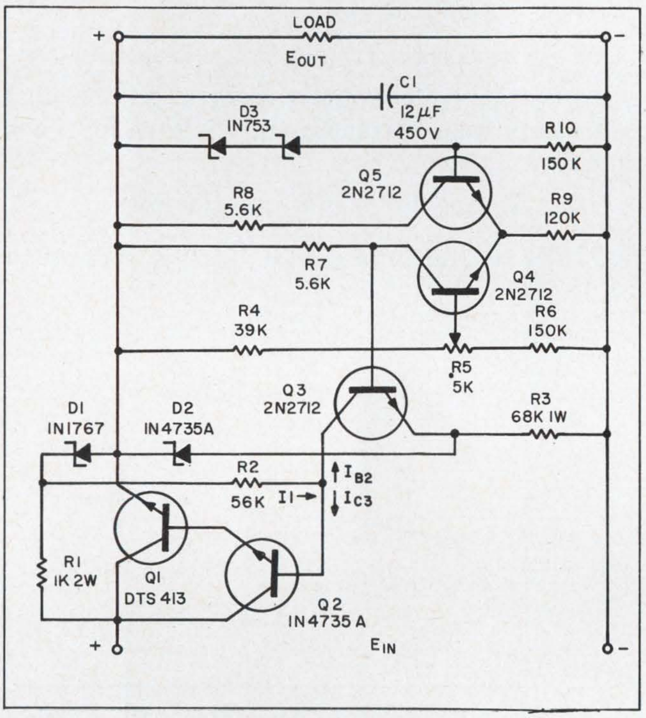
Point 4. V_{CE} is maximum and I_C is minimum. This point must not exceed the maximum V_{CE} rating of the transistor.

Heat sink design is an important factor to consider in a Class-A series regulator. For example, assume the following conditions:

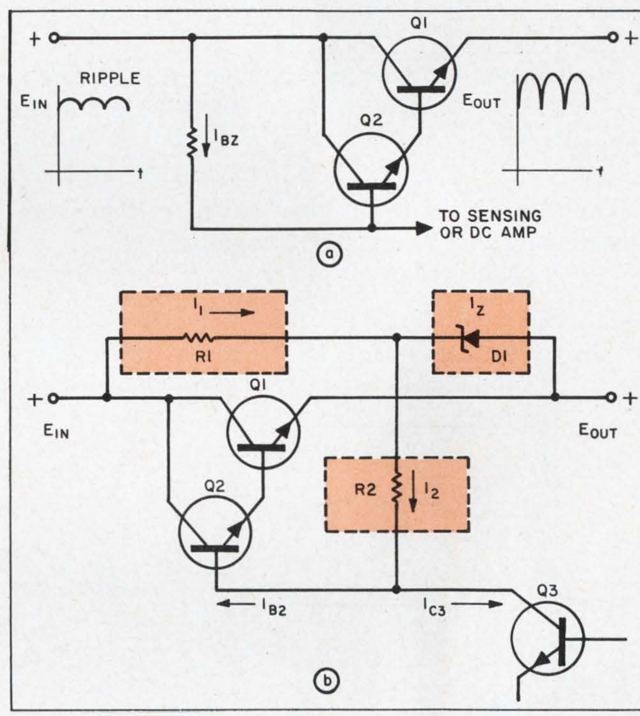
- The application requires a maximum ambient temperature ($T_{A\ max}$) of 75°C.
- Heat sink 7281366* has a surface area of 165 in^2 and a thermal resistance, θ_{hs}, of 1.5°C/W to ambient air for free-air convection.
- The DTS-413 has a maximum thermal resistance (junction to heat sink), θ_{jhs}, of 1.0°C/W and a maximum allowable junction temperature of 150°C.

The maximum allowable dissipation, P_{max}, may

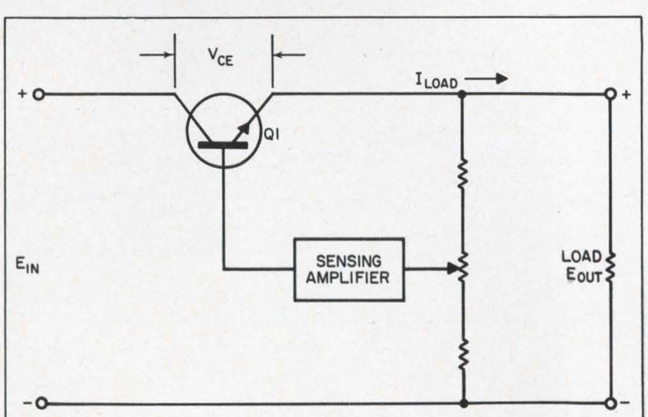
*Delco Radio data sheet 7281366.



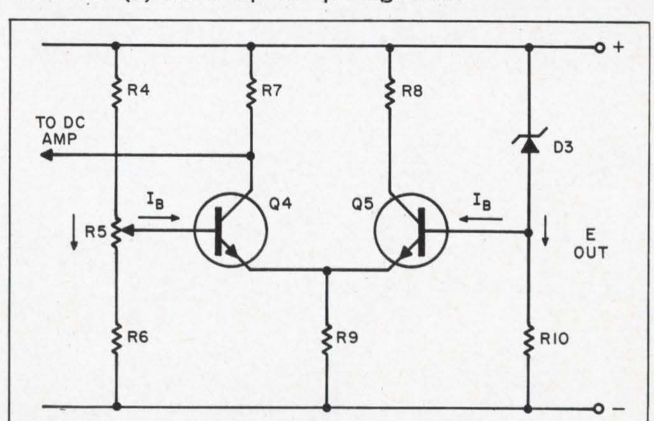
1. **High-voltage silicon transistors make a compact regulator** that can handle high currents while providing tight output voltage regulation. Step-by-step procedure simplifies the design of the regulator circuit.



3. **The preregulator filters ripple current** from the input supply. The ripple is amplified by the series control element Q1 (a). Resistors R1 and R2 together with Zener diode D1 (b) make up the preregulator.



2. **Series control element maintains output voltage** within desired limits. The circuit is basically a two-element voltage divider.



4. **The sensing amplifier samples the output voltage,** compares it with a reference (D3) and produces an error signal proportional to the difference.

be calculated by:

$$P_{max} = (T_{j\ max} - T_{A\ max})/(\theta_{hs} + \theta_{jhs})$$
$$= (150°C - 75°C)/(1.5°C/W + 1.0°C/W)$$
$$= 30\ W.$$

Thus it can be seen from the 30-W curve in Fig. 5 that the heat sink is a factor limiting the operating area of the series element. This area may be extended by limiting the maximum ambient temperature or by improving the heat sink (for instance, with forced-air cooling or liquid cooling†).

In order to minimize power dissipation in the sensing circuit, the output current to the series element should be kept small. Additional gain may be obtained by using a compound, or Darlington, driver for the series control element, as shown in Fig. 6. Allowable base currents for both transistors are calculated by using the maximum allowable collector current for *Q1* (Fig. 5) and the transistor characteristics:

Q1 (DTS-413)—h_{FE} = 25 min where I_C=500 mA,
$\therefore I_{B1} = I_C/h_{FE} = 500\ mA/25 = 20\ mA;$

Q2 (2N3439)—h_{FE} = 40 min where I_C=20 mA,
$\therefore I_{B2} = I_C/h_{FE} = 20\ mA/40 = 0.5\ mA.$

The Darlington driver must have a voltage capability equal to the main series element.

The 2N3439 was selected for the drive transistor because of its gain distribution at 20 mA (h_{FE}=40 min). Its high-voltage characteristics are similar to the DTS-413's.

Preregulator uses Zener diode

Component values for the regulator stage are calculated in the following manner.

We start with I_{B2}=0.5 mA, and assume that $I_{C3} = I_{B2}$. Then $I_2 = I_{C3} + I_{B2} = 0.5 + 0.5 = 1.0$ mA.

Since V_{Z1} may be any value less than $E_{in\ min}$ that will supply sufficient current to *Q2* and *Q3*, a 6.8-V Zener (*D*1) was chosen.

R2 is now calculated:

$$R2 = [V_Z - (V_{EB1} - V_{EB2})]/(I_{B2} + I_{C3})$$
$$= 6.8 - (0.7 - 0.7)V/1.0\ mA$$
$$= 5.4\ k\Omega.$$

A 5.6-kΩ resistor was used.

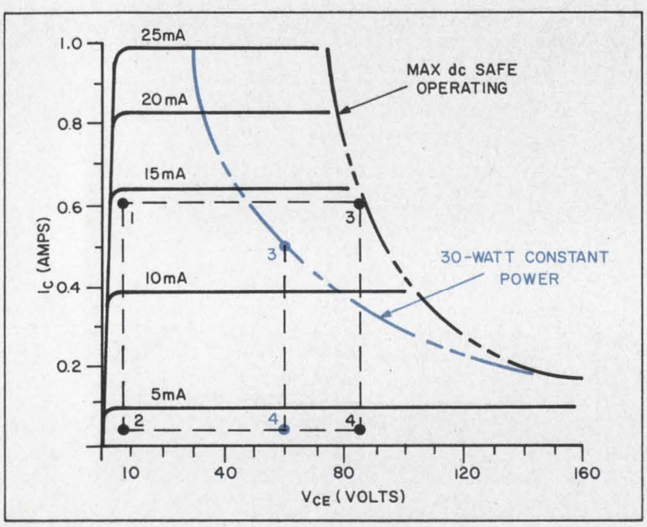
To calculate *R1* we use:

$$R1 = [(E_{in\ min} - E_{out\ max}) - V_{Z1}]/I_1,$$

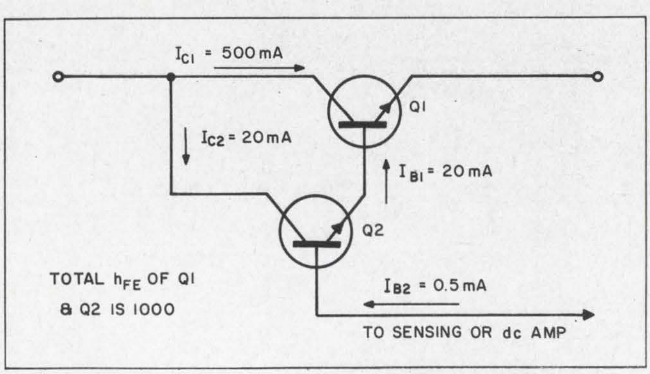
where $I_1 = I_2 + I_Z$. The Zener diode (1N1767) that was chosen has a dissipation of 0.7 W at 70°C and therefore:

$$I_{Z\ max} = 0.7\ W/6.8\ V \approx 100\ mA.$$

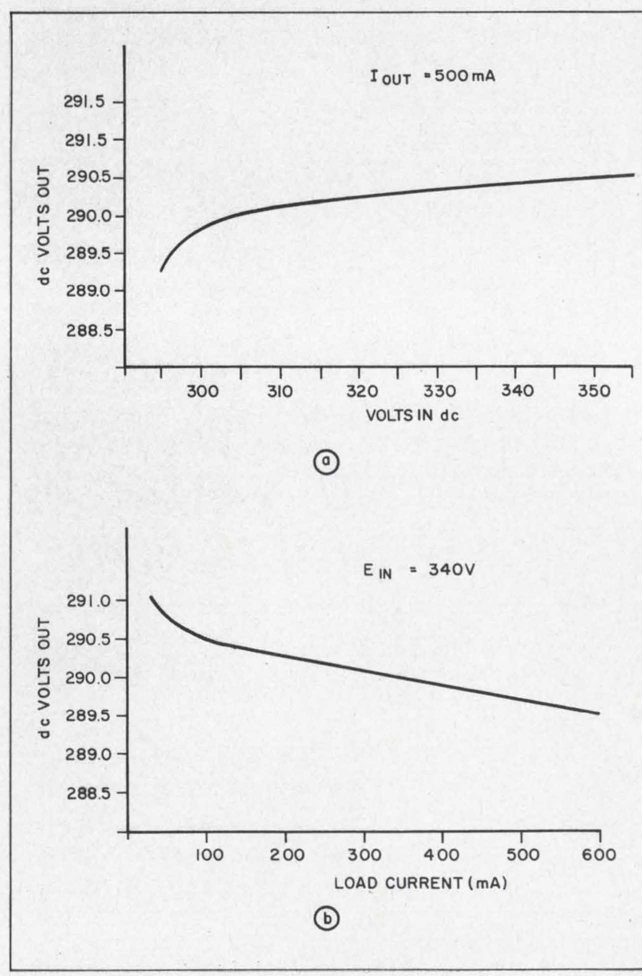
†See "Beat the Heat in Electronic Systems," ELECTRONIC DESIGN, XIV, No. 21 (Sept. 13, 1966), 58-63.



5. **Operating characteristics of the DTS-413** transistor show safe operating range of the device.



6. **Addition of a compound, or Darlington, amplifier** provides additional gain for the series control element.



7. **Varying inputs and loads are easily handled** by the regulator as shown in the performance curves above.

Thus $I_1 = 1 + 100 = 101$ mA. Then:

$$R1 = [(340-280)-6.8]\text{V}/101\text{ mA}$$
$$= 520\ \Omega.$$

This value of *R1* results in a dissipation of 5.2 W; this was considered excessive, so a 1-kΩ resistor was used.

Sensing amplifier completes design

In the sensing amplifier (Fig. 4), silicon Zener diode D_3 is used as the reference element. The breakdown voltage of a Zener is reasonably constant over a range of reverse currents. The temperature coefficient of a Zener diode approaches zero where V_Z is between 5 and 6 V. When breakdown voltages are less than 5 V, the coefficient is usually negative. As breakdown voltages increase above 6 V, the temperature coefficient becomes increasingly positive. To minimize the effects of temperature, two 1N753A (6.2 V) Zeners are used in series. The sum of the two series units (12.4 V), in addition to providing the reference voltage, allows the transistors *Q4* and *Q5* to operate at low voltage. The current through reference element *D3* and the divider (*R4*, *R5* and *R6*) must be much greater than the base currents required by *Q4* and *Q5*. Transistors *Q4* and *Q5* are 2N2712s biased to an emitter current of approximately 1 mA each.

Finally the value of Zener *D2* in the complete circuit (Fig. 1) should be chosen not to exceed the voltage rating of *Q3*. As a rough approximation, the value should be about one volt greater than the voltage drop across *R7* when the differential amplifier is balanced.

The dc supply used to provide power for the regulator is usually some form of rectified ac source. For this design, the supply should have a nominal value of 320 V and must be capable of supplying a minimum of 300 V under full load and a maximum of 340 V under light conditions. The regulator should not be operated under a no-load condition. If this is a requirement, a bleeder resistor should be added across the output to maintain a stand-by current of 40 to 50 mA. The 12-pF capacitor across the output provides stability under light-load conditions.

Performance curves showing the effectiveness of the circuit are shown in Fig. 7.

An important advantage of this particular regulator is that, through the use of a so-called crowbar circuit (SCR overload-sensing circuit), the regulator may be made short-circuit-proof. In the foregoing example, in the case of a short circuit, *Q1* must withstand a collector-to-emitter voltage of 300 V simultaneously with a collector current of 1 A or more. The DTS-413 can withstand this overload for 500 ms. The crowbar circuitry would therefore have to be capable of operating in less than 500 ms. ■ ■

Self-protection built in

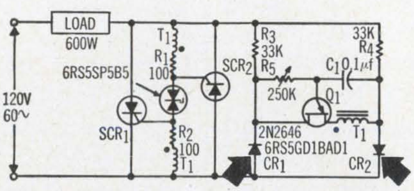
ELECTRONIC INNOVATIONS IN ACTION

Low-cost G-E Selenium Encapsulated Rectifiers

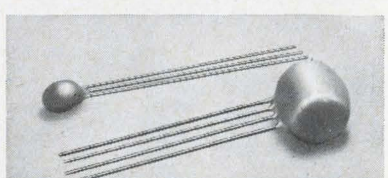
■ Self-protection against transient voltage is built into all General Electric low-cost, low-current Miniature Selenium Encapsulated Rectifiers.

Ideal for light electronics applications, these little wonders (the largest is less than five-eighths inch in diameter) are available with current ratings from 2 ma. to 150 ma. Input voltage can be as high as 540 volts. Frequency capability stretches up to 25 kHz.

G-E selenium miniatures are packed with application potential. Use them for toys and electric razor motor control, electric cigarette lighters, lamp dimmers, and TV antenna boosters. They're also being used in nickel-cadmium battery chargers, and the full wave control circuit shown here is ideal for heaters, fans, and limited range control of lamps.



Full wave control circuit using General Electric 6RS5GD1BAD1 Miniature Selenium Encapsulated Rectifier.



Actual typical size of General Electric Miniature Encapsulated Rectifiers.

Self-protecting G-E rectifiers are available in a variety of circuit configurations including single phase half wave, center tap, doublers, and bridges—plus special types.

Low cost? Sure. A completely assembled encapsulated bridge can be purchased and wired into the circuit at less cost than four surplus silicon diodes.

For further information on Miniature Selenium Encapsulated Rectifiers—or on G.E.'s total electronic capability—write to Section 220-44, General Electric Company, Schenectady, New York. In Canada: Canadian General Electric, 189 Dufferin St., Toronto, Ont. Export: Electronic Components Sales, I.G.E. Export Division, 159 Madison Ave., New York, N. Y.

SEMICONDUCTOR PRODUCTS DEPARTMENT

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ON READER-SERVICE CARD CIRCLE 43

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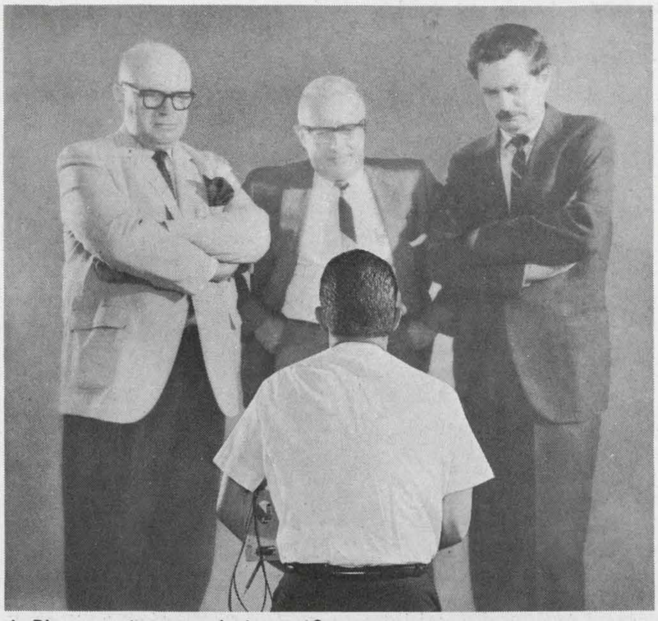
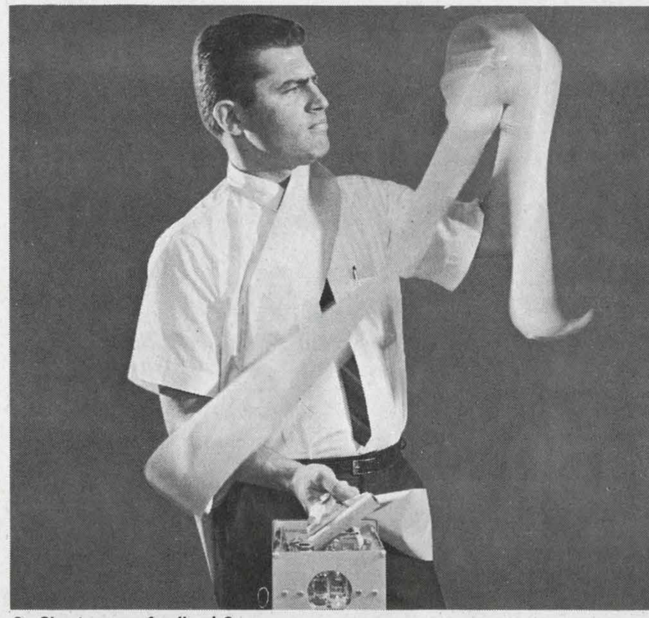
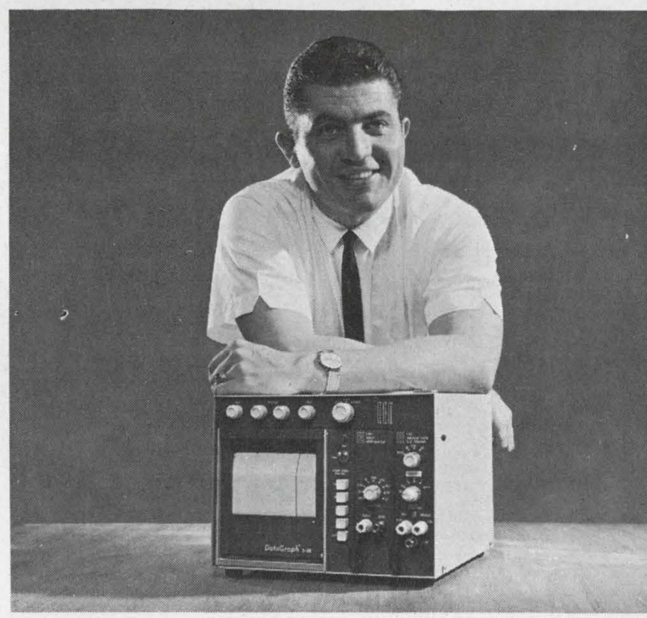


1. Big moment — wrong instrument?



2. Chart paper feedback?

3. Smeared traces — inky hands?



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ON READER-SERVICE CARD CIRCLE 44

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Simplify vector analysis. Use this set of nomographs to eliminate those time-consuming computations.

The addition and subtraction of vectors is usually a tedious computational process. You can eliminate these arithmetic steps by using nomographs.

Given the magnitude and direction of a set of vectors in a three-dimensional system, the first step is to reduce them to their co-ordinate components. Arithmetic operations are then performed, and the resultant set of co-ordinate components can be reconverted to a single vector of the correct magnitude and direction. This can be done more quickly by the use of these nomographs than by actual calculation.

To see how the nomographs work, start with the graphical representation of a vector, **V**. In spherical co-ordinates this vector may be written as:

$$\mathbf{V} = |\mathbf{V}|, \underline{/\phi, \theta,}$$

where

V is the vector,

$|\mathbf{V}|$ is its scalar magnitude,

ϕ is its angular displacement from the **k** vector, and θ is its angular displacement from the **i** vector.

In rectangular coordinates it may be written as:

$$\mathbf{V} = a\mathbf{i} + b\mathbf{j} + c\mathbf{k},$$

where

i, **j** and **k** are unit vectors in their respective planes.

a, b and c are scalar quantities in their respective planes.

Determining co-ordinate components

If $|\mathbf{V}|$, ϕ and θ are known for a given vector, then the nomographs can be used to break the vector down to its co-ordinate components, as follows:

(1) Determine $|\mathbf{V}|$, ϕ and θ. Annotate $|\mathbf{V}|$ in unit decimal terms ($2400 = 2.4 \times 10^3$).

(2) Determine a. Enter $|\mathbf{V}|$, ϕ and θ on Fig. 1. Connect $|\mathbf{V}|$ and ϕ to intersect the Index Line. Connect this index point with θ to intersect the right-hand line. This intersection will give the value of a.

(3) Determine b. Enter $|\mathbf{V}|$, ϕ and θ on Fig. 2. Connect $|\mathbf{V}|$ and ϕ to intersect the Index Line. Connect this index point with θ to intersect the right-hand line. This intersection will give the value of b.

(4) Determine c. Enter $|\mathbf{V}|$ and ϕ on Fig. 3. Connect these points to intersect the right-hand line. This intersection will give the value of c.

Determining the new vector

This process is then repeated for as many vectors as are involved in the operation, until they have all been broken down to their component parts. They may then be added or subtracted simply by adding or subtracting their components as follows:

$\mathbf{V}_1 = a_1\mathbf{i} + b_1\mathbf{j} + c_1\mathbf{k}$.

$\mathbf{V}_2 = a_2\mathbf{i} + b_2\mathbf{j} + c_2\mathbf{k}$.

$\mathbf{V}_t = \mathbf{V}_1 \pm \mathbf{V}_2 = (a_1 \pm a_2)\mathbf{i} + (b_1 \pm b_2)\mathbf{j} + (c_1 \pm c_2)\mathbf{k}$.

$\mathbf{V}_t = a_t\mathbf{i} + b_t\mathbf{j} + c_t\mathbf{k}$.

Enter a_t, b_t and c_t on Fig. 4. Connect a_t and b_t to intersect the Index Line. Connect this index point with c_t to intersect $|\mathbf{V}_t|$. This intersection will give the value of $|\mathbf{V}_t|$.

ϕ_t may then be determined by using Fig. 3 as follows:

(1) Enter $|\mathbf{V}_t|$ on the $|\mathbf{V}|$ line.

(2) Enter $|c_t|$ on the c line.

(3) Connect the two to intersect the ϕ line. Read out the value ϕ_t.

θ_t may now be determined from Fig. 5 as follows:

(1) Enter a_t on the a line.

(2) Enter b_t on the b line.

(3) Connect the two to intersect the θ line and read out the value θ_t.

A practical example

A simple example is worked out where it is desired to resolve the sum of two vectors, such as:

$\mathbf{V}_t = \mathbf{V}_1 + \mathbf{V}_2$.

Assume:

$|\mathbf{V}_1| = 500 (5\times10^2)$, $\phi_1 = 45°$, $\theta_1 = 30°$.

$|\mathbf{V}_2| = 500 (5\times10^2)$, $\phi_2 = 45°$, $\theta_2 = 60°$.

Using Figures 1, 2 and 3 for a, b and c respectively, we get:

$a_1 = 3.06\times10^2$; $b_1 = 1.77\times10^2$; $c_1 = 3.54\times10^2$.

$a_2 = 1.77\times10^2$; $b_2 = 3.06\times10^2$; $c_2 = 3.54\times10^2$.

$a_t = 4.83\times10^2$; $b_t = 4.83\times10^2$; $c_t = 7.08\times10^2$.

Using Fig. 4, we get:

$|\mathbf{V}_t| = 9.8\times10^2$.

Using Fig. 3, we get:

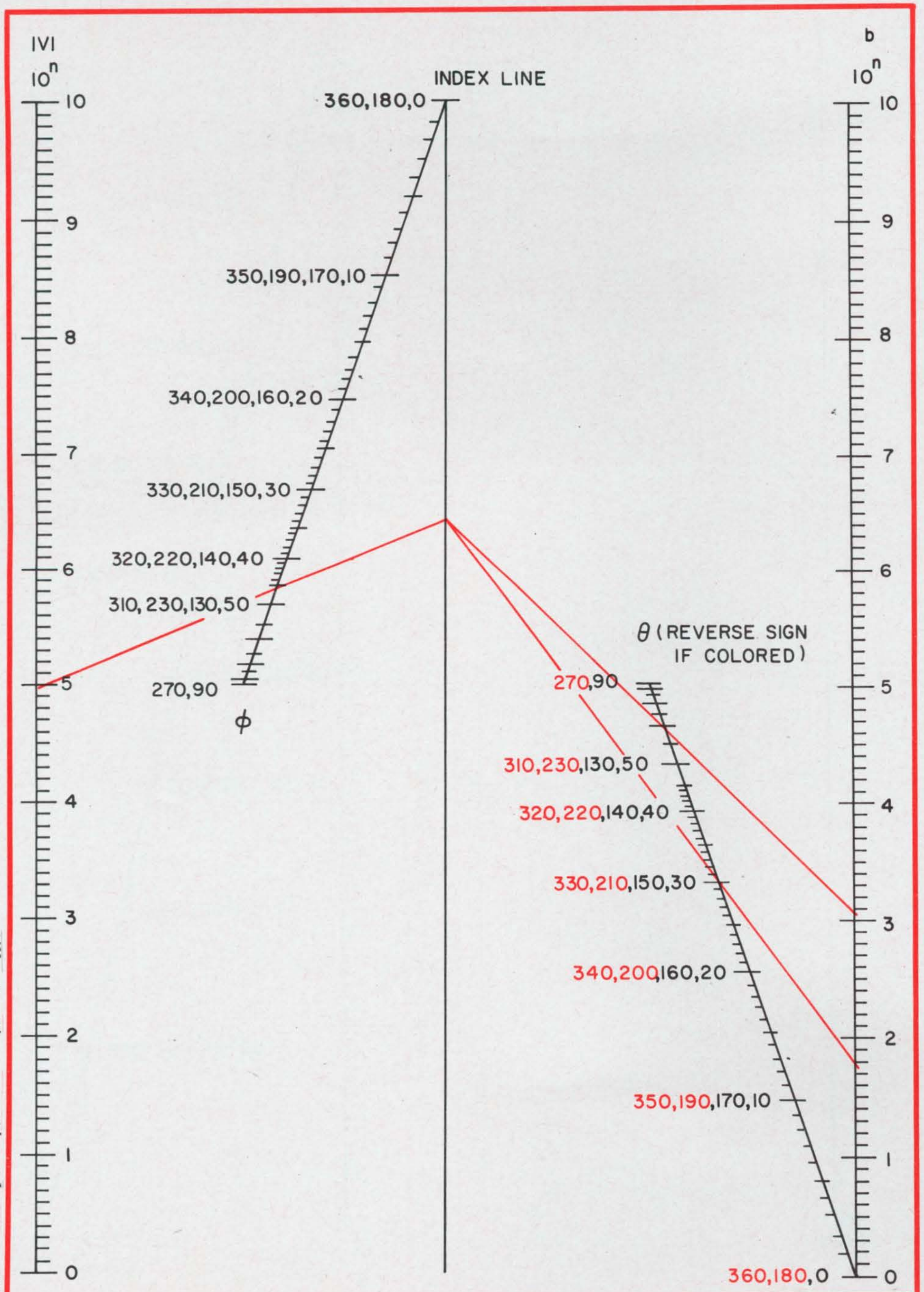
$\phi_1 = 44°$.

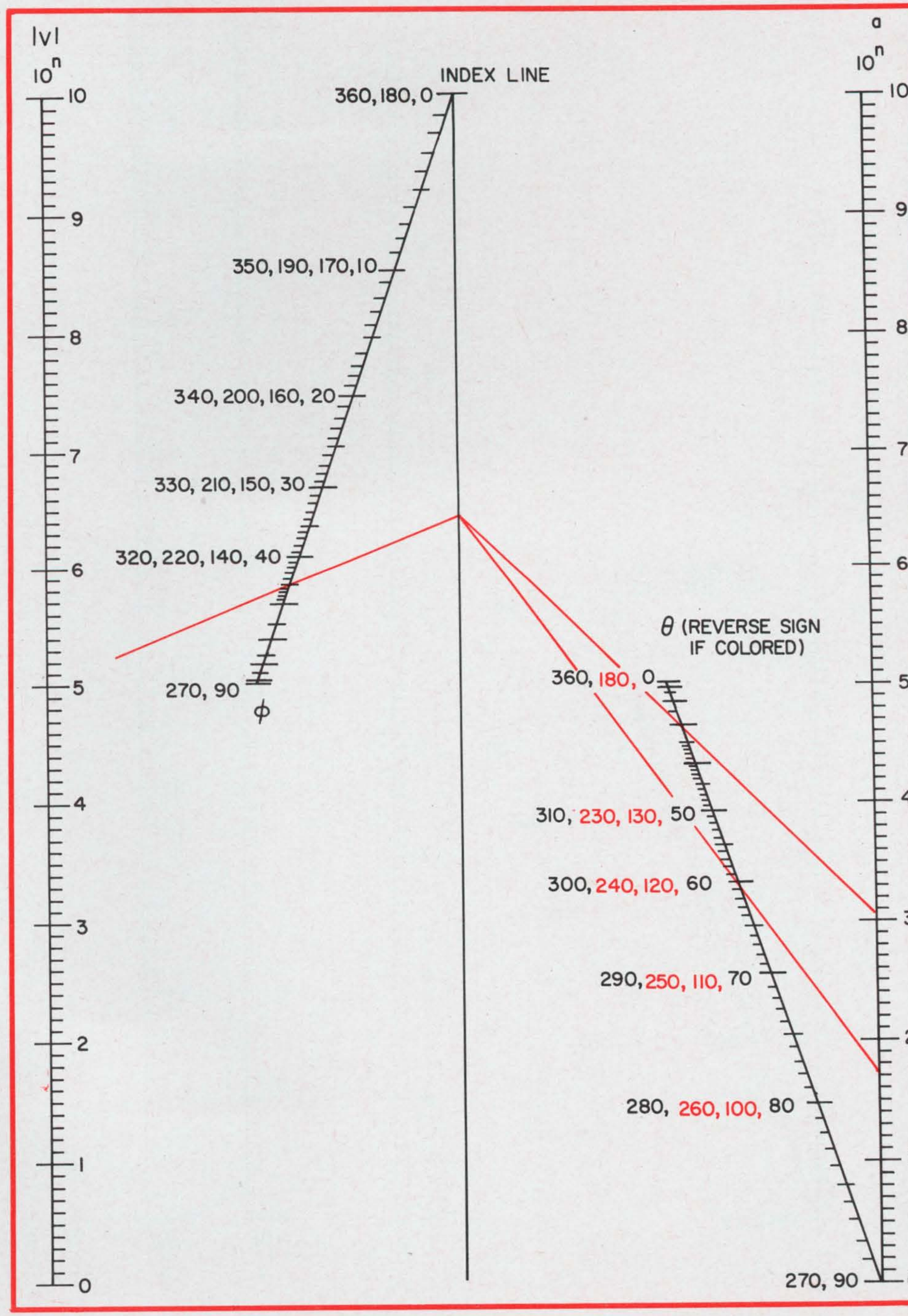
Using Fig. 3, we get:

$\theta_t = 45°$.

It can be seen that these graphs eliminate the large number of trivial computations that would have been required for even this simple problem. The same nomographs can be used for a two-dimensional system by merely setting either ϕ or θ to zero. ■ ■

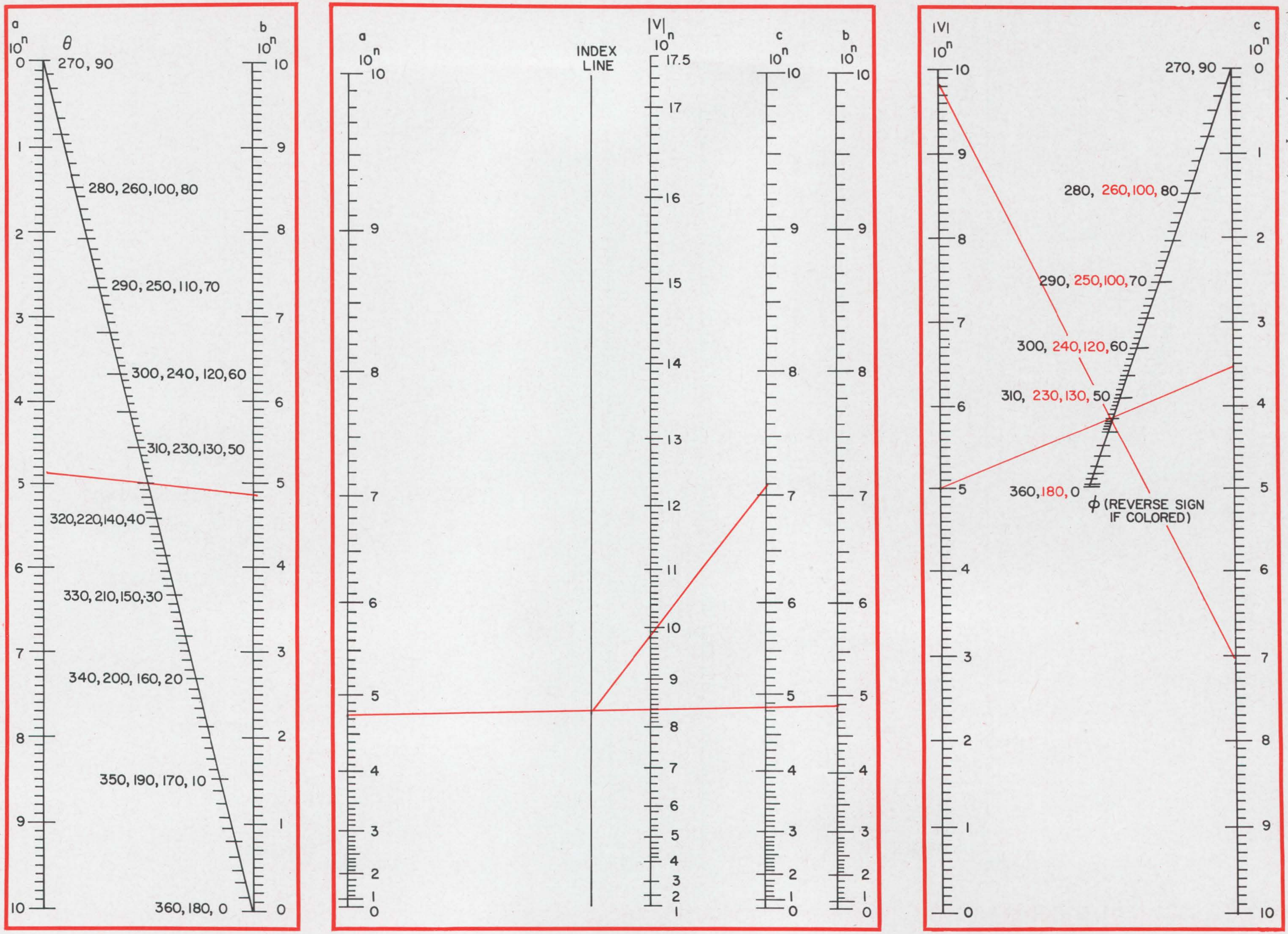
by **Dr. R. L. Peters**, Consultant, New York, N. Y.

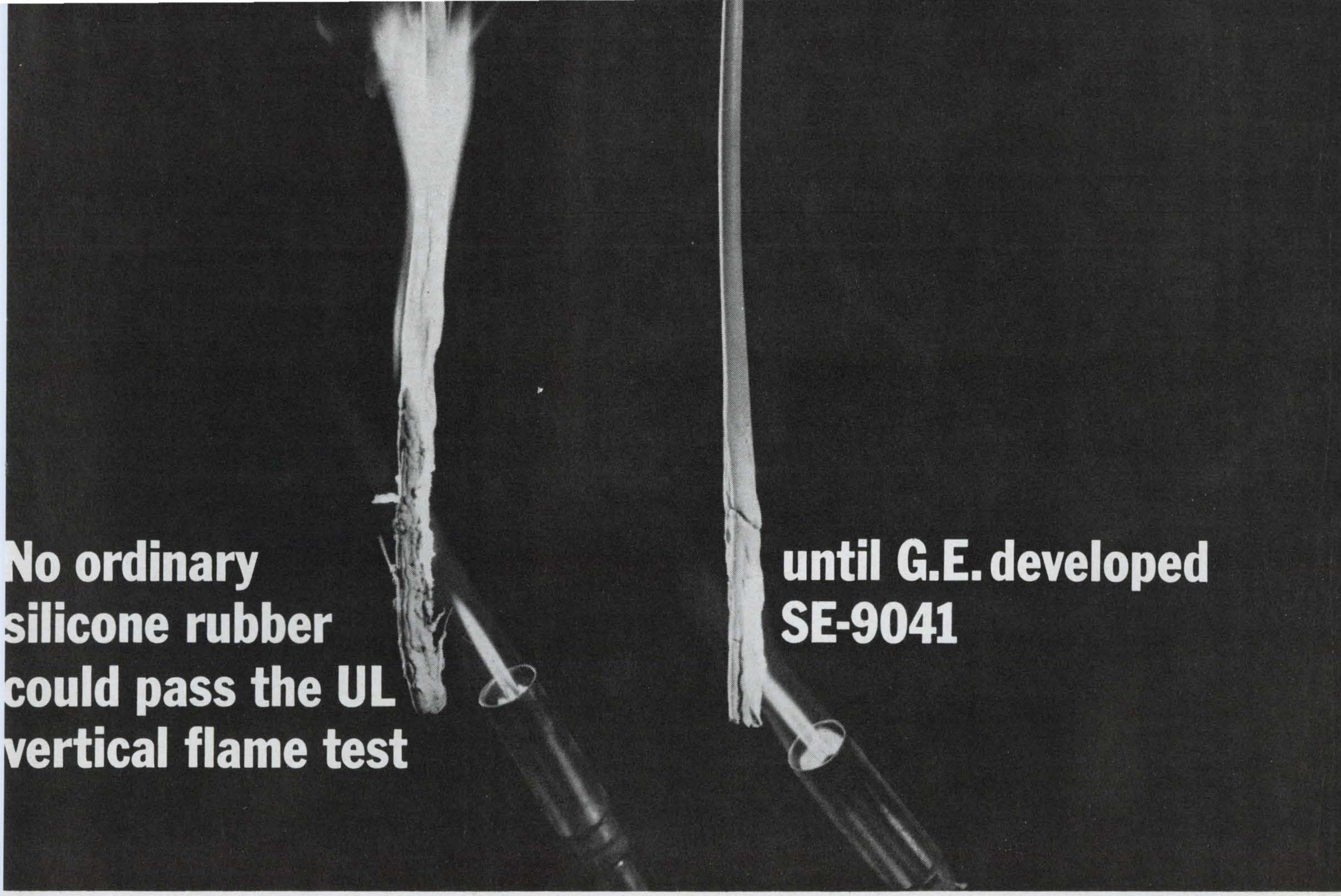




(illustrations continued on p. 84)

(continued from p. 83)

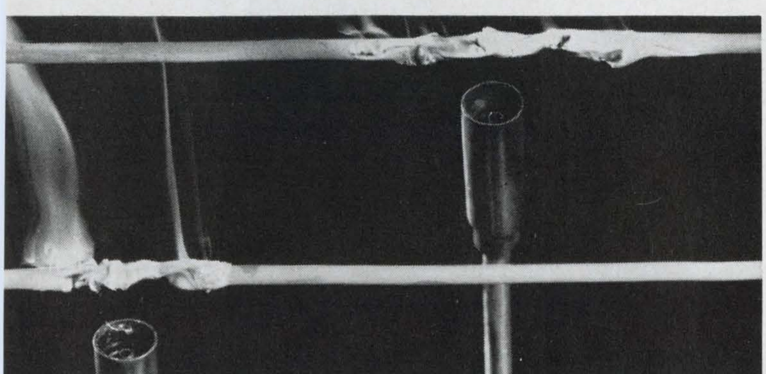




Ordinary silicone rubber wire insulation was only half-safe. It met Underwriters' Laboratories requirements when held *horizontally* over a flame, but flunked UL's *vertical* flame test. That's why General Electric developed SE-9041 – the first economical silicone rubber insulation to pass *both* UL flame tests. New SE-9041 meets UL specifications as insulation for any size conductors without flame-retardant exterior braids or saturants.

SE-9041 is versatile too. Although it was originally developed specifically for television wiring, this new silicone compound can be used in any high voltage circuit from ignition wiring to klystron wiring. In electrostatic precipitators or magnetrons, for example.

But that's only part of the story. SE-9041 is also superior in dielectric strength. A No. 22 AWG conductor insulated with a 75 mil wall of SE-9041 would have a typical breakdown voltage of 500 volts/mil a-c. About 50% higher than values obtained with previous silicone rubber compounds! We especially formulated this new silicone rubber insulation to hold high-voltage stresses for prolonged periods of time.



For horizontal wiring requirements, any silicone rubber insulation provides superior resistance to flame propagation. It's on the vertical jobs that SE-9041 built a reputation as a firefighter. First among lower-priced silicone insulations to pass the demanding UL vertical flame test.

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Want a sample for evaluation? Be our guest.

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Now it can be told . . .

Evading radar detection is a cinch

for aircraft equipped with EASY—a system that takes advantage of a radar's blind spots.

While novel in concept, this radar evasion system has a somewhat restricted range of application. In fact, it can be used only against a low-budget aggressor, who has placed all his defense dollars into the construction of moving-target radars. In the context of a limited war fought against such a shortsighted enemy, the Evasive Aircraft System (EASY) offers tremendous potential. Before proceeding with a detailed description of EASY, it is necessary to appreciate fully those characteristics of certain radar systems that make EASY possible.

Moving target radar has blind spots

Pulse radar detection systems operate by periodically transmitting pulses of electromagnetic energy in a narrow beam. Energy, reflected by a target in the beam, is received after a propagation delay and is processed for an optimum measurement against background noise. If the reflected energy (return) from a target is great enough to trigger a threshold device, the presence of a target is indicated, at a range determined by the propagation delay and at an azimuth corresponding to the beam pointing angle. Figure 1 shows a block diagram of this simple radar.

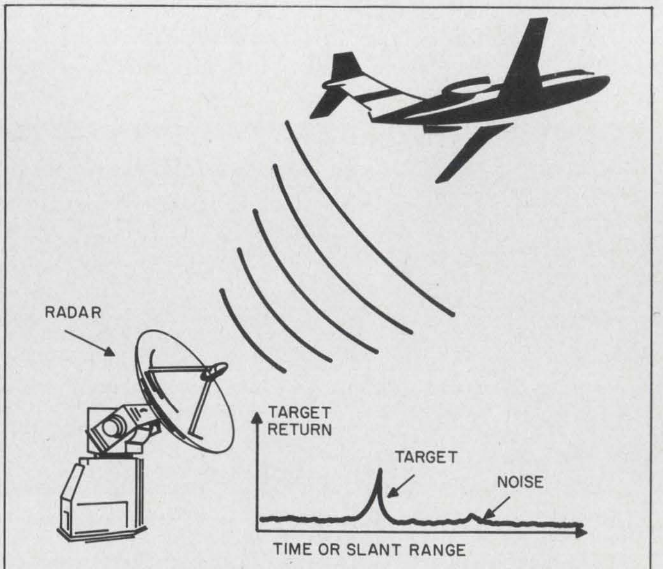
Radars which are equipped with a moving target indicator (MTI) provide enhancement for the return from moving targets. The return from fixed targets differs from that of targets moving radially with respect to the radar. Since signal phase (that is, time delay) is proportional to the distance between the radar and the target, the phase of fixed targets remains constant between pulses. The phase of moving targets varies from pulse to pulse with the distance that the target has moved. If a target has a constant radial velocity, there is a constant rate of change of target return phase, that is a Doppler-shifted return signal. The effect of target radial motion is, more generally, both a frequency shift and a broadening of the target return spectrum. The difference in the return spectra for fixed and moving targets is shown in Fig. 2. The spectrum for fixed targets is centered at $f_0 \pm nf_r$, where f_0 is the transmitted frequency and f_r is the pulse repetition rate.

An MTI radar has provision for comparing successive target returns, and in so doing, canceling the return from fixed targets. A typical cancellation characteristic is seen in Fig. 2. A property of such systems is the periodic nulls, which occur at multiples of the radar repetition rate, and the aircraft radial speeds, which produce corresponding Doppler shifts. The existence of these "blind" speeds is the basis for the EASY system.

EASY system fools the MTI

The EASY system is based on varying the radial speed of an aircraft so that the aircraft will always be traveling at a blind speed of the enemy's radar. Consider a simplified model, which might be applied to a ship or other ground vehicle:

A vehicle travels at constant speed, greater than or equal to the first blind speed, and in the plane of the radar. Where vehicle speed equals blind speed, the proper course is a radial line toward the radar. If vehicle speed is greater than first



1. **Radar detection of an airborne target** is accomplished by the fairly well-known technique of transmitting radio-frequency energy and monitoring any echoes, which result from the reflection of a portion of the transmitted energy from a target object.

Robert M. Goldberg, Staff Engineer, General Instrument Corp., Radio Receptor Div., Hicksville, N. Y.

blind speed, the proper path is a logarithmic spiral. This spiral has a constant angle between its tangent and a radial line to the origin. Clockwise or counterclockwise paths are equivalent. Since radial speed and total speed are constants:

$dr/dt = K_1 = f_r\lambda/2$ (blind speed)

and

$ds/dt = K_2 = [r^2(d\theta/dt)^2 + (dr/dt)^2]^{1/2}$ (vehicle speed),

then slant range:

$$r = \epsilon^C \epsilon^{\theta/K}, \qquad (1)$$

where $K = [(K_2/K_1)^2 - 1]^{1/2}$,

θ = target bearing, and C is an integration constant.

If the radar has maximum and minimum coverage ranges of r_1 and r_2, respectively, then $C = \ln r_1$. It is then necessary to circle the radar by N revolutions to reach safety, i.e., $r = r_2$, where:

$$N = 1/2\pi[(K_2/K_1)^2 - 1]^{1/2} \ln r_2/r_1, \qquad (2)$$

where $1 < K_2/K_1$.

Figure 3 shows the number of revolutions required to penetrate the radar as function of the ratio of vehicle speed to blind speed.

The problem in three dimensions is formulated in cylindrical co-ordinates in Eq. 3. The conversion to spherical is straightforward. In order to keep radial speed constant, the rates of change of total aircraft speed, aircraft altitude, and turning angle with respect to the radar can be varied separately and in conjunction:

$(ds/dr)^2 = (dz/dt)^2 + (r\, d\theta/dt)^2 + (dr/dt)^2$ (vehicle speed);

$dR/dt = K_1$ (blind speed);

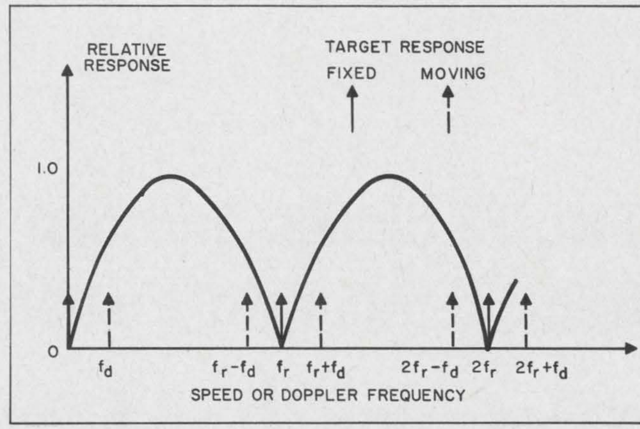
$R^2 = r^2 + z^2$ (slant range);

$$(ds/dt)^2 = [(1 + z^2/R^2 - z^2)\, dz/dt - 2\, RzK_1/R^2 - z^2]\, dz/dt + (R^2 - z^2) + (d\theta/dt)^2 + R^2\, K_1/R^2 - z^2. \qquad (3)$$

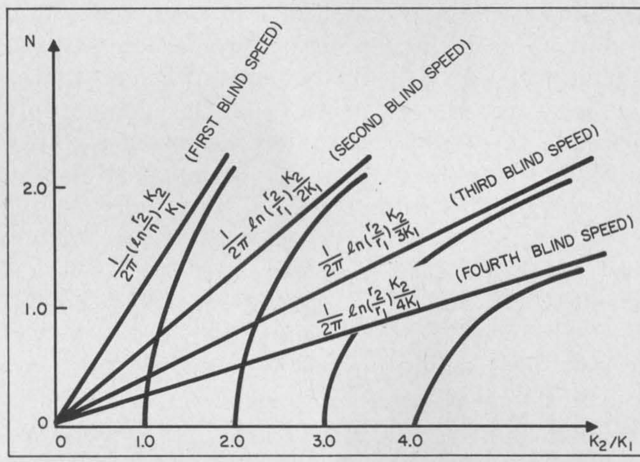
A block diagram of an EASY system instrumentation appears in Fig. 4. As shown in the figure, it is necessary to monitor the enemy radar continuously in order to determine its operating parameters and relative position. The EASY computer compares the relative aircraft-radar position against a desired target location and selects a suitable flight path. Command signals are sent to the autopilot continuously to direct the path of the aircraft.

A reduction in cost can be realized with the system by installing only a single EASY system for each mission. A lead aircraft can then be used to ferry other aircraft around the radar.

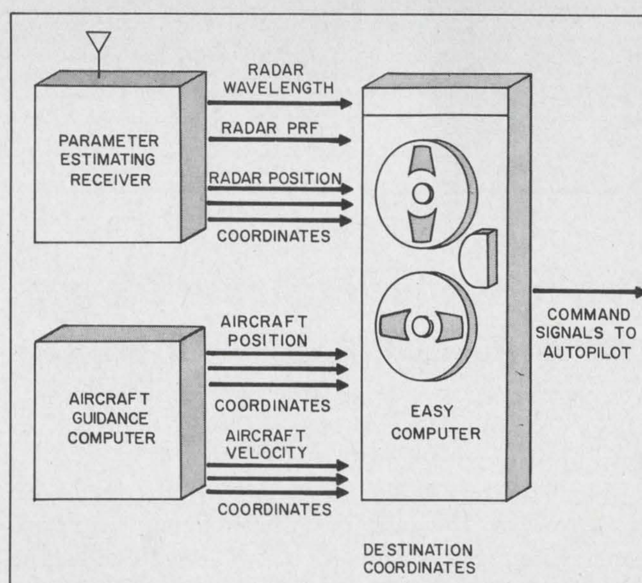
A still greater cost reduction can be achieved by not installing any EASY systems at all, since. as mentioned earlier, the system is ineffective against conventional radars, of which there are many. It is hoped that discussion of the EASY system has nevertheless made clear some of the salient characteristics of MTI radar. ■ ■



2. **Response from a target will differ** depending on whether the target is fixed or moving. In the case of a radar equipped with an MTI (Moving Target Indicator), periodic nulls occur at multiples of the radar's pulse repetition rate. It is these blind spots that make EASY possible.



3. **The number of logarithmic-spiral encirclements, N,** required to take advantage of the radar's blind spots, vary as the ratio of vehicle speed to the radar's blind speed.



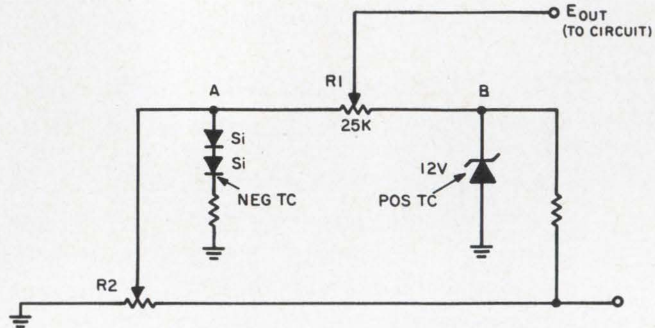
4. **Instrumentation needed to incorporate EASY** into an aircraft, or other vehicle, is relatively uncomplicated when considered on a functional basis. The actual hardware employed is not critical and may consist of anything that's handy.

Two Si diodes and one Zener track temperature changes

Temperature compensation with an offset voltage can be achieved with a pair of silicon diodes and a Zener diode. The circuit introduces a temperature-dependent offset with either a positive or negative temperature coefficient and reduces the compensation to a simple two-point tracking. It is especially useful in cases when high stability is demanded of a production run of oscillators and when the normal tolerances of the temperature characteristics of the components preclude achieving the required degree of stability without hand-tailoring the compensation by repeated temperature runs.

To track a circuit over a temperature range, first adjust *R2* (see schematic) for equal voltages at points *A* and *B* at room temperature. Then raise or lower the temperature to one of the extremes desired and adjust *R1* for tracking.

Approximately equal but opposite incremental voltage changes with temperature will be obtained at points *A* and *B* by placing two forward-biased silicon diodes in one leg of the bridge and a back-biased 12-volt Zener diode in the other leg.



Temperature-dependent voltages are produced at points A and B. The operation is reduced to a simple two-point tracking method.

If the temperature-dependent voltage is always either positive or negative, the superfluous network may be replaced simply by a resistive divider.

For ease of adjustment in some applications, it is not necessary to place the two potentiometers *R1* and *R2* in the temperature chamber for calibration.

Alex. W. Adler, President, Radio Research Co., Rockaway, N. J.

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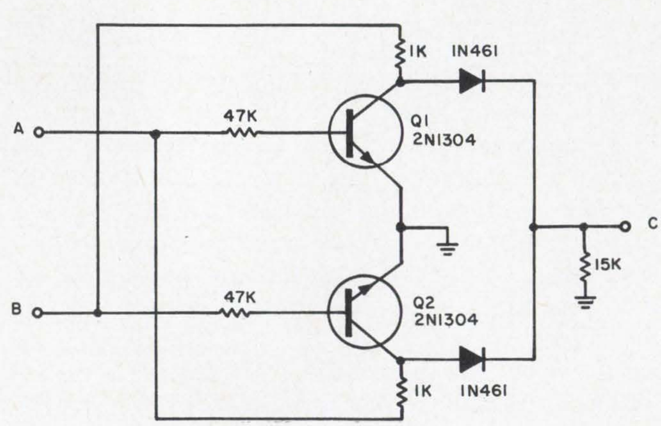
Two-transistor exclusive-OR gate needs no external power supply

Here is a two-transistor exclusive-OR gate (modulo-2 adder) that does not require an external supply voltage.

When the inputs *A* and *B* (see Figure) are both at zero volts, the output *C* is obviously also zero volts. When *A* is +10 volts and *B* is zero volts, the base-to-emitter junction of *Q1* is forward-biased and the collector of *Q1* is at zero volts. There is no potential difference between the base and the emitter of *Q2*, and therefore the collector of *Q2* is at about +10 volts. Since the two diodes and the

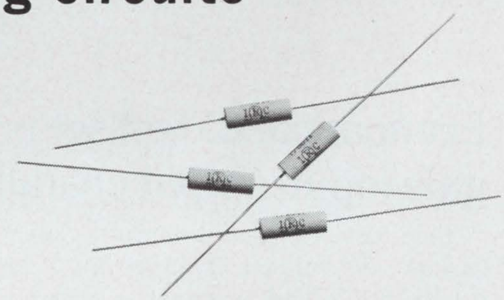


Simple two-transistor OR gate requires no external power source.

CTC

trims size, cuts cost and eliminates temperature compensating circuits

−100 0 +100



New IRC metal film resistors with any specified TC between -100 and +100ppm

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Inductance and capacitance are negligible. CTC resistors replace wire-wound types with space and cost savings, and are far more reliable . . . even at higher resistance values. Write for complete data and prices. IRC, Inc., 401 North Broad Street, Philadelphia, Pa. 19108.

CAPSULE SPECIFICATIONS

SIZE	RN65
TC	Any TC between −100 and +100ppm, ±5ppm
TEMP. SPAN	Any 50°C increment between −55°C and 165°C
RESISTANCE	50Ω to 360KΩ
POWER	¼-W @ 125°C, ½-W @ 70°C
STD. TOLERANCE	0.1, 0.05, 0.025%

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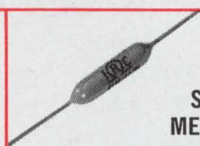

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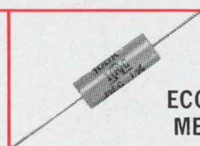

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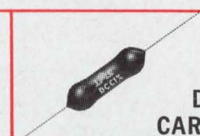

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15-kΩ resistor form a simple OR gate, output *C* is at about +10 volts.

Because the circuit is symmetric, the same reasoning is used when *A* is zero volts and *B* is +10 volts: the output is about +10 volts.

When *A* and *B* are +10 volts, both transistors are driven into saturation. Thus, the collectors of *Q1* and *Q2* are at about zero volts; this makes *C* nearly zero volts.

Hence the truth table for the given circuit is:

A	B	C
0	0	0
0	+10	+10
+10	0	+10
+10	+10	0

and the network forms a two-input modulo-2 adder.

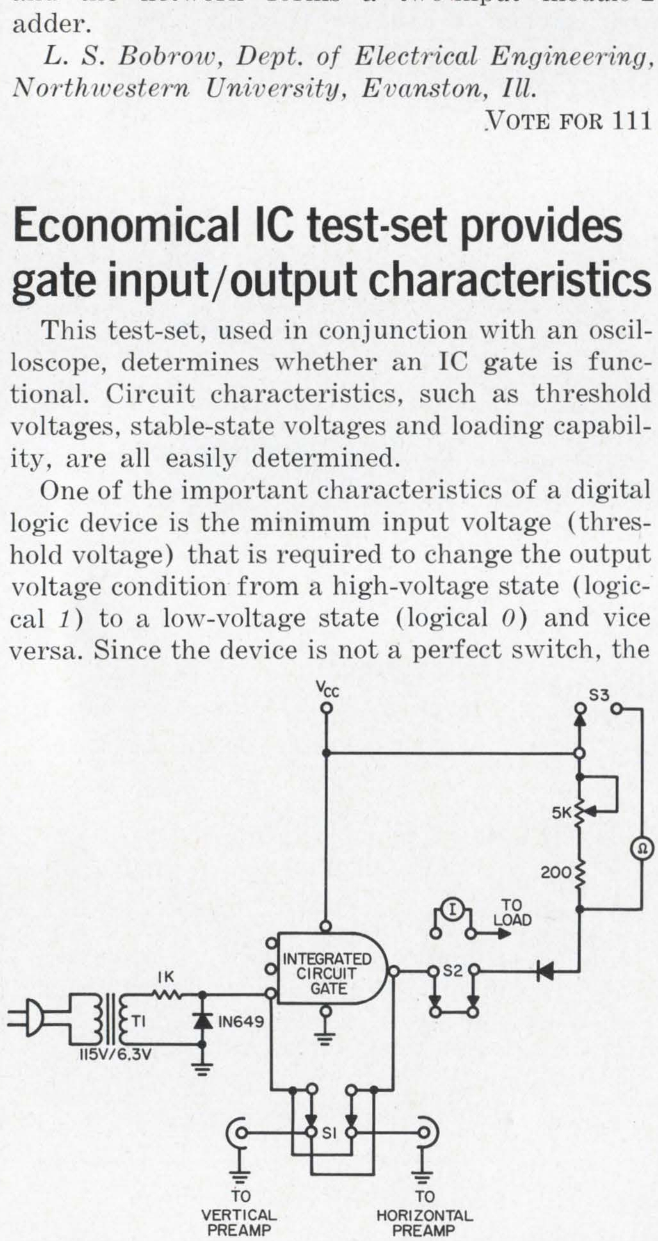
L. S. Bobrow, Dept. of Electrical Engineering, Northwestern University, Evanston, Ill.

VOTE FOR 111

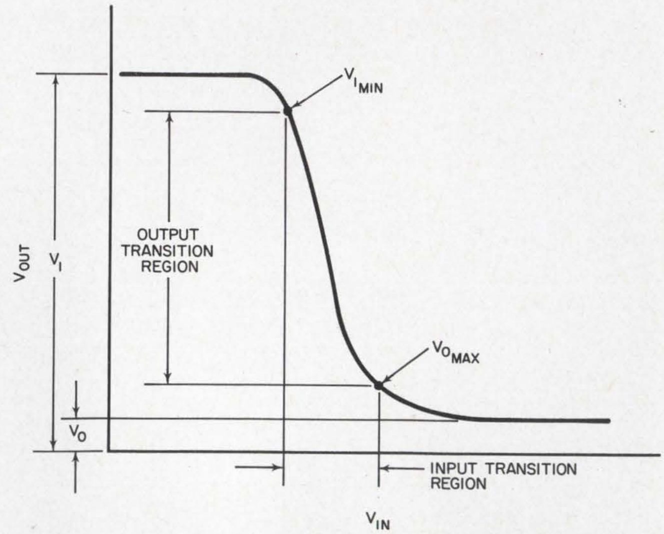
Economical IC test-set provides gate input/output characteristics

This test-set, used in conjunction with an oscilloscope, determines whether an IC gate is functional. Circuit characteristics, such as threshold voltages, stable-state voltages and loading capability, are all easily determined.

One of the important characteristics of a digital logic device is the minimum input voltage (threshold voltage) that is required to change the output voltage condition from a high-voltage state (logical *1*) to a low-voltage state (logical *0*) and vice versa. Since the device is not a perfect switch, the



1. **Characteristic tester uses 60-Hz sinewave,** clamped at ground during the negative cycle, as the input signal to the integrated circuit gate under test.



2. **Input-output characteristic curve of NAND/NOR gate** shows the two points, $V_{1_{MIN}}$ and $V_{0_{MAX}}$, that define the threshold region.

threshold voltage is actually a threshold region, rather than a specific point. To define this region, one must determine the points at which the output will be considered in a stable *1* or 0 state. As shown in Fig. 1, this point, for the high-voltage, stable state, is the minimum voltage above which the output is considered in a stable state, and can be defined as $V_{1_{MIN}}$.

For the low-voltage, stable state, this point is the maximum voltage below which the output would be considered in a stable state and is defined as $V_{0_{MAX}}$. The area between these two parameters is the transition region and is an indeterminate state.

The test circuit (Fig. 2) displays this information. A 60-Hz sine-wave, applied to the input of the gate under test, causes the output to switch between cutoff and saturation and produces the characteristic trace on the oscilloscope. Knowing the oscilloscope zero-volt reference level and the supply voltage, V_0 and V_1 can be read directly from the scope face. Since V_0 increases as the load (fan-out) increases, it is possible to relate the device operation to fan-out; switch *S2* is used to connect an external load to the device under test. To simplify the measurement of unknown loads, switch *S3* (momentary) connects an ohmmeter into the circuit.

G. P. Carter, Product Marketing Engineer, Fairchild Semiconductor, Mountain View, Calif.

VOTE FOR 112

Low-impedance bias circuit improves amplifier linearity

A two-transistor circuit provides high-frequency linear amplifiers with the low-impedance base bias necessary to achieve good linearity.

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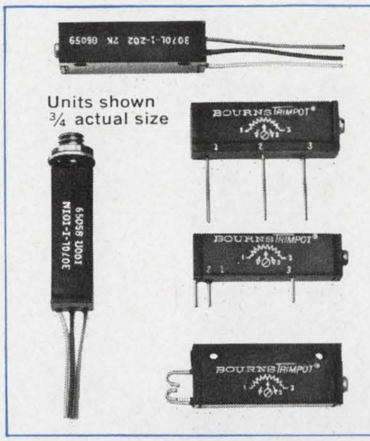

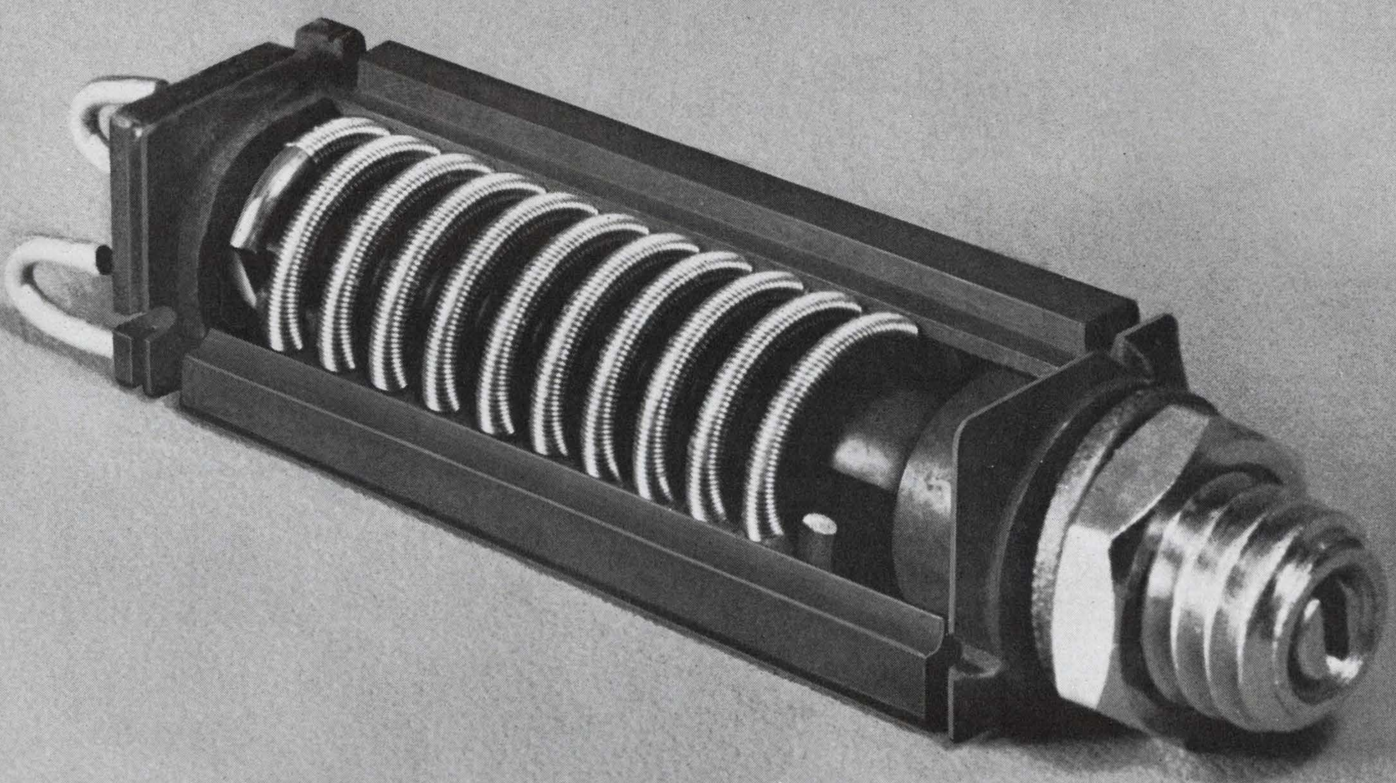

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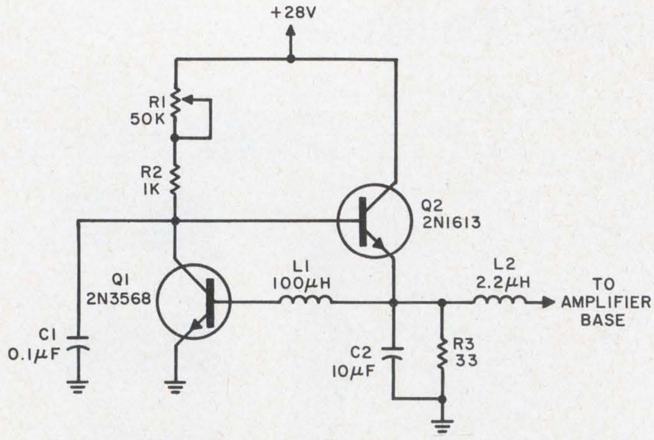


Bias supply voltage varies between 0.547 and 0.690 volt according to the setting of R1. The dc impedance is less than one-half ohm.

single-sideband applications, are often biased with diode and resistor networks. Their impedance, however, is generally so high and voltage-dependent that their linearity becomes degraded, particularly at low rf power, and some power gain is lost.

The dc impedance of this circuit (see schematic) is less than one-half ohm, and the bias voltage is adjustable between 0.547 and 0.690 volts. The emitter-to-base voltage of *Q1* serves as the reference voltage, and is adjusted by varying *R1*. Transistor *Q2* provides current to the base of the rf amplifier and negative feedback to the base of *Q1*. Capacitor *C2* reduces the audio output impedance and *L1* effectively prevents oscillation.

To provide thermal tracking between the emitter-base voltages of the linear amplifier and the bias reference, transistor *Q1* should be mounted as close as possible to the linear amplifier transistor. A good thermal match will prevent large shifts in the quiescent current of the linear amplifier.

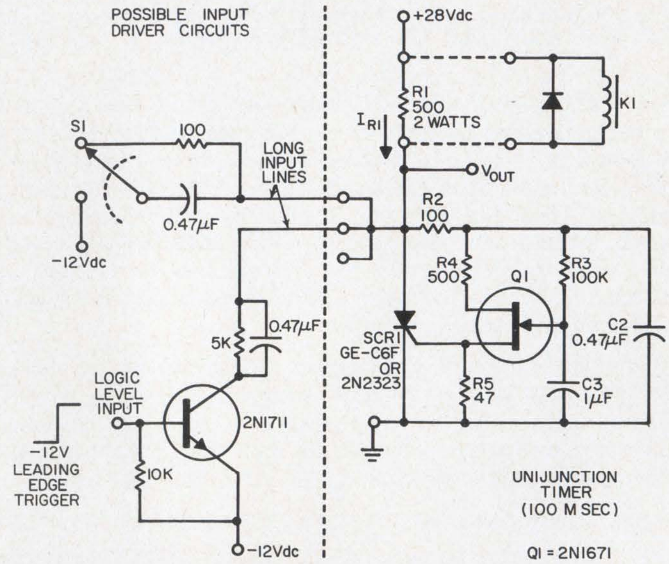
William Alexander, Applications Engineer, Fairchild Semiconductor, Mountain View, Calif.

VOTE FOR 113

SCR and UJT form noise-immune mono

Standard long-delay transistor monostables require bulky and expensive capacitors, as well as careful noise suppression techniques. In the circuit shown, the unijunction timer lowers this capacity while a low-impedance SCR circuit reduces false triggering from noisy input lines, power supply lines and ground loops.

Circuit operation is as follows: Under quiescent conditions, *SCR1* is ON and conducting I_{r1} current. V_{out} is about 1 volt. When a negative pulse occurs on the input lines, SCR1 turns off and V_{out} is 28 volts. This trigger pulse must be longer than



Noise immunity is the strong point of this SCR/UJT monostable. The circuit is simple and easily modified to provide varying delay times or to handle different values of currents and voltages.

the SCR turn-off time (about 40µs) and draw a current greater than $I_{r1} - I_h$ (I_h = holding current of *SCR1*). Low power and/or short noise pulses will not cause false triggering. The unijunction timer circuit fires after a fixed delay of *R3C3* seconds (100 ms in this instance), returning the circuit to the quiescent state. Time constant *R2-C2* is used to suppress noise near the end of this delay, when the unijunction is sensitive to noise. *R2C2* can be deleted if desired.

Applications of this monostable include high-current control type circuits around keypunches, SCR circuits, motor controllers, etc., where a relay or solenoid may be substituted for *R1*, as indicated in the circuit. The circuit can be designed to accommodate shorter or longer delays and higher or lower currents and voltages.

David M. Weigand, Design Engineer, Brookhaven National Laboratory, Upton, N. Y.

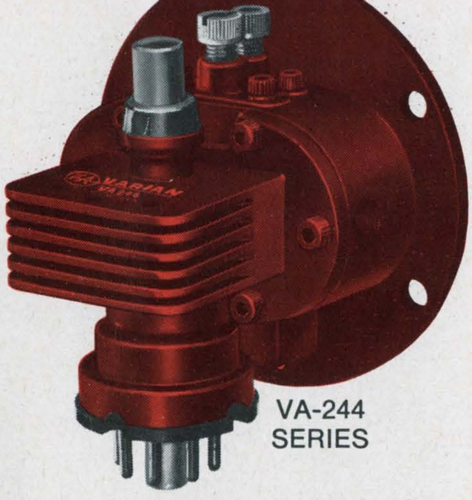
VOTE FOR 114

Square-wave generator uses gate turn-off SCR

A relatively simple square-wave generator utilizes a gate turn-off SCR (GTO) and two 4-layer diodes. The circuit (see Fig. a) was originally designed as a high-frequency chopper operating from a 117-volt line. However, it can be adapted for low-voltage applications by a suitable choice of components.

The ON operation of the circuit is shown in Fig. b, and the OFF operation in Fig. c.

In b, assume that *Q* (the gate turn-off SCR) is not conducting when an appropriate dc voltage is



VA-244
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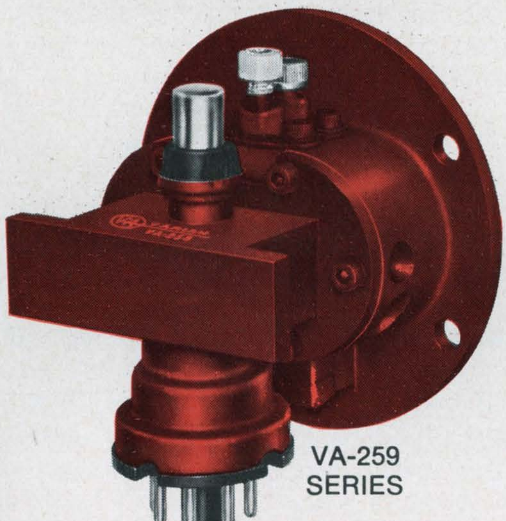

VA-259
SERIES

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For more complete information, write Palo Alto Tube Division, Executive Offices, 611 Hansen Way, Palo Alto, California. In Europe, write Varian A.G., Zug, Switzerland.

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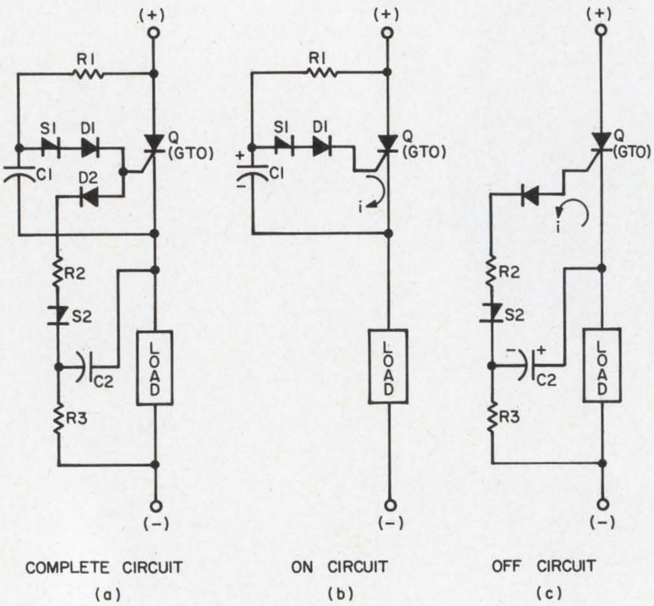
ON READER-SERVICE CARD CIRCLE 48



Square-wave generator circuit (a) is turned on and off by the action of Q, which is a gate turn-off SCR. The ON operation is shown in (b) and the OFF operation in (c).

applied to the marked terminals. Capacitor *C1* is therefore charged by current through *R1*. When *C1* reaches the breakdown value of 4-layer diode *S1*, *S1* conducts. This permits *C1* to discharge through the gate of *Q* in a manner similar to conventional SCR circuitry, causing *Q* to conduct and supply power to the load.

In c, *Q* is conducting, so capacitor *C2* is charged by current through *R3*. When *C2* reaches the breakdown value of 4-layer diode *S2*, *S2* conducts. This causes *C2* to discharge in the reverse direction through the gate of *Q*, causing *Q* to turn off and interrupt the power to the load.

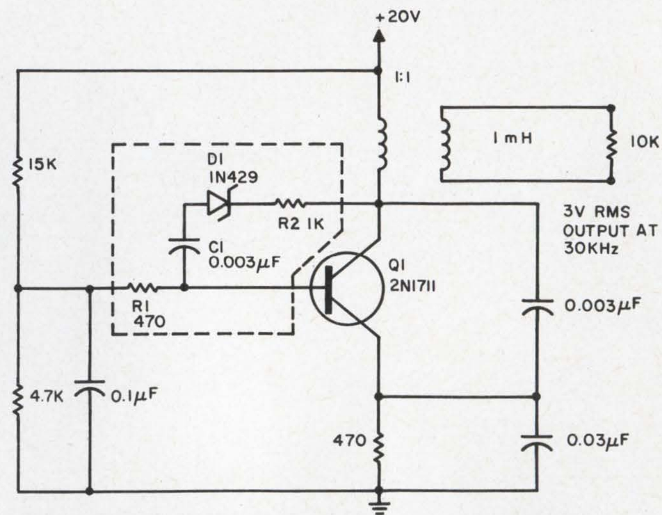
In designing the circuit, *R3* must be chosen so that the current it will permit to flow under a certain applied potential is less than the holding current of *S2*, which sets the upper limit on the speed of turn-off time. *R2* limits OFF gate current to a safe value with respect to the gate power capabilities of *Q*. The size of *C2* is determined by the value of current through *Q* preceeding turn-off. The time constant *R1C1* determines the turn-on time.

Alexander J. Prokop, Design Engineer, Skil Corp., Chicago, Ill.

VOTE FOR 115

Four components stabilize common-base oscillator

A common-base oscillator can operate in the class-A mode with good amplitude stability. The secret is the addition of four components—*R1*, *R2*, *D1* and *C1*, as shown in the circuit.



Common-base oscillator operates in class-A mode. The amplitude instability is less than 5%, because of the negative feedback through D1, R2, C1 and the gain-controlling effect of R1.

The oscillations increase in amplitude until the zener diode, *D1*, begins to conduct. This occurs when the peak-to-peak voltage across the zener exceeds 12 volts. Thus the negative feedback circuit between the base and collector of *Q1* reduces the gain of *Q1*, preventing the oscillation from increasing in amplitude.

R1 and *R2* determine the available negative feedback. If *R1* is increased too much, the *Q1* stage gain will be too low to start or sustain oscillations reliably. If *R2* is decreased too much, the *Q* of the resonator will be reduced to the point where frequency stability and spectral purity may suffer. If very tight amplitude control is desired, an emitter-follower, inserted between the collector of *Q1* and *R2*, will prove useful.

With the circuit constants shown, oscillations occur at 30 kHz. Waveform distortion is under 1%, and amplitude instability is less than 5% for any combination of factors of temperature (0 to 65°C), supply voltage variation (18 to 22 V), and load (10 KΩ to infinity). Reliable starting is assured, because of the presence of a large positive feedback before the operating amplitude is reached.

Murray F. Feller, M. F. Feller Industries, Santa Maria, Calif.

VOTE FOR 116

IFD Winner for Aug. 16, 1966

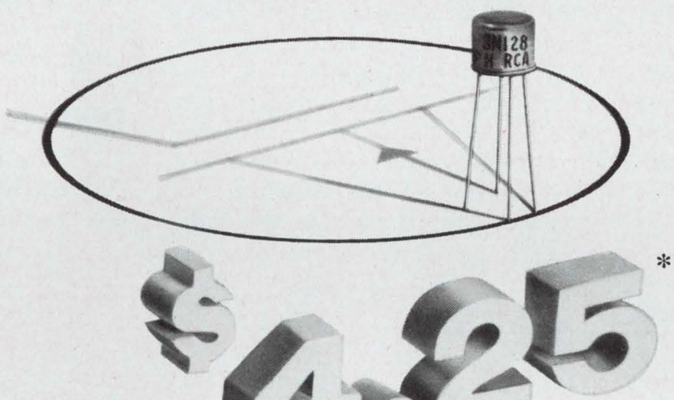
Andrew F. Cooper, Computer Engineer, Paragon Div. of Texaco, Long Island City, N. Y.

His Idea, "Universal waveform comparator uses UJT relaxation oscillators," has been voted the $50 Most Valuable of Issue Award.

Cast Your Vote for the Best Idea in this Issue.

RCA Announces the NEW 3N128 (MOS) FET for VHF applications

features: □ low feedback capacitance (0.2 pF max.) □ high power gain (18 dB typ. at 200 MHz) □ high forward transconductance (5,000 μmho min.) □ low noise (4 dB typ. at 200 MHz) □ low cross-modulation distortion □ a hermetically sealed metal case



*Price in quantities of 1,000 and up

RCA's 3N128 N-channel, depletion type, MOS field-effect transistor is now available in production quantities for communications and industrial applications. This new insulated gate MOS transistor exhibits (1) extremely low gate-leakage current (0.1 pA typ.) which permits stable operation over wide temperature ranges, (2) feedback capacitance substantially lower than that of conventional junction-gate devices, and (3) extremely high input resistance of 10^{14} ohms typ.

The RCA 3N128 simplifies your designs because you can use conventional electron-tube type biasing techniques. In addition, the drain current exhibits a negative temperature coefficient which makes thermal runaway virtually impossible. These attributes, combined with a large signal-handling capability and low cross-modulation distortion, make the 3N128 MOS a "must" for critical front-end designs.

Call your RCA Field Representative for complete technical information, price and delivery on the new 3N128 (MOS) FET. For Application Note AN-3193, or for a technical data sheet, write RCA Electronic Components and Devices, Commercial Engineering, SectionEG-11-4,Harrison, N. J. 07029.

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Bits and Pieces

Wisdom and levity,well-developed fruits of frustration, will rarely be found, except in bits and pieces.....

Engineering waste

Grab the nearest engineering manager you know. Buy him a cup of coffee, and get his views on the shift from the technical to the managerial side of engineering.

Often, you'll get a picture of the engineering manager as a man who finds administrative tasks a waste of time and who wishes he could spend more time working with the technical details of a job. But he goes on with his administrative duties, and spends even less time with technical details.

Many people have discussed this problem, officially and unofficially, and the conclusion has often been —"waste of professional man-power." Here is an opposing viewpoint. Eldon Sweezy, executive director, Management Counsel, Bethesda, Md., speaking to the conferees attending the 1966 Joint Engineering Management Conference, said:

". . . Let us dispose of one of the oldest wives' tales in technical management. From studies we have made . . . we can find no evidence that the selection of competent, intelligent, imaginative, rational people-conscious engineers to fill vital posts in the managerial structure is a significant source of "waste" of professional people. . . . Some [managers] viewed with nostalgia, as many of us do, the recently passed halcyon days of our earlier years, their days in the "lab," but as mature adults they recognized that these were not rational ends to their careers. The only conditions under which this type of assignment would be wasteful which we could identify were that the engineer was not qualified to perform executive actions or was not motivated though qualified. As in every walk of life, no man should be made a manager who is qualified but not motivated or who is motivated but not qualified."

Engineering goals

To review and comment on the ASEE's (American Society for Engineering Education) "The Preliminary Report, Goals of Engineering Education," a panel was convened recently by the Engineers' Joint Council. The report of this panel, which has ". . . addressed itself to certain broad issues and problem areas of fundamental importance to the teaching and practice of engineering," includes the following three points:

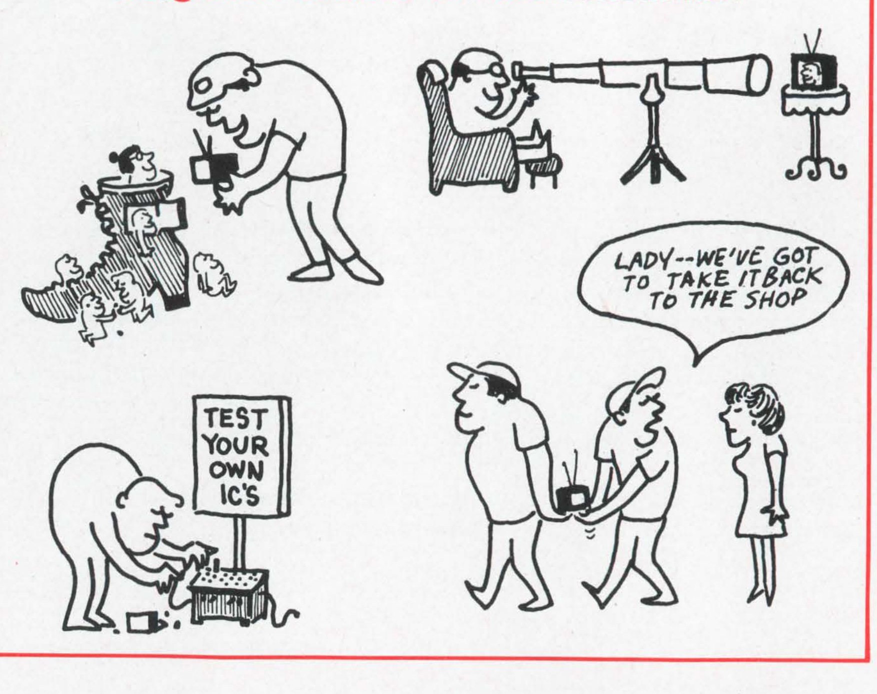
- ". . . the emphasis on instruction must be placed more upon the development of the potential capacities and insights in the individual and less upon the transfer of generally prescribed content in standardized courses."
- ". . . it is contrary to sound educational policy to standardize curricula, degrees, methods, or periods of instruction across institutions at the expense of flexibility, experimentation, and wholesome diversity among and within institutions."
- "To the extent that the licensing principle represents a restrictive influence on flexibility and innovation in engineering education, the principle itself and the laws on which it is based should be reviewed and modifications considered by the professional and technical societies concerned."

Did you know . . .

. . . **"Engineering . . .** for the Human Environment" is the theme of the forthcoming National Engi-

(continued on p. 99)

Integrated circuits for the consumer?



Have you got a contribution? We'll compensate. Be it a letter, commentary, puzzle, cartoon, or cartoon idea, send it along to: RC, Electronic Design, 850 Third Ave., New York, N. Y. 10022.

CAREER INQUIRY – confidential

Respond to the career opportunities advertised in this issue. Fill out and send us this handy resume. **Electronic Design** will do the rest – neatly typed copies of this form will be mailed to the companies of your choice, indicated by the circled Career Inquiry Numbers at the bottom of this page.

26

Name			**Home Phone**
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Age	**U.S. Citizen** ☐ Yes ☐ No	**Security Clearance**	

Prime Experience	**Secondary Experience**

Desired Salary	**Availability Date**

Employment History – present and previous employers

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City, State			
Dates	to	to	to
Title			
Specialty			

Education – indicate major if degree is not self-explanatory

Degree			
College			
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Dates	to	to	to

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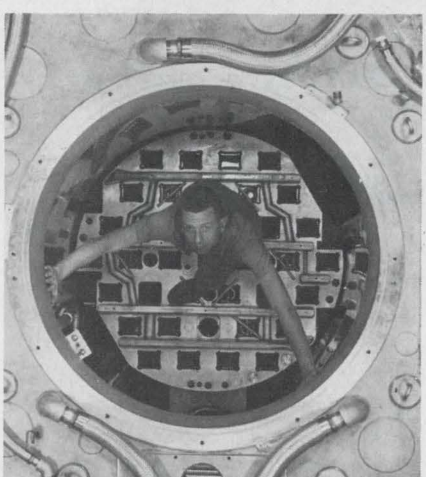
Bits and Pieces CONTINUED

(continued from p. 96)

neers' Week. Sponsored by the National Society of Professional Engineers, it will be observed during the week of February 19-25, 1967. This theme will call attention to the increasing role that engineering plays in daily life—solutions to pollution, transportation and safety problems.

. . . **"Dataport"** is a recently announced device, developed by Carnegie Institute of Technology, that provides instant access to any time-sharing computer system over an ordinary telephone line. The unit is a portable keyboard that plugs into the ac line. From home, office or field location, you can now instantly communicate with the company computer.

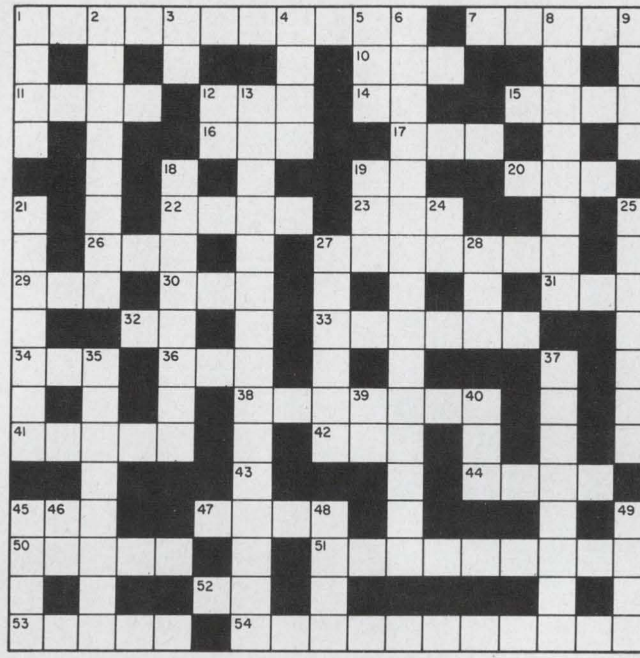
. . . **"The appliance and consumer** electronics industry is doing more than any other segment of the economy to fight inflation," as stated by Armin Allen, vice-president of Philco-Ford. Whereas a housewife's average purchase costs 13.8% more now than in 1957-1959, Allen pointed out that a black and white TV set, selling at $100 then, would sell for $82.20 today.



You mean it's true? After seeing the cartoon in our October 11 issue (Bits and Pieces p. 110), someone came up with this photograph. However, the above gentleman stands, not on an integrated circuit as depicted in the cartoon, but in the core of the National Bureau of Standards' newly acquired nuclear reactor.

Crossword Puzzle # 141

Edited by Rene' Colen
Submitted by James R. Kimsey



(solution on page 155)

Across

1. Information recorder.
7. Line.
10. Not pos.
11. 1/2 bc sin A.
12. Hawaiian dish.
14. Not deb.
15. See 40 down.
16. Time zone: Abbr.
17. Million: Prefix.
19. Chem. element.
20. Fixed attenuator.
22. Leave out.
23. Binary digit.
26. Turntable drive.
27. Transmission line.
29. Employ.
30. Greek letter.
31. ____ -of-transmission.
32. Greek letter.
33. Useful biography.
34. ____ -top.
36. Knot.
38. Order.
41. House cable.
42. Second choice: Abbr.
44. Hole____.
45. To soak.
47. Feedback____.
50. Distribution line.
51. Line interference.
52. Current unit.
53. ____modulation.
54. Transmission (shf).

Down

1. Trace.
2. Magnetic component
3. Amplitude mod.
4. One of anything.
5. Unfin.
6. Equipment at end of a microwave system.
8. Changeable (memory).
9. Radar return.
12. IEEE abbreviation.
13. Antenna type.
18. Sophisticated calculator.
19. Also.
21. Frequency distortion.
24. Out of: Prefix.
25. Decrease signal.
27. Color quality.
28. Computer mfr.
35. Audio output circuit.
37. Not grounded.
39. Cap. unit.
40. Telegraph term.
45. ____function.
46. ____gate.
48. ____position indicator.
49. Trial.

Book Reviews

Radio astronomy

Radio Astronomy, John D. Kraus (McGraw-Hill Book Co., New York). 481 pp. $13.75.

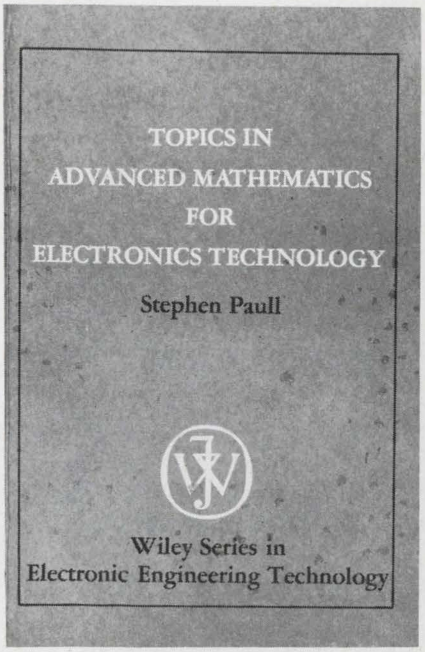
This text is largely an outgrowth of lecture material presented by the author in courses on radio astronomy at Ohio State University. It brings together a selection of topics on astrophysics and radio-telescope receiver and antenna design. Particularly noteworthy is Chapter 8, the longest in the book, dealing with both galactic and extragalactic radio sources and our present knowledge of them as deduced from both radio and optical observations.

The book is aimed at the senior undergraduate and the junior graduate, and requires a knowledge of vector analysis and elementary electromagnetic and circuit theory. For those wishing to delve into a particular subject area more deeply, numerous references and extensive bibliographies are included.

Electrical instruments

Electrical Instruments in Hazardous Locations, Ernest C. Magison (Plenum Press, New York), 225 pp. $22.50.

This text gives the technical information needed to understand what is required for the safe, economical use of electrical instruments in hazardous locations. Much of the book is based on the work by the Instrument Society of America's Recommended Practice Committee, "Instruments for Hazardous Locations" (Publication no. 8D-RP12). Wherever possible specific sources or papers presented by committee members have been cited. Chapters deal with such topics as Article 500 of the National Electrical Code, explosions, electrical ignition of gases and vapors, principles of hazardous reduction and sealing. It is intended for use in courses on electrical safety and should be of value to electrical and safety engineers and instrumentation specialists of all sorts.



Compact math reference strong on applications

Topics in Advanced Mathematics For Electronics Technology, Stephen Paull (John Wiley & Sons, Inc., New York), 420 pp. $4.95.

An engineer's skill with mathematics often varies in direct (if not exponential) proportion to the amount of use that he has for it. Even with highly developed mathematical skill, he will frequently find the need to refresh himself in some areas of mathematics. At other times the need for familiarization with a new topic arises.

In either of these cases, reference to a standard text may be inconvenient because of time, availability, etc.

In one compact volume, Stephen Paull has presented a valuable reference covering those mathematical topics most useful to the practicing electronic engineer. In eight chapters, the author treats Infinite series, Fourier series, Fourier integrals, ordinary differential equations, Laplace transforms, Gamma and Bessel Functions, Vector analysis, determinants and matrix algebra.

A valuable feature of the book is the application examples in the text coupled with the practical problems provided for the reader's solution.

This application information is especially useful for the engineer who meets a particular area of math for the first time.

Of special interest is the chapter covering matrix algebra, an area of mathematics that is increasing in importance as the use of digital computers for circuit analysis and design grows. In this chapter, as in others, the author has provided interesting and useful applications information.

Author Paull ends his book with appendices containing derivations of Fourier coefficients, derivations of differential equations for simple linear circuits, and a table of Laplace transform pairs.

Those engineers needing a handy reference, or wanting to investigate some unfamiliar aspect of mathematics, will find this little volume a very worthwhile addition to their libraries.

—Joseph J. Casazza

Electron microscopy

Introduction to Electron Microscopy, Cecil E. Hall (McGraw-Hill Book Company, New York). 397 pp. $17.50

This second edition offers a thorough background in the theories and practices of electron microscopy. Starting with the development of the theory of electron lenses and a description of their characteristics and functions, the book leads up to a final chapter describing the special techniques for preparing specimens for observation with the microscope. In the light of recent advances, revisions have been made in the discussion of high-resolution electron lenses evaluation and interpretation of the image, and techniques for preparing specimen materials. Many typical micrographs are provided to show how to evaluate and interpret normal and abnormal images quickly.

Phaselock techniques

Phaselock Techniques, Floyd M. Gardner (John Wiley & Sons, New York), 182 pp. $8.95.

Practicing communications engineers, who have to design, specify or use phaselock systems, will find this book an invaluable reference. The volume starts with the fundamental theory of the phaselocked loop with chapters on linearized transfer functions and behavior in noise. Tracking performance and acquisition problems are covered, followed by discussion of the operation of circuit components and optimazation of loop parameters in the next two chapters. The remainder of the book is devoted to applications of phaselock techniques with emphasis on sensitive receivers and frequency discriminators. Also provided is a bibliography with over 150 entries and a list of design equations.

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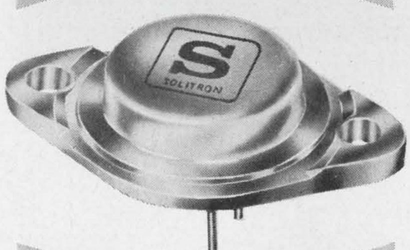
VCEO (SUS)

325 v
300 v
250 v
225 v
200 v



in a 10 Amp. NPN Silicon Planar Power Transistor Plus

50 mcs . . . . 150 pfs

Type Number	Pkg. Size	DESIGN LIMITS						PERFORMANCE SPECIFICATIONS					
		T_J	θ	P_T Watts	BV_{CBO}	V_{CEO} (SUS)	BV_{EBO}	h_{FE}		V_{BE} (sat) Volts	V_{CE} (sat) Volts	I_{CBO} μA	f_T
		°C	°C/W	@100°C Case	Volts	Volts	Volts	@I_C = 5A V_{CE} = 5V		@I_C = 5A I_B = 0.5A	@I_C = 5A I_B = 0.5A	V_{CB} = 100V	mc
		Max.	Max.	Max.	Min.	Min.	Min.	Min.	Max.	Max.	Max.	Max.	Min.
MHT7201	TO-3	200	1.5	65	225	200	8	20	60	1.2	0.5	1.0	50
MHT7202	TO-3	200	1.5	65	250	225	8	20	60	1.2	0.5	1.0	50
MHT7203	TO-3	200	1.5	65	275	250	8	20	60	1.2	0.5	1.0	50
MHT7204	TO-3	200	1.5	65	325	300	8	20	60	1.2	0.5	1.0	50
MHT7205	TO-3	200	1.5	65	350	325	8	20	60	1.2	0.5	1.0	50

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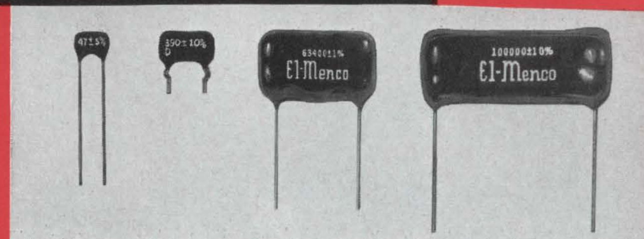

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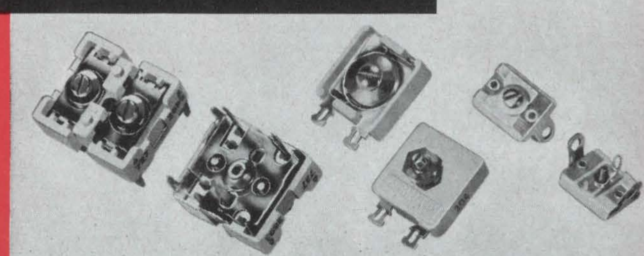

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- Dielectric strength: 2 or 2½ times rated voltage, depending upon working voltage.
- Exceed all electrical requirements of E.I.A. specification RS-164 and military specifications MIL-C-91A and MIL-C-25A.

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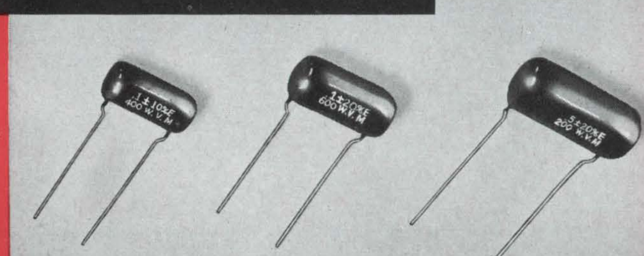

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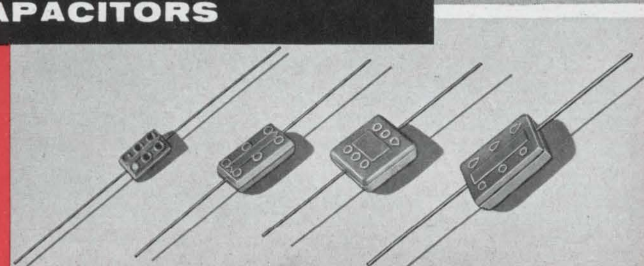

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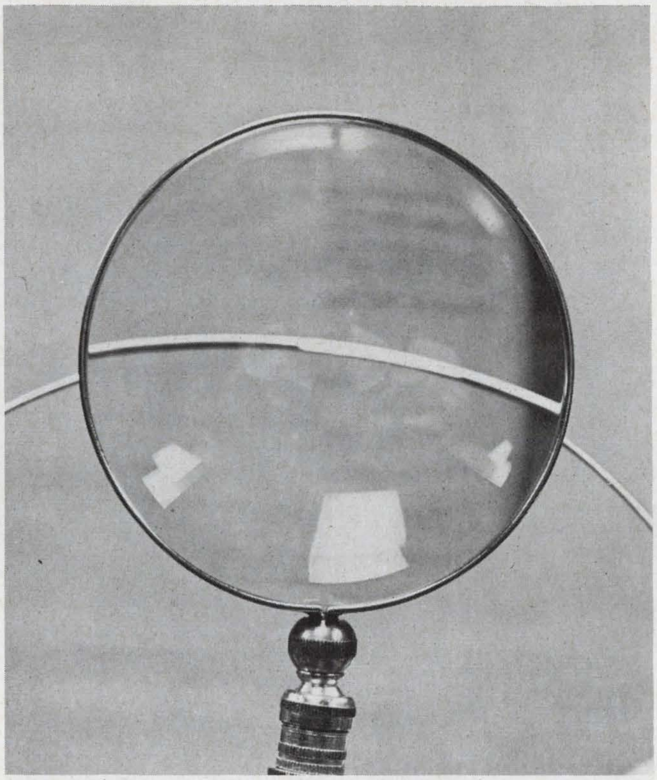
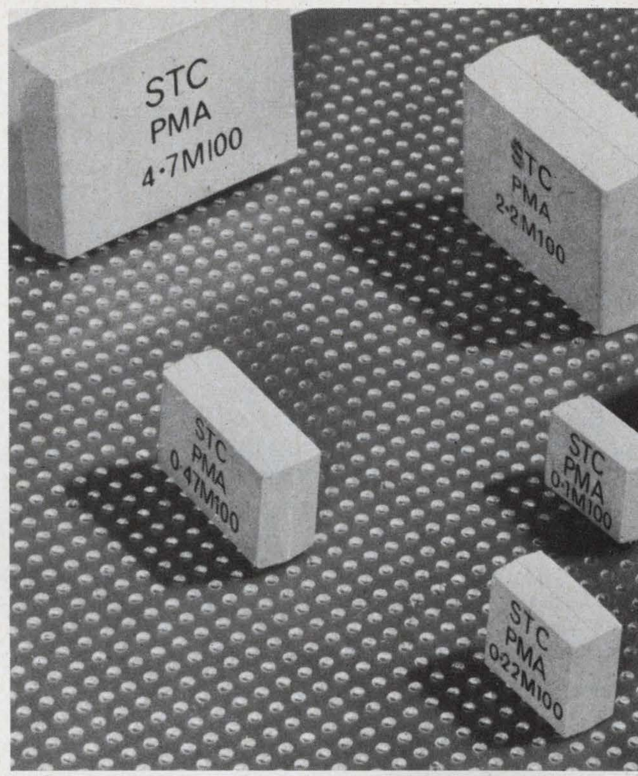
ON READER-SERVICE CARD CIRCLE 52

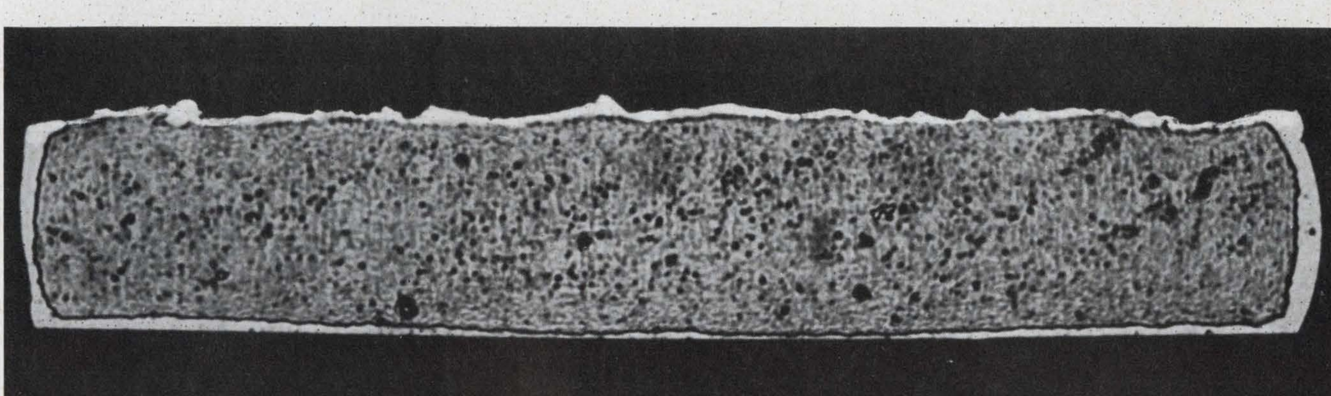
Products



See the aluminum glittering where the copper is scraped. This wire saves copper. Page 132



This switching matrix saves time in checking equipment. Program it in advance. Page 126



If your conductor needs some spring, this gold-plated, nickel-steel may be just what a material conjurer would provide. Good stuff for relay and switch contacts? Page 133

Also in this section:

A miniature sweep generator is all solid-state. Page 114

A yellowish liquid dissolves urethane potting compound. Page 133

A quiz can test your knowledge of op-amps in an hour. Page 153

Integrated low-input, high-output drivers for FET analog switches.

Siliconix, Inc., 1140 W. Evelyn Ave., Sunnyvale, Calif. Phone: (408) 245-1000. P&A: $25.30 to $29.90 (100 lots); stock.

The first units of a family of integrated analog gate drivers are available. The major purpose behind their development is to provide a designer with a convenient buffer device that can receive low-level inputs and produce amplified, level-shifted outputs. These characteristics make them particularly useful in multiplexing analog signals, where FETs are used as gates and the switching signals arrive from commonly employed low-level logic.

The most outstanding characteristics of the drivers can be summarized as follows:

- Inputs as low as 0.5 V.
- Level-shifted outputs up to 30 V.
- OFF power dissipation <1 mW/driver.
- Choice of input circuit configurations.
- Flexibility in power vs speed trade-offs.

The driver family has been designated by its developer, Siliconix, Inc., as the D011F-series of analog gate drivers. At this time six of the drivers of this family are available off the shelf.

For an article describing the design approach used in developing these drivers, see pp. 50-54.

The D011F and D019F are two-channel inverting circuits (See Fig. 1). That is, a positive-going input voltage will produce a negative-going output voltage, once the 0.5-volt minimum threshold is exceeded for the driver's input transistor base-emitter diode. This is indicated in Fig. 1b in the specially devised driver symbols by vertical arrows—up for positive, down for negative. Below this threshold, the maximum input current is 5 μA. To produce a 30-volt output swing requires a maximum positive input swing of 0.8 volt and a 100-μA input current. Consult the table for output current ranges and corresponding propagation time delays.

The D012F and D020F are two-channel noninverting circuits (i.e., a negative-going input voltage produces a negative-going output voltage). With these circuits, the switching threshold is controlled by V_L, which can be set anywhere from 3 to 25 volts above V_{EE}. When the input voltage is 0.5 volt below V_L, the input current spec is 20 μA maximum, while a 1.5-mA maximum driving current will produce full output.

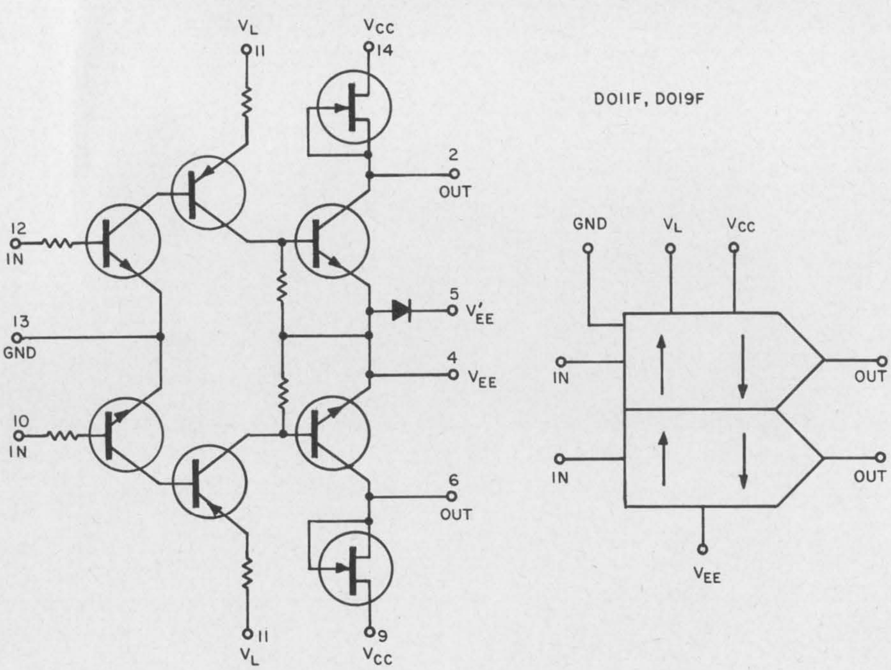
The D013 and D021F are two-channel inverting circuits that require 1 mA of input drive current to drop the output voltage to 1 volt above V_{EE}. A maximum positive input swing of 0.8 volt above ground is necessary to produce this.

All the drivers use FET current-limiting diodes for the collector load in each output state.

The prime purpose of these drivers is to amplify low-level logic signals and provide the high-level control voltage necessary to operate FET gates. However, the wide variety of integrated circuit logic blocks currently in use and the multifarious assortment of n- and p-channel junction and MOS-FETs available for switches or gates present an important dc level-shifting problem for the driver stage. Accommodating almost any dc level input is easiest with the D012F and

Table–Current ranges and time delays

Type number	Output stage I_C range: Minimum	Output stage I_C range: Maximum	Maximum propagation delays (driving 1 Mohm & 6 pf): Turn-on	Maximum propagation delays (driving 1 Mohm & 6 pf): Turn-off
D011F, D012F, D013F	0.4 mA	1.8 mA	0.15 μs	1.2 μs
D019F, D020F, D021F	2.3	5.7	0.25	0.3



a b

1. **Typical analog gate driver** circuit (a) employs output current "pull-up" FETs. New logic symbols (b) have been devised to represent the drivers. The arrows indicate input and output voltage polarities for the driver ON condition: up for positive, down for negative. Also see pp. 50-54.

Worlds of Clifton Quality

in our NEW, Competitively Priced DC Motors

Built to exacting Clifton and MIL-E-5272 standards, these DC motors are a completely new design. They offer many advantages such as: stainless steel, corrosion resistant housings and ball bearings, and brush springs which maintain constant pressure over brush life. Brush life itself is up to 1000 hours depending upon environmental conditions and application.

These motors feature a five bar commutator. Due to the inherent design, the rotor produces a magnetic detent under zero excitation which minimizes gear train drift. Units available in both 14 and 28 volt excitation. Special voltages, shafts and housings available upon request.

Clifton Precision Products, Division of Litton Industries, Clifton Heights, Pa., Colorado Springs, Colo.

The illustration of our Solar System shows the nine planets and their 31 satellites in scale with each other and the enormous sun. The procession starts with Mercury at the left and ends with Pluto on the far right.

cppc CLIFTON
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ON READER-SERVICE CARD CIRCLE 53

D020F drivers. Here the threshold level is set by V_L. The other four types can provide some input threshold level adjustment by connecting a bias voltage to the common ground terminal.

The output dc levels are controlled by the polarity and magnitude of V_{CC} and V_{EE}. The sum of these two supply voltages cannot exceed 30 volts. Thus if $V_{CC} = +15$ volts and $V_{EE} = -15$ volts, the output will swing symmetrically with respect to ground. Another typical combination is when $V_{CC} = +10$ volts and $V_{EE} = -20$ volts; the output control voltage will then swing from around -20 to $+10$ volts. Since the magnitude of drive voltage needed to control a FET gate ranges from 5 to 15 volts, plus the peak-to-peak voltage being gated, the foregoing output levels are ideal. For example, given a ± 5-volt range of analog signal, to be gated by a p-channel normally OFF MOS-FET that requires $V_{GS} = -15$ volts to obtain an acceptable ON resistance level, the FET gate voltage must swing from -20 volts to $+5$ volts.

The user has two other options worth mentioning. First, with the drivers D011F, D019F, D013F, and D021F, it is practical to place diodes in series with the common ground lead, which will raise the threshold level and provide a significant improvement in noise immunity. Second, the V_{EE} supply may be connected through a series diode to avoid output loading in case the V_{EE} supply goes to zero. Although this connection decreases the available V_{EE} by 0.6 V, it ensures that the FET gate (connected to the output terminal) will never be current-loaded by a forward-biased substrate diode in the driver chip.

In addition to their prime function to operate as buffers between low level logic and FET gates, it is clear that they can be used for other purposes as well. To give just one example, consider a case where a low level logic output has to provide current drives exceeding its capacity. One of the new drivers can be selected to provide the needed assist.

All six of the series are mounted on TO-84 fourteen-lead flat packs.

CIRCLE NO. 230

evaluating
semiconductors?

use one of these Tektronix transistor curve tracers to meet your needs

The performance range of the Type 575 enables you to evaluate the dynamic characteristics of most semiconductor devices.

Several transistor characteristic curves may be displayed including the collector family of NPN or PNP devices in a common base or a common emitter configuration with forward or reverse biasing. The Type 575 features collector sweep supply ranges continuously variable from 0 to 20 V at 10 A, or 0-200 V at 1 A. A base or emitter step generator, operating at either 2 or 4 times the line frequency, provides 4 to 12 steps per family of characteristic curves in single or repetitive display modes. The step generator provides voltage increments from .01 V/step to 0.2 V/step or current increments from .001 mA/step to 200 mA/step.

Choose the Type 575 MOD 122C transistor curve tracer for evaluating higher voltage devices.

The Type 575 MOD 122C has the same features of the Type 575 plus the capability of diode breakdown test voltage variable from 0 to 1500 V at 1 mA and a much higher collector supply voltage of up to 400 V at 0.5 A.

For evaluating high current semiconductors, add the Type 175 High Current Adapter to either of these curve tracers.

The Type 175 features collector sweep supply ranges of 0-200 A at 0-20 V and 0-40 A at 0-100 V. The Type 175 step generator provides current ranges from 1 mA/step to 1000 mA/step and voltage steps from 0.5 to 10 V/step with driving resistance selectable from 11 values ranging from 0.5 ohms to 1 k ohm. Other resistance values may be added externally.

Type 575 Transistor Curve Tracer (including accessories) $1075

Type 575 Transistor Curve Tracer MOD 122C (including accessories $1325

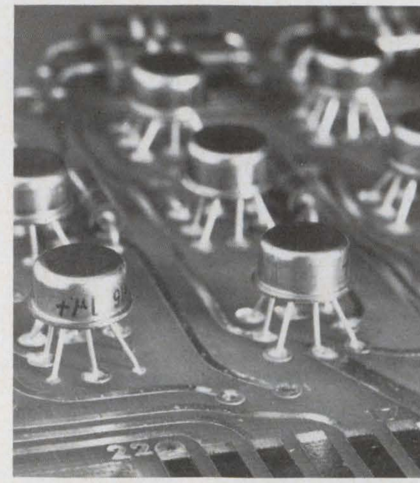
Type 175 High Current Adapter (including accessories) $1475

U. S. Sales Prices f.o.b. Beaverton, Oregon

Tektronix, Inc.

For complete information, contact your nearby Tektronix field engineer or write:
Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97005

ON READER-SERVICE CARD CIRCLE 55



Integrating digital meter is 75 per cent integrated circuits

Fairchild Instrumentation, 475 Ellis St., Mountain View, Calif. Phone: (415) 962-2011. Price: $1995.

High IC content and low price are features of the Model 7100A Integrating Digital Meter. The self-contained unit provides accurate measurement of dc voltages, voltage ratios and resistance.

Five-digit read-out is provided in the Model 7100A, with decimal point placement and polarity automatically selected. The unit gives direct read-out of voltages with full-scale ranges of 0.16, 1.6, 16, 160 and 1100 volts. Resistance ranges are 16 kΩ, 160 kΩ, 1.6 MΩ and 16 MΩ full-scale. Voltage ratios of 0.0001:1 to 1.6:1 can be measured in a single range of 1.6:1.

Separate floating and guarded input connectors are used in the Model 7100A for voltage and resistance measurements. An additional rear connector is provided for voltage input in ratio measurements. Optional remote programing and data output units can provide remote selection of range and mode, as well as BCD read-out information and range/mode output.

Ratio measurements

Unknown input:	±1 mV to +15 V; input resistance >1000 MΩ.
Reference input:	+5 to +15 V; input resistance 3 kΩ.
Accuracy:	+10 V reference, 0.01% of reading ±1 digit; +5 to +15 V, 0.02% of reading ±1 digit.

Dc voltage measurements

Ranging:	automatic or manual, switch selectable.
Accuracy:	±0.01% of reading ±1 digit; for 160-mV range, ±0.01% of reading ±2 digits.
Input resistance:	1000 MΩ; for 160- and 1100-V ranges, 10 MΩ.
Offset current:	20 pA maximum.
Max. input voltage:	1100 V.
Measurement time:	250 ms; 50 ms possible on four high ranges.

Resistance measurements

Ranging:	automatic or manual, switch selectable.
Accuracy:	±0.02% of reading ±1 digit.
Measurement current:	1 mA, 100 μA, 10 μA and 1 μA on the 16-kΩ through 16-MΩ ranges, respectively.
Measurement time:	50 ms maximum.

Standard plug-in unit DM-01B provides manual selection of range and mode. With optional automatic ranging, it also selects automatic voltage and resistance modes. High-sensitivity ac-to-dc conversion is possible with an additional plug-in unit, DM-03.

Pertinent specifications of the Model 7100A are as shown:

P&A: $1995. Fairchild Instrumentation, 475 Ellis Street, Mountain View, Calif. Phone: (415) 962-2011.

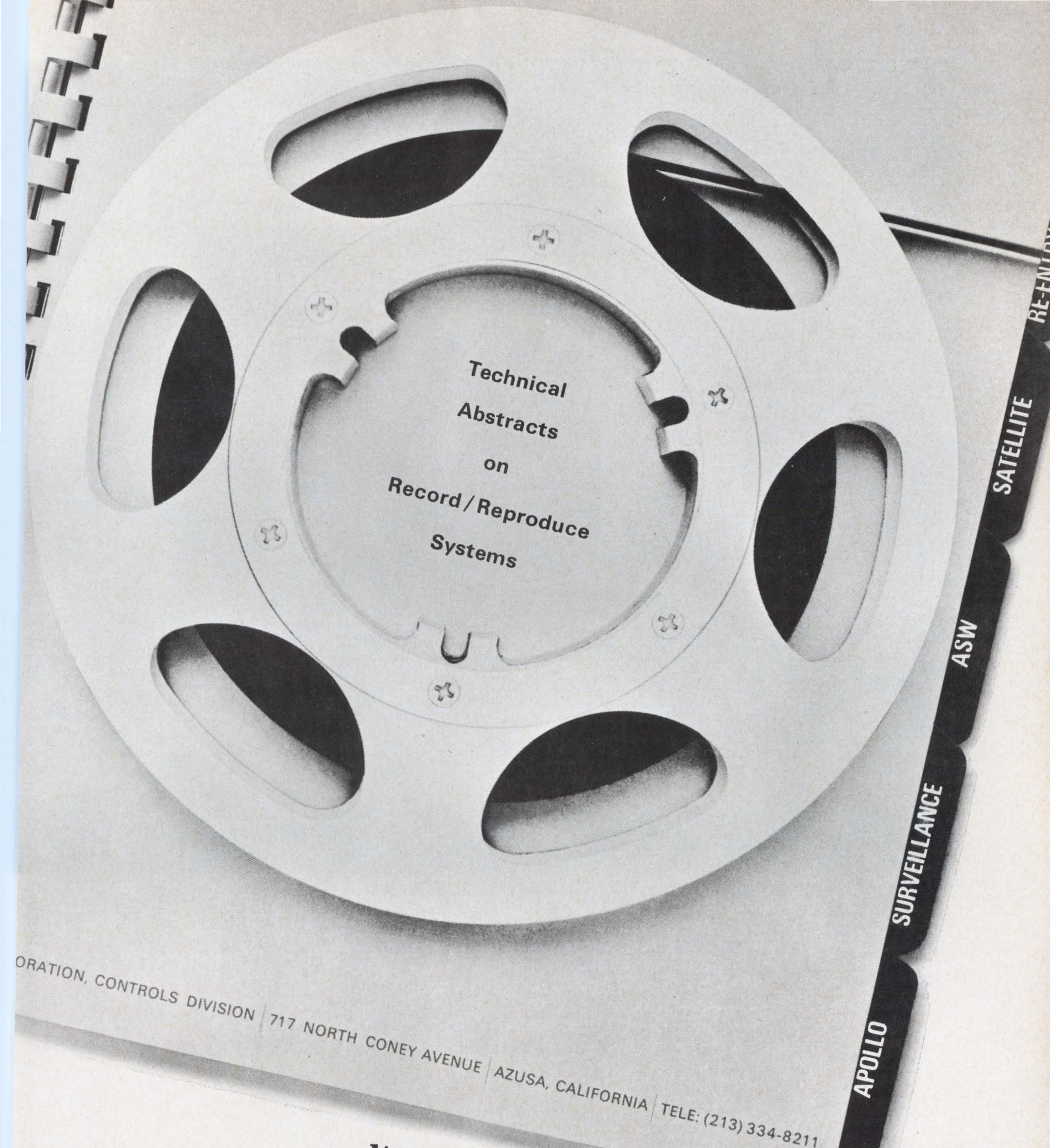
CIRCLE NO. 231

Deviation calibrator accurate to 1%

Cushman Electronics, Inc., 166 San Lazaro Ave., Sunnyvale, Calif. Phone: (408) 739-6760.

A companion to the CE-2B communications monitor, the Model 107 FM deviation calibrator provides accuracies to 1%, guaranteed by the manufacturer. Operating on power supplied by the CE-2B, the Model 107 is said to establish the accuracy of the deviation meter ranges in a few minutes. The instrument is fully transistorized.

CIRCLE NO. 232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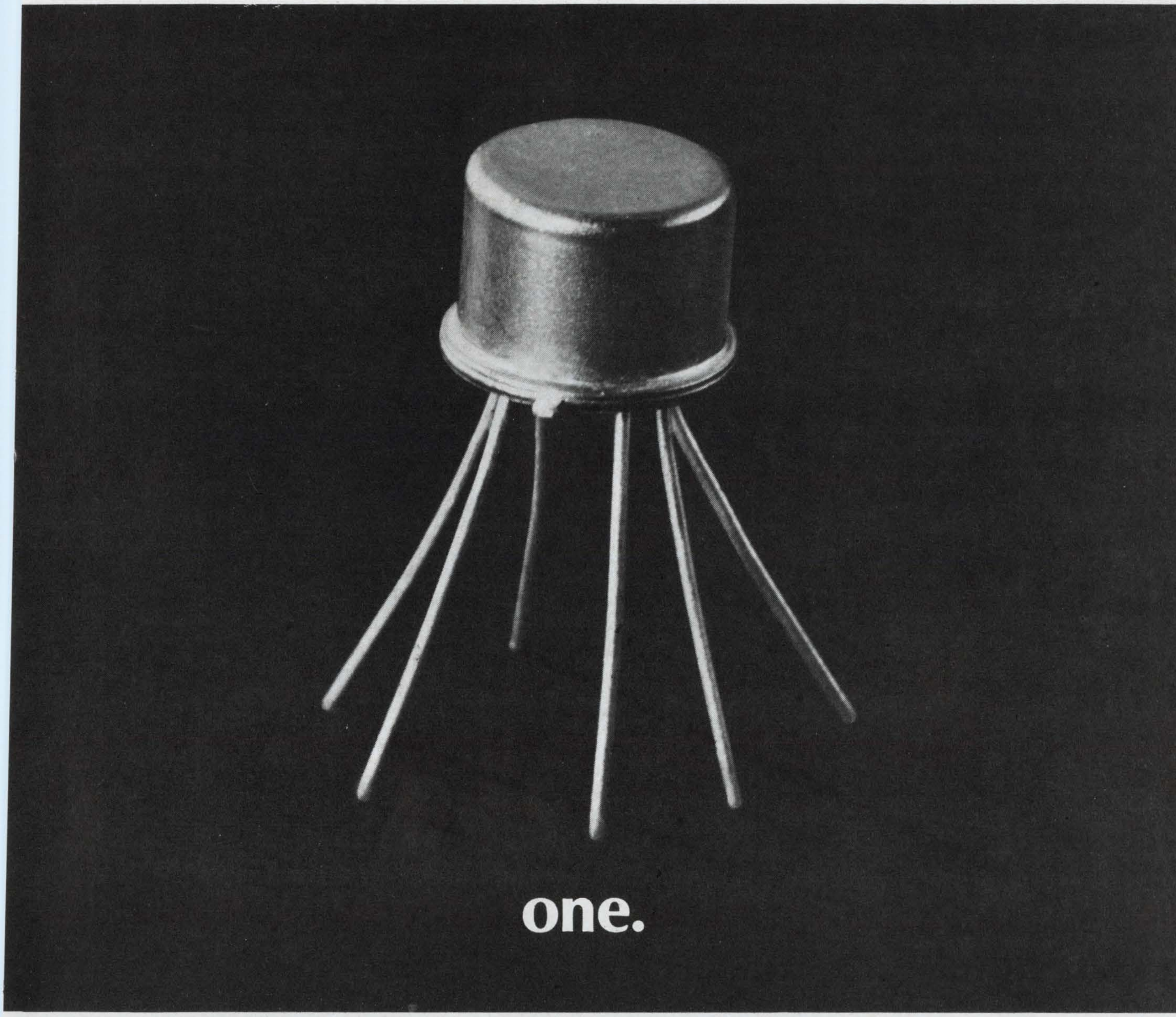
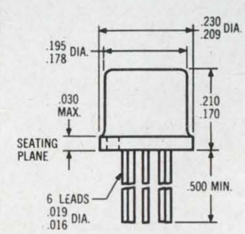
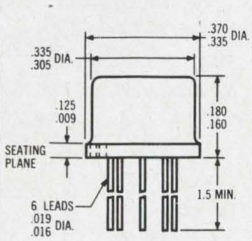
Fairchild dual transistors and differential amplifiers save space, give you greater design flexibility and provide uniform performance. You can get two discrete transistors into the space normally occupied by one. Pick virtually any of Fairchild's catalog PNP or NPN transistors for dual encapsulation. See table for several of Fairchild's PNP dual transistors and differential amplifiers. For differential amplifiers we select adjacent chips off the same wafer to give you the closest possible match of electrical characteristics. For price, delivery, and complete specifications, check with any Fairchild Distributor, or write for our new brochure.



Selected PNP High-Gain, Low-Noise Dual Transistors and Differential Amplifiers: (Write for full line PNP and NPN Brochure)



FT PACKAGE CONFIGURATION



2N PACKAGE CONFIGURATION

Differential Amplifiers:

	2N4020 FT4020	2N4021 FT4021	2N4022 FT4022	2N4023 FT4023	2N4024 FT4024	2N4025 FT4025
LV_{CEO}	—45V	—60V	—60V	—45V	—60V	—60V
$\frac{h_{FE1}}{h_{FE2}}$ @ $I_C = 100\mu A$ to $1.0mA$; $V_{CE} = -5.0V$	0.8 min. 1.0 max.	0.8 min. 1.0 max.	0.8 min. 1.0 max.	0.9 min. 1.0 max.	0.9 min. 1.0 max.	0.9 min. 1.0 max.
h_{FE} @ $V_{CE} = -5.0V$;						
$I_C = 1.0\mu A$	180 min.	60 min.	180 min.	180 min.	60 min.	180 min.
$I_C = 10\mu A$	250 min.	100 min.	250 min.	250 min.	100 min.	250 min.
$I_C = 100\mu A$	250 min.	100 min.	250 min.	250 min.	100 min.	250 min.
$I_C = 1.0mA$	250 min.	100 min.	250 min.	250 min.	100 min.	250 min.
NF @ $I_C = 20\mu A$; $V_{CE} = -5.0V$; $f = 100Hz$; $BW = 15Hz$; $R_S = 10k\mu$	4.0db max.	10db max.	4.0db max.	4.0db max.	10db max.	4.0db max.
$\lvert V_{BE1} - V_{BE2} \rvert$ @ $I_C = 100\mu A$	5.0mV max.	5.0mV max.	5.0mV max.	3.0mV max.	3.0mV max.	3.0mV max.

Dual Transistors:

	2N4017 FT4017	2N4018 FT4018	2N4019 FT4019
h_{FE} @ $V_{CE} = -5.0V$;			
$I_C = 1.0\mu A$	60 min.	60 min.	180 min.
$I_C = 10\mu A$	100 min.	100 min.	250 min.
$I_C = 100\mu A$	100 min.	100 min.	250 min.
$I_C = 1.0mA$	100 min.	100 min.	250 min.
LV_{CEO}	—80V	—60V	—45V
NF @ $I_C = 20\mu A$; $V_{CE} = -5.0V$; $f = 100Hz$; $BW = 15Hz$; $R_S = 10k\mu$	10db max.	10db max.	4.0db max.

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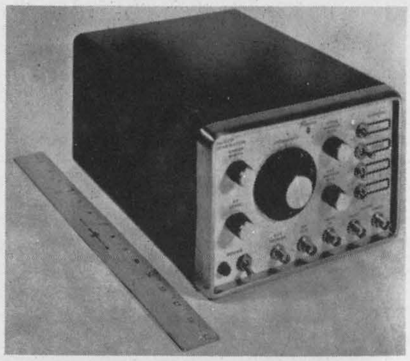
ON READER-SERVICE CARD CIRCLE 57

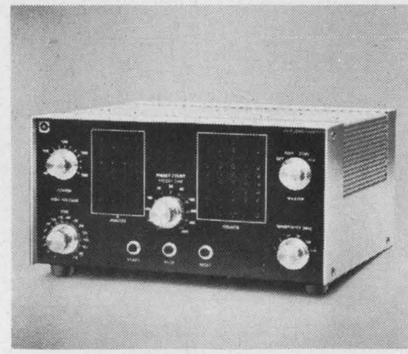


You select the range of small sweep generator

Texscan Corp., 51 Koweba Lane, Indianapolis, Ind. Phone: (317) 632-7351. P&A: $575; 2 to 3 wks.

A miniature, low-cost solid-state sweep generator offers either variable (0.1% to an octave) or fixed sweep widths and provisions for eight single-frequency or harmonic plug-in markers for accurate frequency identification. An external marker input is also available. Output is 0.5 V rms into a 50-Ω load and flatness is ±0.5 dB at maximum sweep width. Sweep rate is 50/60 Hz.

CIRCLE NO. 233



Scaler/timer for nuclear systems

Nuclear-Chicago Corp., 359 E. Howard Ave., Des Plaines, Ill. Phone: (312) 827-4456.

Combining scaling, timing and high-voltage detection in a single module, the Model 8775 is designed for nuclear-system use with most Geiger, gas-flow and scintillation radiation detectors. The scaler has a 1 μsec pulse-pair resolution and a max accumulated count of 100,000. Timing range is 0-100 minutes in increments of 0.01 minute. Input sense is 1-250 mV variable and high voltage varies from 400-3100 V.

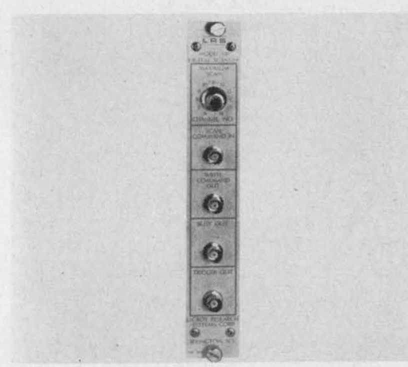
CIRCLE NO. 235

Power supply tester checks 6 parameters

Pacific Measurements, 940 Industrial Ave., Palo Alto, Calif. Phone: (415) 328-0300. Price: $750.

Power supply tests for transient response, loop stability, output impedance, ripple, and regulation line and load are provided by the model 1003 test assembly. The instrument has a regulated electronic load capable of pulse loading a power supply to 20 amp at 45 V. Oscilloscope readout is used to measure response, impedance, regulation and stability.

CIRCLE NO. 234



Digital scanner solves data interface problems

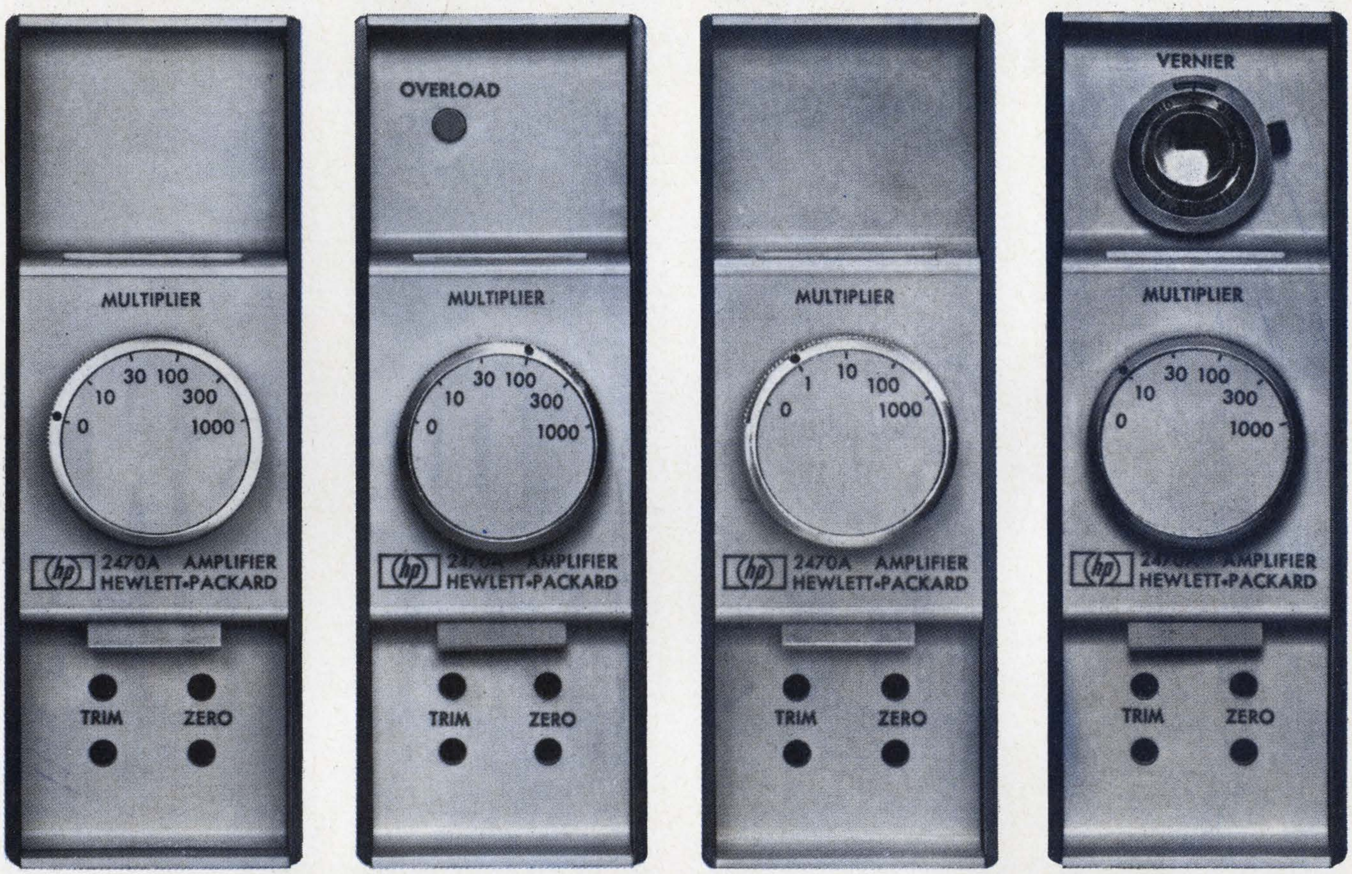
LeCroy Research Systems Corp., Irvington-On-Hudson, N. Y. Phone: (914) 591-7668.

The model 141A digital scanner is said to solve interface problems between primary data acquisition equipment and recorder-storage. Actually a buffer, the 141A permits the output of up to 18 LRS callers or A/D converters to be presented in sequence to a tape recorder, tape punch or computer. In scanning, the unit connects 6 volts, in turn, to each of 18 output lines.

CIRCLE NO. 236

OUTSTANDING PERFORMANCE...AT REASONABLE COST *HIGHEST ACROSS-THE-BOARD PERFORMANCE AVAILABLE FROM A WIDEBAND DIFFERENTIAL DATA AMPLIFIER*

New Hewlett-Packard 2470A Differential Data Amplifier...$585



Top electrical performance: Compare, spec to spec—DC gain X10 to X1000 (optional precision vernier, X1 gain), output ±10 v, 0-100 ma. Gain accuracy ±0.02% range; constant 50 kHz bandwidth. Differential input for low drift, high cmr (120 db at 60 kHz on gains down to x30, 90 db at x1). Full output across full bandwidth (10^7 v/sec RTO). High 1000-meg input impedance all gain settings, output impedance 0.1 ohm +10 μh. DC linearity of 0.002% on both polarities; dc gain stability of 0.005% per month achieved without chopper stabilization. Low drift and noise. Fast 100 microsecond settling, 100 microsecond overload recovery, excellent overload protection, optional overload indicator. Input and output isolated by internally driven guard shields; dual output available with fixed 2-pole filter.

Built-in reliability: The predicted MTBF of the 2470A is in excess of 20,000 hours. Silicon transistors are used throughout, and passive and active components are selected for dependability, as well as performance. Amplifier meets spec at 95% humidity at 40°C. Critical parameters (zero drift, full-scale accuracy, common mode rejection) are verified after 100 hours of "run-in" at elevated temperature.

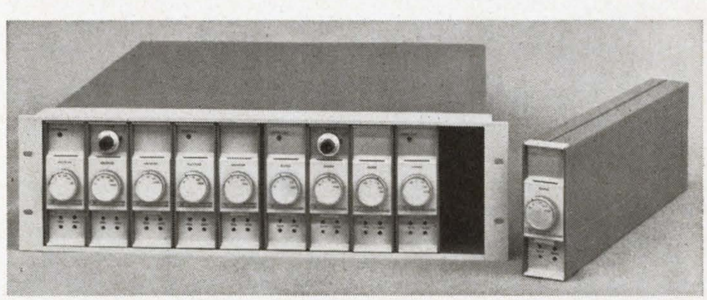
Packaging for value, compactness: Amplifier and self-contained power supply are enclosed in a unique, rugged molded dielectric case. Combining case, bench stand, power and signal cables, plus many other accessories, are available.

Use if for: Amplifying signals from low-level resistive transducers, such as thermocouples, strain gages. High input and low output impedance make it ideal for amplification over long transmission lines; use it, with resistive or reactive loads, such as x-y, strip-chart or oscillographic recorders, digital voltmeters, null detectors and servo systems, telemetry systems . . . or use it as a high-performance bench amplifier.

Call your Hewlett-Packard field engineer for complete information or write the Dymec Division of Hewlett-Packard, 395 Page Mill Road, Palo Alto, California 94306, Tel. (415) 326-1755; Europe: 54 Route des Acacias, Geneva.

Price f.o.b. factory.
Data subject to change without notice.

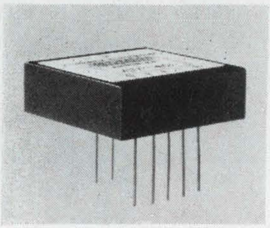
HEWLETT PACKARD DYMEC DIVISION



1306

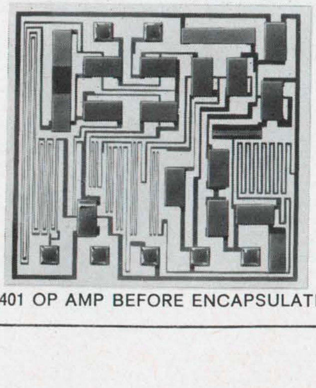
ON READER-SERVICE CARD CIRCLE 59

Amperex announces the ATF-401... the operational amplifier made possible by our special production-line methods and thin film/LID circuit technology...

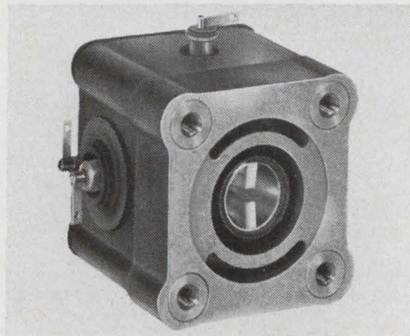
IF THIS  DOESN'T HYBRID LINEAR IC'S,

ATF-401 OP AMP QUICK REFERENCE DATA

VOLTAGE GAIN
(open loop, $R_L = 5k$)............50,000 min
FREQUENCY FOR UNITY GAIN...2 MHz min
RATED OUTPUT......± 11V @ ± 2.2 mA min
INPUT NOISE ($R_{in} = 1k$)...........5 μV max
INPUT VOLTAGE
OFFSET........................ 10 mV max
(externally adjustable to zero)
TEMPERATURE DRIFT........10 μV/°c max
INPUT CURRENT
OFFSET.........................50 nA max
TEMPERATURE DRIFT.........2 nA/°c max
INPUT IMPEDANCE
DIFFERENTIAL ....200 kilohms min
COMMON MODE ....10 megohms min
POWER REQUIREMENTS
OPERATING (under load) ±15V, ± 7 mA max
SHORT CIRCUIT CURRENT ± 20 mA max
DIMENSIONS...... .80 x .80 x .25 inches



ATF-401 OP AMP BEFORE ENCAPSULATION

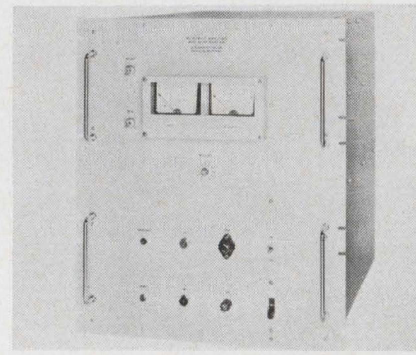


Pulsed magnetron for radar detection

Microwave Associates, Inc., South St., Burlington, Mass. Phone: (617) 272-3000.

A new fixed-frequency pulsed beacon magnetron is designed for use in radar detection systems and missile and ground support equipment. The MA-252A magnetron is of ceramic and metal construction and provides 250-watts in the 818- to 916-GHz range. Pulse width is 0.5 μsec and duty ratio is 0.005. Since this is a positive-pulse tube, it can be supplied for operation at other power/duty cycle combinations.

CIRCLE NO. 237

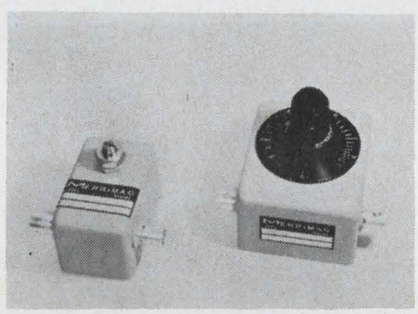


12 microwave amps cover vhf to X-band

Alto Scientific Company, Inc., 4083 Transport St., Palo Alto, Calif. Phone: (415) 321-3434. Availability: 60-75 days.

A line of 12 self-contained amplifiers covers vhf through X-band. Power out ranges from 100 W to 300 W cw depending on the frequency. Typical small-signal gain is 30 dB and typical noise is 35 dB. The 300-watt units are liquid cooled and lower ratings are forced-air cooled by integral blowers. All power supplies are electronically regulated.

CIRCLE NO. 239



Variable attenuators range over 30 MHz

Merrimac Research & Development, Inc., 41 Fairfield Pl., W. Caldwell, N. J. Phone: (201) 371-1616. P&A: \$60 to \$80; stock to 30 days.

Applied in areas such as audio, video and IF level-setting and control, the AR series of matched attenuators can be used up to 30 MHz without performance degradation. The series consists of two models, AR-1 which is uncalibrated and AR-2 which is calibrated accurate to 0.5 dB. Attenuation range is 0 to 20 dB, insertion loss is below 0.75 dB and typical vswr is 1.2.

CIRCLE NO. 238

Mixer/preamplifiers for low-noise mixers

Varian LEL Division, Akron St., Copiague, N. Y. Phone: (516) 264-2200. P&A: \$995; 1 month.

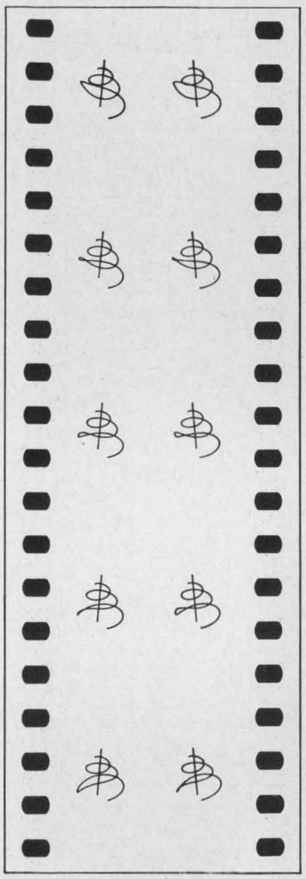
Low-noise wideband orthogonal-mode waveguide mixers are used in the seven models of a new series of mixer-preamplifiers. The series covers the frequency range of 5.4 to 39 GHz. A typical unit of the series covers 8.2-12.4 GHz with a noise figure of 9-10 dB. Intermediate frequencies are 30, 60, or 70 GHz.

CIRCLE NO. 240

Report from

BELL LABORATORIES

A 3-D Glimpse of the Hearing Process



THE MOVIE shows the basilar membrane as a "stereo pair" of spiral lines. The sequential frames shown here represent the motion of the membrane responding to the sound "oo" in the word "too" as pronounced by R. C. Lummis, one of the scientists responsible for the film.

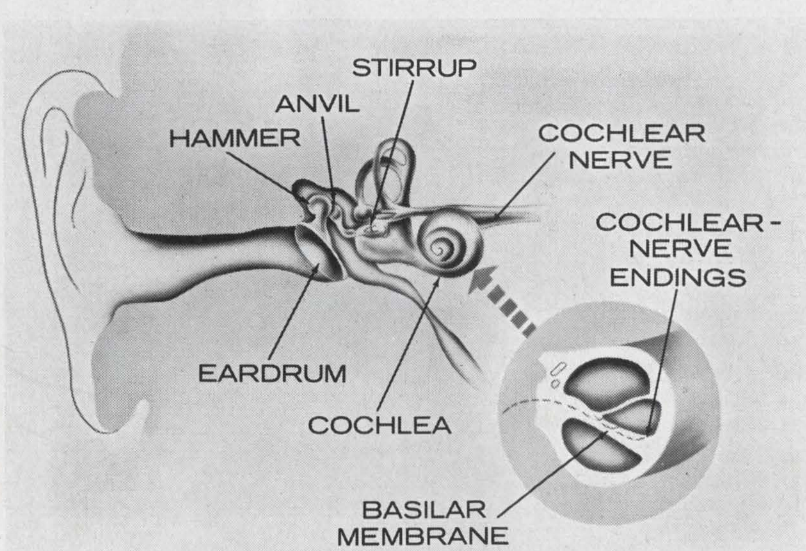
To view this illustration in 3-D, place a sheet of paper on edge between one stereo pair. Position your head so each eye sees only one image. The pictures should then seem to converge and appear three-dimensional.

For screen projection, polarized light and polarized eyeglasses are used to obtain a 3-D image.

THE BASILAR MEMBRANE is a lengthwise partition in the spiral, fluid-filled cochlea (figure). Sound, from the eardrum by way of the hammer, anvil, and stirrup, produces vibrations in this membrane. The end nearest the stirrup resonates at the highest audible tones (approximately 20,000 Hz); the end near the apex of the spiral resonates at the lowest (approximately 20 Hz).

The cochlear nerve terminates near the membrane and, by sensing the vibration at each point, converts the mechanical motion into nerve impulses which the brain perceives as a sound.

Because of its filtering and analytical functions the basilar membrane is a center of interest in hearing research. Since it is embedded in the skull, direct study is extremely difficult.



At Bell Telephone Laboratories, basic research in voice communications does not end with telephone equipment. For instance, three scientists here have made a stereoscopic motion picture showing how the ear's principal transducer—the basilar membrane—moves in response to sound.

A number of steps were involved: First, equations describing the membrane's response were converted to digital form, suitable for machine computation. Next, a program was devised so a computer could determine the precise motion of each point on the membrane as a function of any complex sound input. Finally, the resulting data were processed with another program which introduced the parallax effects inherent in binocular vision.

The output was a series of pairs of stereoscopic images. The computer drew these on the face of a cathode-ray tube where they were automatically photographed to form the frames of the movie.

In this film, the membrane's movements (actually microscopic) are greatly enlarged and slowed down for detailed examinations. Thus we have developed a promising tool for the study of hearing. For example, movies made in this way could help us evaluate theories of the basilar membrane's role in converting sound to nerve impulses. (Several complex mathematical relationships have been proposed; now we may see them in simulated action and measure their properties.)

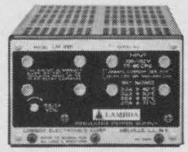
The scientists who made this film are Robert C. Lummis, A. Michael Noll, and Man Mohan Sondhi. The membrane-response equations from which they began were originated by James L. Flanagan, also of Bell Laboratories. His work was based on anatomical measurements made by Nobel laureate Georg von Békésy of the University of Hawaii.

Meet any programable or fixed voltage need

Up to 150 volts • Up to 95 amps

A

B

C

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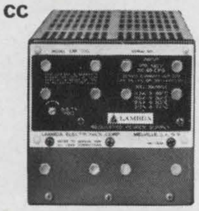
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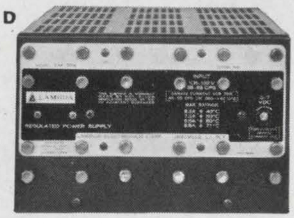
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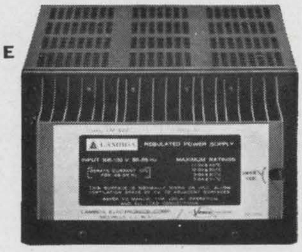


FEATURES and DATA

Full line of accessories and options to meet your system needs. Meet Mil. Environment Specs. **RFI**—MIL-I-16910: **Vibration:** MIL-T-4807A: **Shock:** MIL-E-4970A • Proc. 1 & 2: **Humidity:** MIL-STD-810 • Meth. 507: **Temp. Shock:** MIL-E-5272C • (ASG) Proc. 1: **Altitude:** MIL-E-4970A • (ASG) Proc. 1: **Marking:** MIL-STD-130: **Quality:** MIL-Q-9858: **Fungus Proofing** (optional) all models available with MIL-V-173 varnish for all nutrient components.

Convection cooled—no heat sinking or forced air required

Wide input voltage and frequency range—105-132 VAC, (200-250 VAC, optional at no extra charge) 45-440 cps

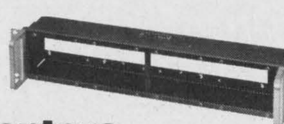
Regulation (line) 0.05% plus 4MV **(load)** 0.03% plus 3MV:

Ripple and Noise—1 MV rms, 3MV p to p

Overvoltage protection available for all models up to 70 VDC

High Performance Option—All models available with these specifications for $25.00 extra: **Line regulation**—.01% + 1MV; **Load regulation**—.02% + 2MV: **Ripple and Noise**—½MV rms; 1½MV p to p: **Temp. Coef.**—.01%°C

ACCESSORIES and OPTIONS



System Rack Adapters

LRA-5 • 3½" height by 2 7/16" depth. Price $35.00

LRA-4 • 3½" height by 14" depth. (For use with chassis slides) Price $55.00

LRA-5 and **LRA-4** mount the following combinations of LM models: up to 4 A package sizes • 3 B or 3 C package sizes • 2 A and 1 B or 1 C package sizes

LRA-3 • 5¼" height by 2 7/16" depth. Price $35.00

LRA-6 • 5¼" height by 14" depth. (For use with chassis slides) Price $60.00

LRA-3 and **LRA-6** mount the following combinations of LM models: up to 4 A, B or C package sizes • 3 CC package sizes • 2 D or 2 E package sizes • 2 A, B or C and 1 CC or 1 D or 1 E package sizes • 1 CC and 1 D or 1 E package sizes • 1 D and 1 E package sizes

Metered Panels • 3½" Metered panel MP-3 is used with rack adapters LRA-4, LRA-5 and packages A, B and C. Price $40.00

5¼" Metered panel MP-5 is used with rack adapters LRA-6, LRA-3 and packages A, B, C, CC, D and E. Price $40.00

To order these accessory metered panels, specify panel number which MUST BE FOLLOWED BY the MODEL NUMBER of the power supply with which it will be used.

F and G LM Packages are full rack power supplies available metered or non-metered. For metered models, add suffix M to the Model No. and $30 to the non-metered price.

Other Options • Also available are Overvoltage Protectors, Fungus Proofing, and High Performance Options at moderate surcharges.

WIDE VOLTAGE RANGE

PROGRAMABLE LM SERIES MODELS

PACKAGE A 3 3/16"x3¾"x6½"	ADJ. VOLT. RANGE VDC	*MAX. AMPS AT AMBIENT OF: 40°C	50°C	60°C	71°C	Price**
LM 251	0-7	0.35	0.31	0.29	0.27	$ 69
LM 201	0-7	0.85	0.75	0.70	0.55	79
LM 202	0-7	1.7	1.5	1.4	1.1	89
LM 252	0-7	2.0	1.8	1.4	1.1	99
LM 257	0-14	0.27	0.24	0.23	0.22	69
LM 203	0-14	0.45	0.40	0.38	0.28	79
LM 204	0-14	0.90	0.80	0.75	0.55	89
LM 258	0-14	1.2	1.1	1.0	0.80	99
LM 259	0-24	0.18	0.16	0.15	0.14	69
LM 260	0-24	0.35	0.30	0.25	0.20	79
LM 261	0-24	0.70	0.65	0.60	0.45	89
LM 262	0-24	0.80	0.75	0.70	0.60	99
LM 263	0-32	0.14	0.12	0.11	0.10	69
LM 205	0-32	0.25	0.23	0.20	0.15	79
LM 206	0-32	0.50	0.45	0.40	0.30	89
LM 264	0-32	0.66	0.60	0.50	0.32	99
LM 265	0-60	0.08	0.07	0.07	0.06	79
LM 207	0-60	0.13	0.12	0.11	0.08	89
LM 208	0-60	0.25	0.23	0.21	0.16	99
LM 266	0-60	0.35	0.31	0.28	0.25	109
LM 267	0-120	0.10	0.09	0.08	0.07	109
LM 268	0-120	0.13	0.12	0.10	0.09	119

PACKAGE B 3 3/16"x4 15/16"x6½"	ADJ. VOLT. RANGE VDC	*MAX. AMPS AT AMBIENT OF: 40°C	50°C	60°C	71°C	Price**
LMB-0-7	0—7	2.8	2.6	2.3	1.5	$109
LMB-0-14	0—14	1.6	1.5	1.3	1.2	109
LMB-0-32	0—32	0.80	0.70	0.60	0.5	109
LMB-0-60	0—60	0.45	0.40	0.35	0.3	109
LM-217	8.5—14	2.1	1.9	1.7	1.3	119
LM-218	13—23	1.5	1.3	1.2	1.0	119
LM-219	22—32	1.2	1.1	1.0	0.80	119
LM-220	30—60	0.70	0.65	0.60	0.45	129

PACKAGE C 3 3/16"x4 15/16"x9⅜"	ADJ. VOLT. RANGE VDC	*MAX. AMPS AT AMBIENT OF: 40°C	50°C	60°C	71°C	Price**
LM-225	0—7	4.0	3.6	3.0	2.4	$139
LMC-0-14	0—14	2.2	2.0	1.8	1.5	139
LMC-0-32	0—32	1.1	1.0	0.90	0.80	139
LMC-0-60	0—60	0.60	0.55	0.50	0,45	139
LM-226	8.5—14	3.3	3.0	2.5	2.0	139
LM-227	13—23	2.3	2.1	1.7	1.4	139
LM-228	22—32	2.0	1.8	1.5	1.2	139
LM-229	30—60	1.1	1.0	0.80	0.60	149

PACKAGE D 4 15/16"x7½"x9⅜"	ADJ. VOLT. RANGE VDC	*MAX. AMPS AT AMBIENT OF: 40°C	50°C	60°C	71°C	Price**
LM-234	0—7	8.3	7.3	6.5	5.5	$199
LMD-0-14	0—14	4.9	4.2	3.4	2.7	199
LMD-0-32	0—32	2.5	2.1	1.7	1.3	180
LMD-0-60	0—60	1.3	1.1	0.95	0.75	239
LM-235	8.5—14	7.7	6.8	6.0	4.8	199
LM-236	13—23	5.8	5.1	4.5	3.6	209
LM-237	22—32	5.0	4.4	3.9	3.1	219
LM-238	30—60	2.6	2.3	2.0	1.6	239

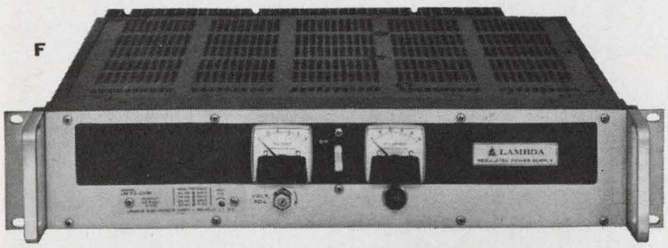
PACKAGE E 4 15/16"x7½"x11⅞"	ADJ. VOLT. RANGE VDC	*MAX. AMPS AT AMBIENT OF: 40°C	50°C	60°C	71°C	Price**
LME-0-7	0—7	12.0	10.5	8.5	6.8	$249
LME-0-14	0—14	7.4	6.4	5.2	4.1	249
LME-0-32	0—32	3.7	3.2	2.6	2.1	249
LME-0-60	0—60	2.1	1.7	1.4	1.1	249

PACKAGE F 3½"x19"x16½"	ADJ. VOLT. RANGE VDC	*MAX. AMPS AT AMBIENT OF: 40°C	50°C	60°C	71°C	Price**
LMF-0-7	0—7	25.0	21.0	17.0	14.0	$425

PACKAGE G 5¼"x19"x16½"	ADJ. VOLT. RANGE VDC	*MAX. AMPS AT AMBIENT OF: 40°C	50°C	60°C	71°C	Price**
LMG-0-7	0—7	35.0	29.0	24.0	20.0	$575

with Lambda Modular Power Supply Systems

F



G

FIXED VOLTAGE RANGE

LM SERIES MODELS

PACKAGE B 3³⁄₁₆"x4¹⁵⁄₁₆"x6½"	ADJ. VOLT. RANGE VDC	*MAX. AMPS AT AMBIENT OF: 40°C	50°C	60°C	71°C	Price**
LM B3	3 ±5%	3.8	3.3	2.6	1.6	$119
LM B3P3	3.3±5%	3.8	3.3	2.6	1.6	119
LM B3P6	3.6±5%	3.8	3.3	2.6	1.6	119
LM B4	4 ±5%	3.8	3.3	2.6	1.6	119
LM B4P5	4.5±5%	3.7	3.2	2.5	1.5	119
LM B5	5 ±5%	3.7	3.2	2.5	1.5	119
LM B6	6 ±5%	3.2	2.9	2.4	1.4	119
LM B8	8 ±5%	3.2	2.9	2.4	1.4	119
LM B10	10 ±5%	2.7	2.5	2.2	1.4	119
LM B12	12 ±5%	2.5	2.3	2.1	1.3	119
LM B15	15 ±5%	2.2	2.0	1.8	1.3	119
LM B18	18 ±5%	2.0	1.8	1.7	1.3	119
LM B20	20 ±5%	1.8	1.6	1.5	1.2	119
LM B24	24 ±5%	1.4	1.3	1.2	1.1	119
LM B28	28 ±5%	1.3	1.2	1.1	1.0	119
LM B36	36 ±5%	1.1	1.0	0.90	0.85	129
LM B48	48 ±5%	0.9	0.85	0.80	0.75	129
LM B60	60 ±5%	0.7	0.65	0.60	0.54	129
LM B100	100 ±5%	0.37	0.34	0.30	0.28	139
LM B120	120 ±5%	0.30	0.28	0.25	0.23	139
LM B150	150 ±5%	0.25	0.23	0.20	0.19	149

PACKAGE C 3³⁄₁₆"x4¹⁵⁄₁₆"x9⅜"	ADJ. VOLT. RANGE VDC	*MAX. AMPS 40°C	60°C	Price**
LM C3	3 ±5%	5.3	3.7	$139
LM C4	4 ±5%	5.2	3.6	139
LM C4P5	4.5±5%	5.1	3.5	139
LM C5	5 ±5%	5.1	3.4	139
LM C6	6 ±5%	4.8	3.3	139
LM C12	12 ±5%	4.0	2.9	139
LM C15	15 ±5%	3.5	2.8	139
LM C20	20 ±5%	3.1	2.6	139
LM C24	24 ±5%	2.5	2.2	139
LM C28	28 ±5%	2.3	2.0	139
LM C48	48 ±5%	1.6	1.3	149
LM C150	150 ±5%	0.39	0.33	169

NEW PACKAGE CC 4¹⁵⁄₁₆"x4¹⁵⁄₁₆"x9⅜"	ADJ. VOLT. RANGE VDC	*MAX. AMPS 40°C	60°C	Price**
LM CC3	3 ±5%	11.0	8.2	$179
LM CC4	4 ±5%	11.0	8.2	179
LM CC4P5	4.5±5%	10.5	8.0	179
LM CC5	5 ±5%	10.5	8.0	179
LM CC6	6 ±5%	9.0	7.7	179
LM CC12	12 ±5%	7.3	5.9	169
LM CC15	15 ±5%	6.0	5.1	169
LM CC20	20 ±5%	5.0	4.2	169
LM CC24	24 ±5%	4.0	3.4	169
LM CC28	28 ±5%	3.5	3.1	169
LM CC48	48 ±5%	2.5	2.2	189
LM CC150	150 ±5%	0.7	0.62	199

PACKAGE D 4¹⁵⁄₁₆"x7½"x9⅜"	ADJ. VOLT. RANGE VDC	*MAX. AMPS 40°C	60°C	Price**
LM D3	3 ±5%	13.1	9.2	$199
LM D4	4 ±5%	13.1	9.2	199
LM D4P5	4.5±5%	13.1	9.2	199
LM D5	5 ±5%	12.6	9.2	199
LM D6	6 ±5%	12.4	8.9	199
LM D12	12 ±5%	10.0	8.3	199
LM D15	15 ±5%	9.0	7.9	209
LM D20	20 ±5%	7.4	6.5	209
LM D24	24 ±5%	6.7	5.8	219
LM D28	28 ±5%	6.0	5.2	219
LM D48	48 ±5%	4.1	3.6	239
LM D150	150 ±5%	1.1	0.90	254

PACKAGE E 4¹⁵⁄₁₆"x7½"x11⅞"	ADJ. VOLT. RANGE VDC	*MAX. AMPS 40°C	60°C	Price**
LM E3	3 ±5%	22.0	16.5	$269
LM E4	4 ±5%	21.0	16.5	269
LM E4P5	4.5±5%	20.0	16.4	269
LM E5	5 ±5%	20.0	16.4	269
LM E6	6 ±5%	19.0	15.6	269
LM E12	12 ±5%	15.0	12.3	269
LM E15	15 ±5%	14.0	11.5	269
LM E20	20 ±5%	12.0	9.8	269
LM E24	24 ±5%	11.0	9.0	269
LM E28	28 ±5%	10.0	8.0	269
LM E48	48 ±5%	6.0	4.9	299
LM E150	150 ±5%	1.4	1.2	299

PACKAGE F 3½"x19"x16½"	ADJ. VOLT. RANGE VDC	*MAX. AMPS 40°C	60°C	Price**
LM FA3	3 ±5%	31.5	24.0	$375
LM FA4	4 ±5%	31.5	24.0	375
LM FA4P5	4.5±5%	31.5	24.0	375
LM FA5	5 ±5%	31.5	23.7	375
LM FA6	6 ±5%	30.5	22.0	375
LM FA12	12 ±5%	22.0	16.2	375
LM FA15	15 ±5%	19.4	15.2	375
LM FA20	20 ±5%	16.0	12.6	350
LM FA24	24 ±5%	14.0	11.4	350
LM FA28	28 ±5%	13.5	10.4	350
LM FA48	48 ±5%	8.1	6.5	375
LM FA150	150 ±5%	2.4	1.8	410
LM F3	3 ±5%	48.0	34.0	425
LM F4	4 ±5%	48.0	34.0	425
LM F4P5	4.5±5%	48.0	34.0	425
LM F5	5 ±5%	48.0	33.0	425
LM F6	6 ±5%	47.0	32.0	425
LM F12	12 ±5%	33.0	22.0	425
LM F15	15 ±5%	28.0	19.0	425
LM F20	20 ±5%	23.0	17.0	395
LM F24	24 ±5%	20.0	14.0	380
LM F28	28 ±5%	19.0	13.0	380
LM F48	48 ±5%	10.0	7.5	425
LM F150	150 ±5%	3.1	2.1	460

PACKAGE G 5¼"x19"x16½"	ADJ. VOLT. RANGE VDC	*MAX. AMPS 40°C	60°C	Price**
LM G3	3 ±5%	95.0	62.0	$575
LM G4	4 ±5%	85.0	62.0	575
LM G4P5	4.5±5%	85.0	62.0	575
LM G5	5 ±5%	80.0	62.0	575
LM G6	6 ±5%	80.0	62.0	525
LM G12	12 ±5%	56.0	37.0	525
LM G15	15 ±5%	45.0	36.0	525
LM G20	20 ±5%	35.0	28.0	525
LM G24	24 ±5%	32.0	21.0	480
LM G28	28 ±5%	28.0	21.0	480
LM G48	48 ±5%	17.0	12.0	575
LM G150	150 ±5%	5.5	4.5	675

NOTE:
Space does not permit listing all LM Series fixed-voltage power supplies. In every package size there are models for each voltage range listed under the B package and all units are multi-current-rated for 40°C, 50°C, 60°C and 71°C. Call or write for data and prices.

* Current rating is from zero to I max. at ambient. Current rating applies over entire output voltage range.

Current rating applies for input voltage 105-132 VAC 55-65 cps.

For operation at 45-55 cps derate current rating 10%.

For operation at 360-440 cps consult factory for ratings and specifications.

** Prices F.O.B. Factory, Melville, N. Y. All specifications and prices subject to change without notice.

5 Year Guarantee

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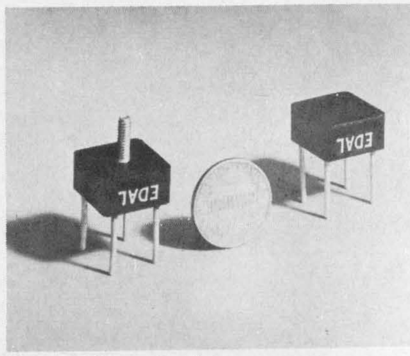
LAMBDA ELECTRONICS CORP. A Veeco SUBSIDIARY
515 BROAD HOLLOW ROAD · MELVILLE, L. I., NEW YORK · 516 MYRTLE 4-4200

ON READER-SERVICE CARD CIRCLE 62

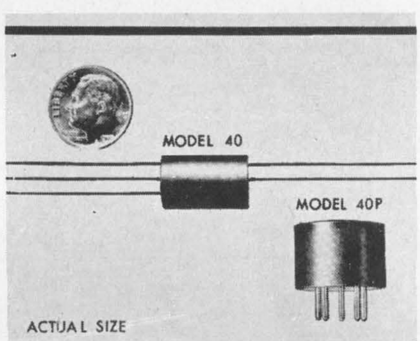


Rectifier bridge saves wiring time

Edal Industries Inc., 4 Short Beach Rd., East Haven, Conn. Phone: (203) 467-2591.

By eliminating the need for assembling diode-bridge circuitry, the Series B191 single-phase bridge silicon rectifier is said to save assembly time and reduce inventory requirements. The 6-A module contains double-diffused controlled avalanche junctions in a cold case design. Voltage ratings range from 50 to 1200 V PIV.

CIRCLE NO. 226

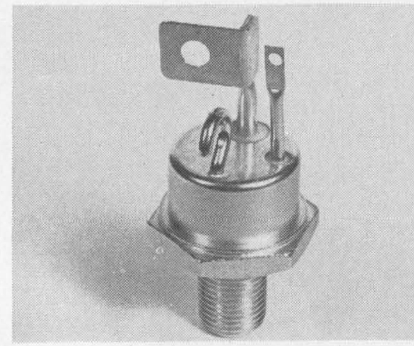


Solid-state chopper ranges dc to 50 kHz

Solid State Electronics Co., 15321 Rayen St., Sepulveda, Calif. Phone: (213) 364-2271.

As choppers or demodulators, the model 40 and 40P have operating ranges of dc to 50 kHz. Linear chopping or demodulation can be accomplished with inputs from a fraction of a millivolt to 15 volts. Model 40 is identical to 40P except that 40 is tubular and is equipped with axial leads while 40P is a 7-pin plug-in module. All silicon transistors are used.

CIRCLE NO. 227

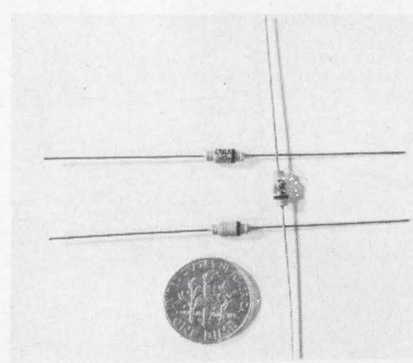


NPN Si power device controls 100 amps

Solitron Devices, Inc., 1177 Blue Heron Blvd., Riviera Beach, Fla. Phone: (305) 848-4311. Availability: stock.

Meeting MIL-S-19500, 2N4866 and 2N4865 provide a 100-amp capability as high-current inveters for supplies and regulators. Combined with the 100-amp capability is a power rating of 350 watts. Sustaining voltage is 80 volts for the 2N4865 and 120 volts for the 2N4866. Cut-off for both is 10 MHz. The transistors have a h_{FE} of 10-40 at 70 amps and 5 at 90 amps.

CIRCLE NO. 228



Mil-type "Varicaps" priced for industry

TRW Inc., 650 Sepulveda Blvd., El Segundo, Calif. Phone: (213) 322-2566. P&A: $4.20; stock.

Priced for industrial use, the JAN IN4801A through 15A Varicap voltage variable diode series conforms to MIL-S- 19500/329B. The devices are packaged DO-14 and suggested for use in voltage controlled oscillators, delay lines and AFC circuitry. A variety of lead materials are offered.

CIRCLE NO. 229

DC-500 MHz Mixers at realistic prices

RELCOM engineers have produced a new family . . . indeed, a new generation . . . of broadband mixers. Six models in three sizes for frequency mixing, phase detection, amplitude and pulse modulation.

Small size — .75x.5x.4" to 2x1x.6." Realistic prices — starting at $50 for the miniature model M8. Only $150 for the pocket-lighter size model M1. Heavy discounts on higher quantities. If you're looking for more than size and price in a rugged, lightweight mixer, RELCOM offers other significant plus factors.

• PC mounting • Exceptional balance • Low level intermodulation products • Low noise figure • Very low 1/f noise • Extremely wide dynamic range • ±0.3 dB from 1 MHz thru 50 MHz • Excellent RFI performance • −20 to +65°C operation • 1 year warranty

SPECIFICATIONS

MODEL	IMP. (Ohms)	FREQ.* RANGE (MHz)	Type	BALANCE L to R & I (dB) 0.2–50 MHz	BALANCE L to R & I (dB) Remaining Freq. Range	CONV. EFF. & SSB NOISE FIGURE (dB) 1.0–50 MHz	CONV. EFF. & SSB NOISE FIGURE (dB) Remaining Freq. Range	CONN.	SIZE (in.)	PRICE 1–4	PRICE 5–9	PRICE 10–29
M1	50	0.2–500	Double	40	20	6.5	8.5	BNC	2x1x.6	**$150**	**$133**	**$126**
M2	50–75	0.2–500	Single	35	15	6.5	8.5	BNC	2x1x.6	**110**	**98**	**92**
M5	50	0.2–500	Double	35	20	6.5	9.5	Pins	1x.5x.4	**100**	**98**	**92**
M6	50–75	0.2–200	Double	35	20	6.5	7.5	Pins	1x.5x.4	**90**	**80**	**76**
M7	50–75	0.2–500	Single	35	15	6.5	8.5	Pins	.75x.5x.4	**70**	**62**	**59**
M8	50–75	0.2–200	Single	35	15	6.5	7.5	Pins	.75x.5x.4	**50**	**44**	**42**

*R & L ports shown. I port: DC-500 MHz.

RELCOM's new family of mixers now available. Call collect to place orders.

RELCOM

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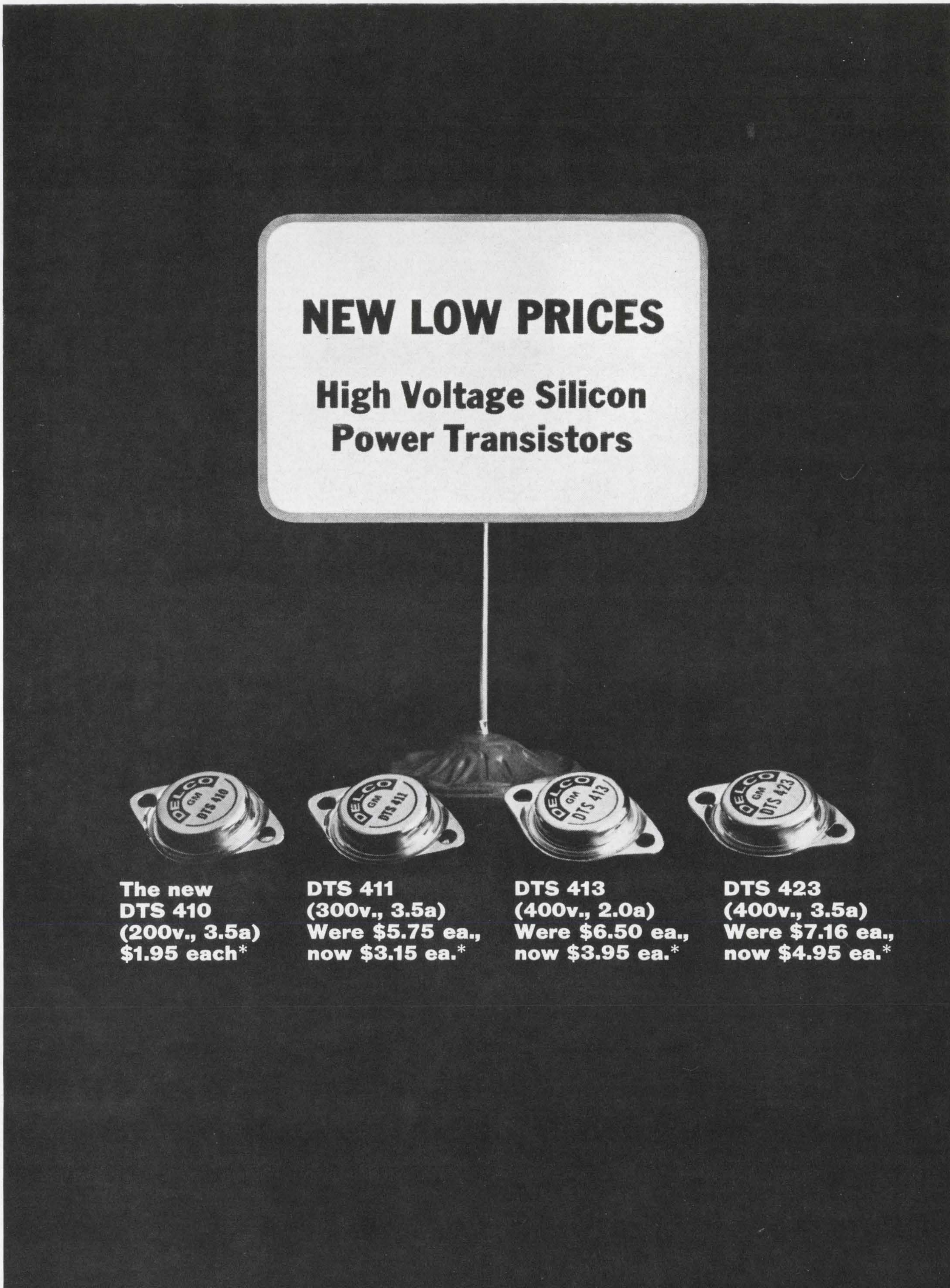
ON READER-SERVICE CARD CIRCLE 64


NEW LOW PRICES
High Voltage Silicon
Power Transistors
DELCO GM DTS 410
DELCO GM DTS 411
DELCO GM DTS 413
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The new
DTS 410
(200v., 3.5a)
$1.95 each*
DTS 411
(300v., 3.5a)
Were $5.75 ea.,
now $3.15 ea.*
DTS 413
(400v., 2.0a)
Were $6.50 ea.,
now $3.95 ea.*
DTS 423
(400v., 3.5a)
Were $7.16 ea.,
now $4.95 ea.*

We just lowered the cost of lowering the cost of high-energy circuits.

From now on, the cost-cutting advantages of Delco NPN high voltage silicon power transistors cost even less. Look over the new low prices on the opposite page.

You can use these transistors in applications ranging from large screen video deflection and line operated class A audio output to high voltage, high efficiency regulators, converters and (VLF) amplifiers.

By using Delco high voltage silicon power transistors, you can reduce the number and complexity of input, output and filtering components. Fewer components mean lower assembly cost, shorter assembly time. There's less chance for breakdown—lower maintenance costs. Circuitry can be more compact, lighter and easier to keep cool.

*Prices shown are for quantities of 1,000 or more.

These NPN silicon transistors are fabricated by our unique Delco 3-D process that provides high voltage protection, high frequency response and low saturation resistance. Each is packaged in a solid copper coldweld Delco TO3 case for low thermal resistance. Inside, they are ruggedly mounted to withstand mechanical and thermal shock due to special bonding of the emitter to base contacts.

Contact your nearest Delco sales office or distributor for complete data, application assistance or immediate delivery.

TYPE	V_{CEO}	V_{CEO} (sus)	I_C Max	h_{FE} Min $V_{CE}=5V$ @ I_C	Power Diss Max
DTS 410	200V	200V (min)	3.5A	10 @ 2.5A	80W
DTS 411	300V	300V (min)	3.5A	10 @ 2.5A	100W
DTS 413	400V	325V (min)	2.0A	15 @ 1.0A	75W
DTS 423	400V	325V (min)	3.5A	10 @ 2.5A	100W

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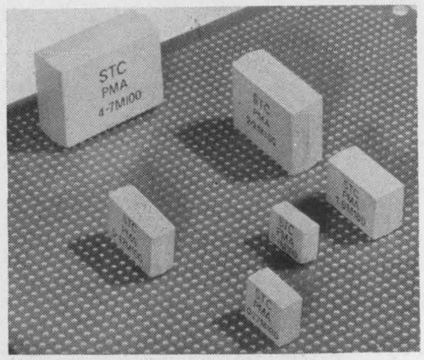
DELCO RADIO
Division of General Motors, Kokomo, Indiana

GM
MARK OF EXCELLENCE

ON READER-SERVICE CARD CIRCLE 65

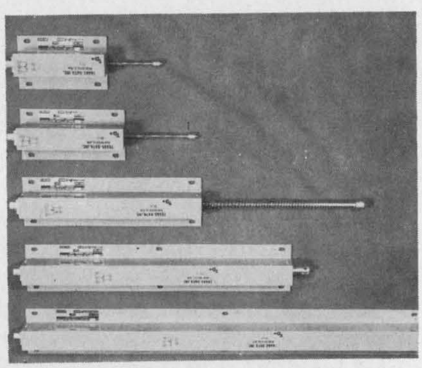


Data switch gives up to 512 closures

3M Company, 300 S. Lewis Rd., Camarillo, Calif. Phone: (805) 482-1911.

A programable switching matrix can save valuable set-up and execution time in a check-out operation. For comparatively sophisticated systems, the 3900 series data switch programs up to 512 contact closures. Programing is via address and BCD interconnect and command. For even more capacity, the matrix can be expanded in 4 x 16 increments.

CIRCLE NO. 241

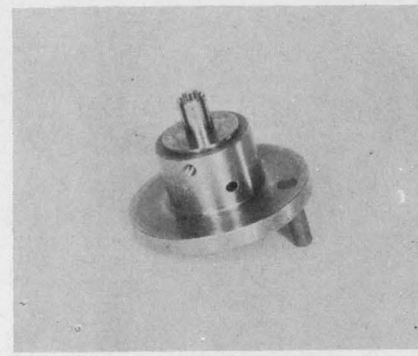


Transducers have infinite resolution

Trans-Data Inc., 821 Wheeler Ave., Huntsville, Ala. Phone: (205) 539-2237.

A family of infinite resolution linear displacement transducers from Trans-Data feature low output impedance. These transducers have standard displacements from 1 to 16 inches spring loaded in or out, or without spring loading. Max output impedance is 10 ohms and sensitivity is 1-mV/in./volt. Calibration is internal and terminal linearity is 0.15%.

CIRCLE NO. 242

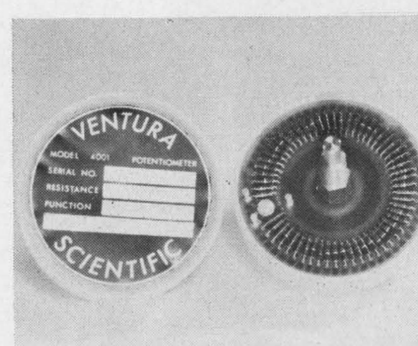


Coupling unit aids in mechanical phasing

Designatronics Inc., 76 E. Second St., Mineola, N. Y. Phone: (516) 741-7070.

Close tolerance adjustments of the relative angular relationship between rotating components, after installation, is the function of the 9902 zero-adjustable coupling. The coupling is operated with an adjusting wrench that varies the angular phase of the coupling halves at the rate of 9°/turn. The unit is balanced to operate at high speeds without vibration and the requirements of MIL-E-5272 are met.

CIRCLE NO. 243

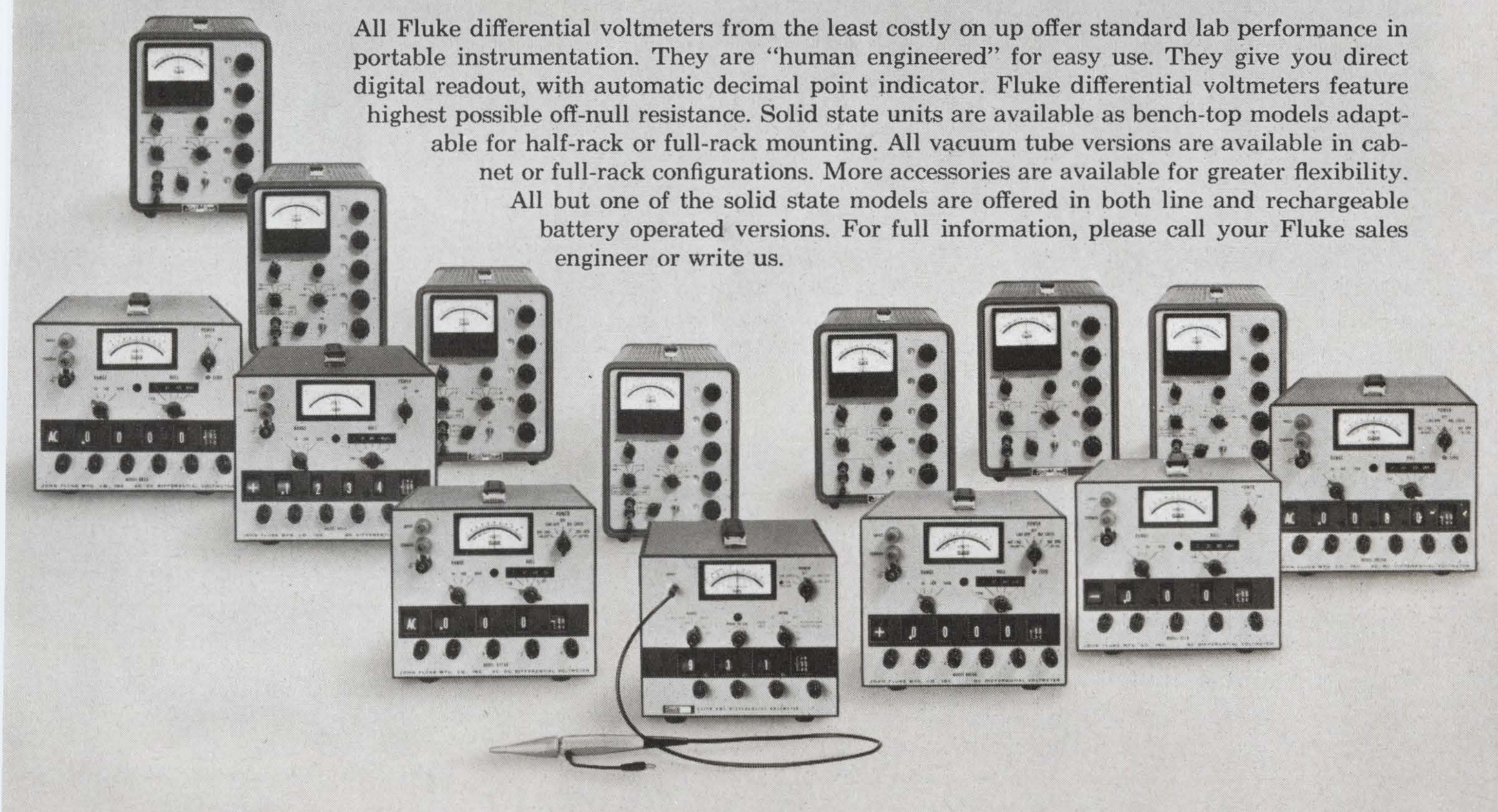


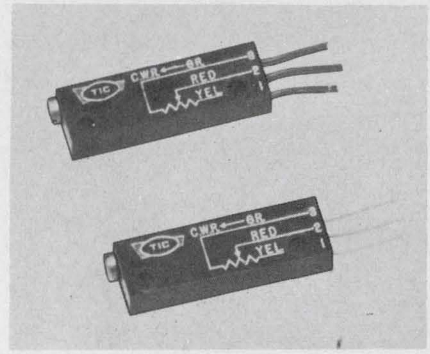
Special-function pot based on new design

Ventura Scientific, P. O. Box 1202, Thousand Oaks, Calif.

Special-function potentiometer cost and lead time are said to be cut sharply by use of the model 4001 pot. The component can be fabricated to your specs quickly and at reduced costs since it uses resistor-bridged commutator segments rather than the usual continuous resistance element. From 57 to 60 resistors are used to perform a function within these pots.

CIRCLE NO. 244



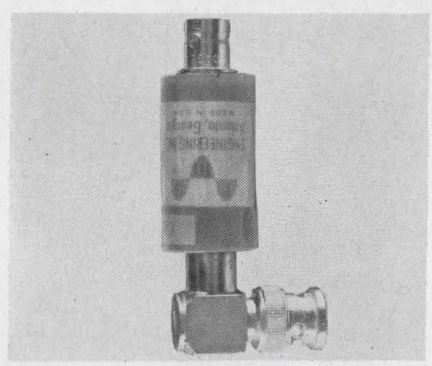


Miniature trimmers have ceramic mandrels

Technology Instrument Corp. of California, 850 Lawrence Dr., Newbury Park, Calif. Phone: (805) 498-2165.

Ceramic mandrels and multiple, wire-welded terminals are the leading features of the TR-2 series RT-10 trimmers. Eleven standard resistances are offered in a range from 10 ohms to 20 kΩ. Meeting the requirements of MIL-R-27208A, the trimmers are housed in heat-resistant plastic and will serve at ambients from −65° to +175°C. Power handling is rated 1 W at 70°C.

CIRCLE NO. 245

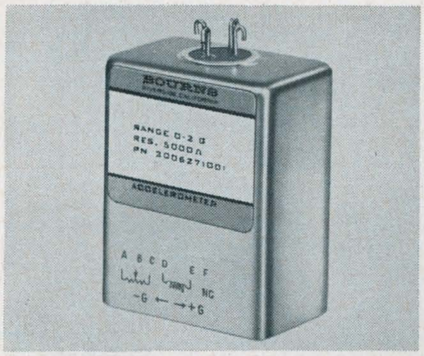


Coax transformer steps-up, isolates

RMS Engineering Inc., 486 Fourteenth St., N. W., Atlanta. Phone: (404) 873-5257. P&A: $13.00; stock.

At the end points of a frequency reference distribution system, the Model 5920 coaxial transformer gives needed isolation. It also allows the use of low-level distribution systems with instruments such as counters that require several volts for an external frequency reference. Toroidal design is used with turns ratios of 1:1, 1:3 or 1:5. Bandwidth is 100 KHz to 1 MHz.

CIRCLE NO. 246

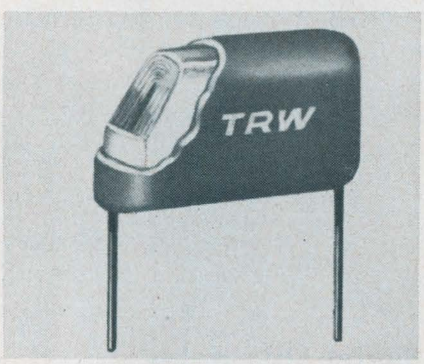


Linear accelerometers sensitive to 0.015 G/G

Bourns, Inc., 1200 Columbia Ave., Riverside, Calif. Phone: (714) 684-1700.

A transverse sensitivity of 0.015 G/G is typical for the Model 625 and 627 translational/potentiometric linear accelerometers. Both are designed with a translational spring-mass system that is said to minimize cross-axis error and hold it constant throughout the instrument range. Model 627 offers the additional feature of wiper lift-off to eliminate element wear during storage and transportation or when the unit is unenergized.

CIRCLE NO. 247

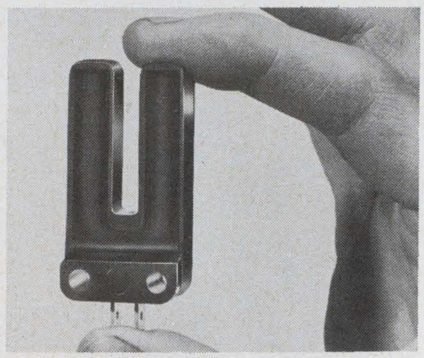


Mylar capacitors metallized, epoxy dipped

TRW Inc., 1100 Glendon Ave., Los Angeles, Calif. Phone: (213) 477-6061. Availability: 3 weeks.

For printed circuit applications the X601PE epoxy dipped metallized Mylar capacitors have flattened radial lead configurations. These components are said to be 50% smaller than film foil units of comparable value. Available values are 0.01 mfd to 10 mfd in 20%, 10% and 5% tolerances and ratings of 100 and 200 V.

CIRCLE NO. 248

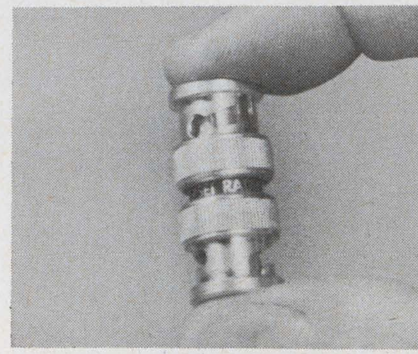


Vane-switched reed for industrial control

Amperex Electronic Corp., Hicksville, N. Y. Phone: (516) 931-6200. P&A: $4.50; stock.

Designed to be used as a limit switch, position indicator or as a signal source for low counting speeds, an iron vane-switched reed measures 0.245 x 0.561 x 2.17-in. long. The unit consists of a magnet and a reed switch encapsulated in a U-shaped plastic housing. In conjunction with dc amplifiers or with thyristor trigger module, the switch can also be used for power switching.

CIRCLE NO. 249

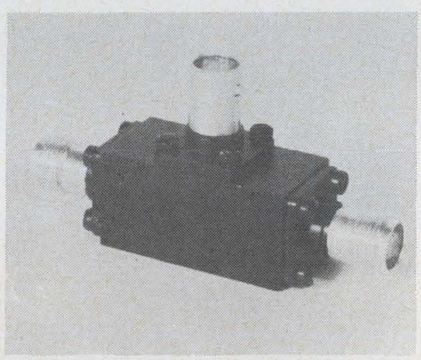


Step-recovery diode ranges dc to 10 GHz

Somerset Radiation Laboratory, Inc., 2060 North 14th St., Arlington, Va. Phone: (703) 525-4255. P&A: $130; 5 days.

A single harmonic generator and pulser for the entire zero to 10 GHz range is seen in the B830 step recovery diode multiplier. Conversion efficiency is 200% divided by the operating harmonic number. For highest efficiency output at one frequency, an external cavity or tank can be used. For a comb of harmonics the B830 can be used with a low-Q output circuit.

CIRCLE NO. 251

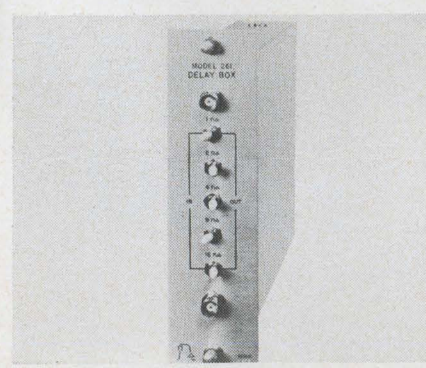


50 dB diode switch with low insertion loss

Alpha Industries, Inc., 381 Elliot St., Newton Upper Falls, Mass. Phone: (617) 969-6480.

Rock-bottom insertion loss, 0.3 dB at 50 dB isolation, is the primary specification of the MT-3002 diode switch. The component gives spst action over the 1200-1450 MHz range. Other specs include: max peak power rating of 1 kW, max cw power rating of 2 W, and a nominal switching speed of 25 nsec. Similar units are offered for uhf and L-band use.

CIRCLE NO. 250

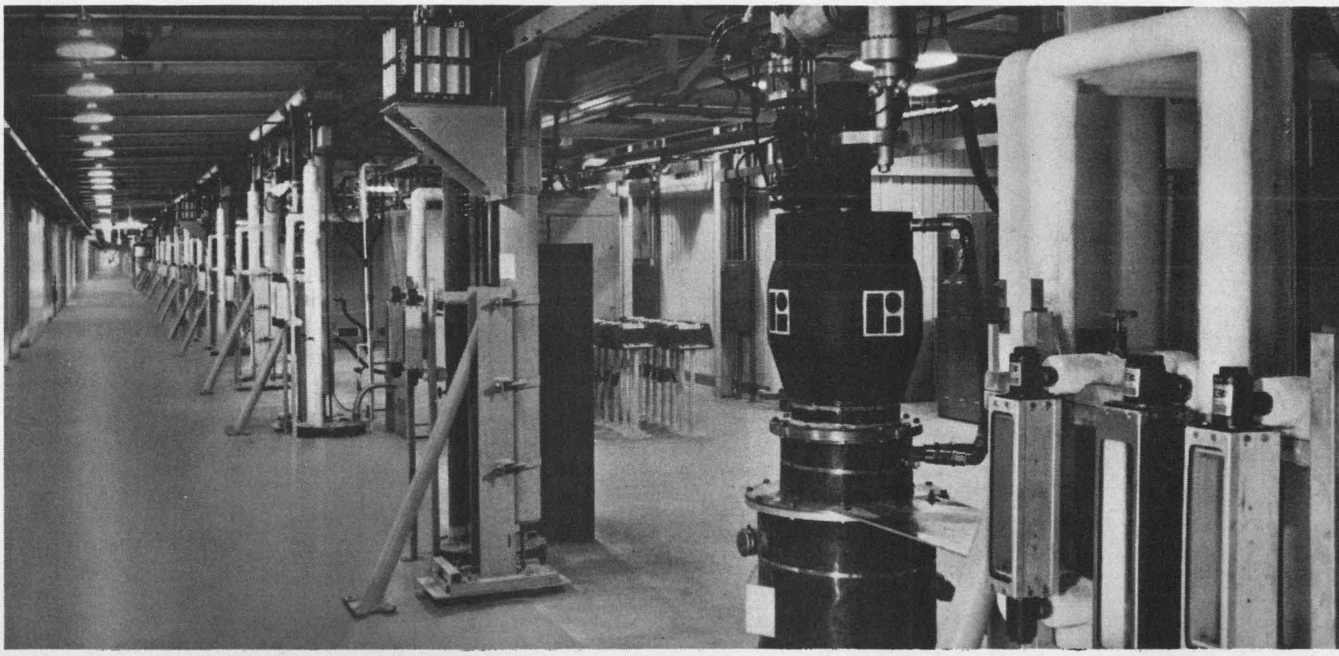


Switchable delay incremented to 1 nsec

Nanosecond Systems, Inc., 176 Linwood Ave., Fairfield, Conn. Phone: (203) 255-1008.

Following the binary system for application convenience, the 261N passive delay is switchable in 1-nsec increments. With a rated accuracy of +0.1 nsec the unit has a total max delay of 31 nsec. Input and output connections are made via BNC connectors and impedance is 50 ohms. Packing is either per AEC Report TID 20893 or 2 x 7-1/2 x 8-1/2-in. modules.

CIRCLE NO. 252



In linear accelerator klystrons, the real problem is achieving long life at low operating cost.

That's why we designed the new L-3980.

Litton's new S-band pulsed amplifier klystron assures years of operation at 21Mw peak power on a .0009 duty cycle. And does it at a cost as low as $.75 per hour.

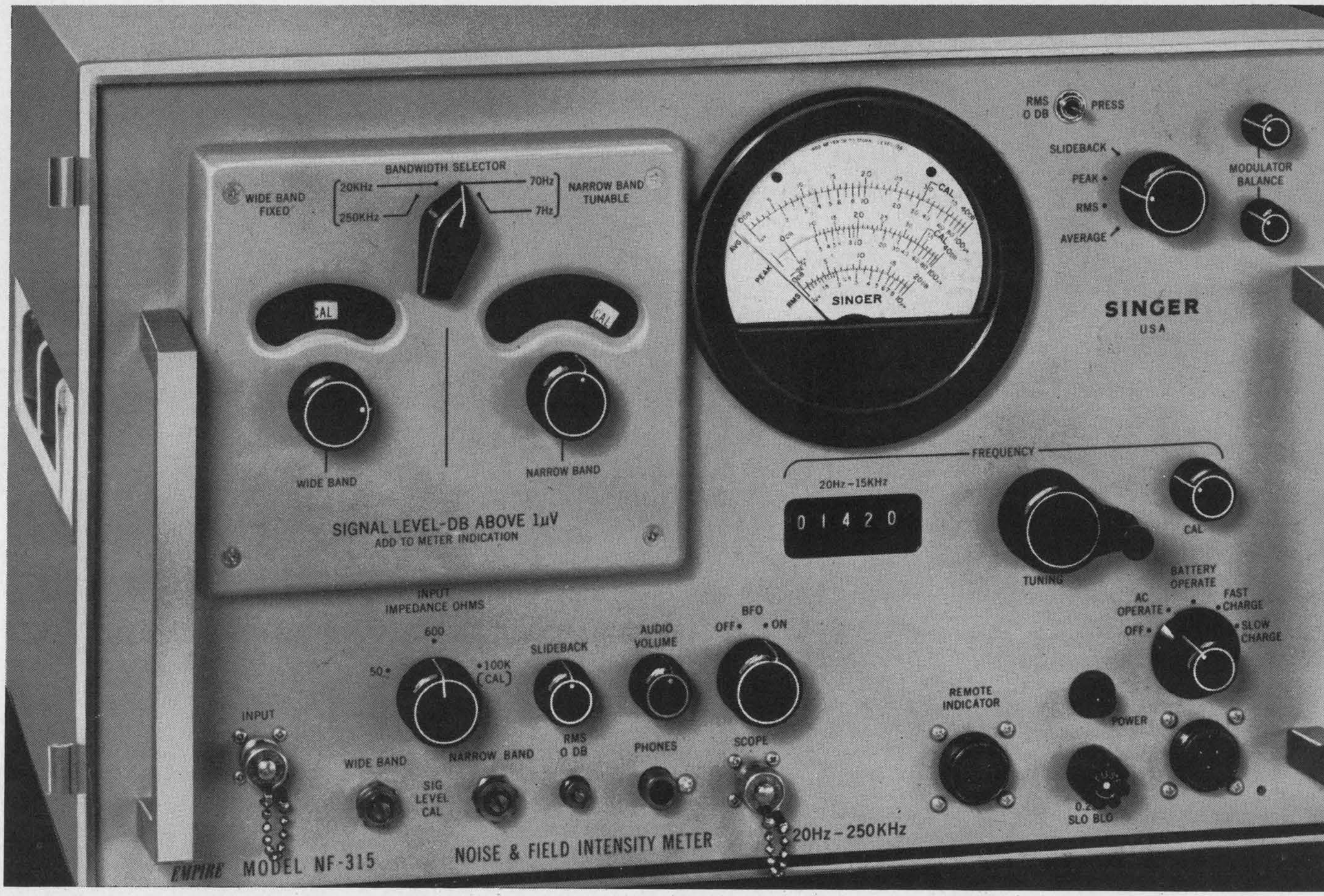
Only Litton can offer klystrons with this kind of guaranteed low operating cost. That's because only Litton has the design and production experience to make it possible.

Put this ingenuity to work on your klystron applications.

Contact us with your requirements, or send for our L-3980 Data Package. Electron Tube Division, 960 Industrial Road, San Carlos, California 94070.

LITTON INDUSTRIES
ELECTRON TUBE DIVISION

ON READER-SERVICE CARD CIRCLE 71



MATERIALS

Clad-metal wire saves copper

Texas Instruments, Inc., Attleboro, Mass. Phone: (617) 222-2800.

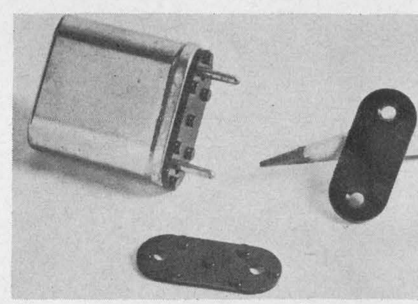
The scarcity of copper prompts the introduction of a line of clad metal wire made up of a skin of copper covering an aluminum body. This process, according to the manufacturer, enables wire suppliers to stretch their copper supply by as much as ten times and save up to 40% on material costs. The clad wire is equal to a solid copper conductor 24% smaller at low frequencies and virtually equal in high-frequency use. **CIRCLE NO. 253**

Epoxy adhesive cures at room temperature

Resin Formulators Co., Div. of E. V. Roberts & Assocs., 9601 W. Jefferson Blvd., Culver City, Calif. Phone: (213) 870-9561.

For general use, the two-part epoxy Resinbond 907 cures at room temperature to form a bond to 4000 psi. Features include a negligible shrinkage factor, −300 to 180°F temperature range and the ability to be drilled, sanded, machined or panted after cure. The resin is pale green in color when cured.

CIRCLE NO. 254

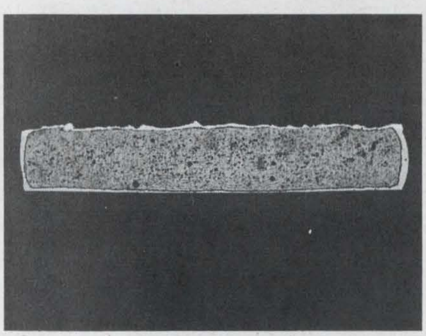


Frequency crystals can be soldered to PC boards

Milton Ross Co., 511 Second St., Pike, Southampton, Pa. Phone: (215) 355-0200.

Frequency crystals can be soldered directly to a printed-circuit board with the #10274-DAP Transipad. This support allows for wash-away of solder flux after the can is attached to its board. Seven spacers allow air-flow under the crystal, preventing moisture accumulation. The pad is molded of black diallyl phthalate and measures 0.312 x 0.730 in. with 0.70-in. diameter holes on 0.486-in. centers.

CIRCLE NO. 255



Nickel-alloy ribbon plated with gold

Engelhard Industries, 113 Astor St., Newark, N. J. Phone: (201) 242-2700.

You can emboss gold-clad Iconel ribbon to finishes as rough as 90 μin. without rupturing the gold. The ribbon, with a 0.0003-in. plate, is offered to combine the characteristics of cold-worked Iconel with those of a gold-alloy sheath. Typical ribbon size is 0.0035-in. thick by 0.018-in. wide. Applications where spring-strength and conductivity are required are suggested.

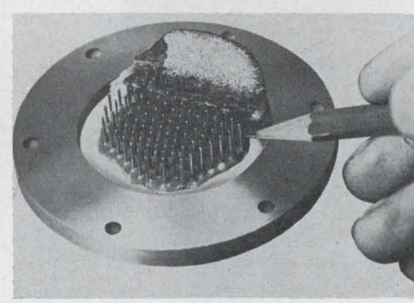
CIRCLE NO. 256

Potting compound conducts heat

Astrodyne Inc., 207 Cambridge St., Burlington, Mass. Phone: (617) 272-3850. Price: from $4.25/small box.

For effective heat transfer from components to chassis or heat sink, Astrodyne offers Compound 166. The two-component system has a low thermal coefficient of expansion and a conductivity of 7.4 BTU/hr-ft^2-°F/inch. It was specifically developed for potting transformers, resistors and rectifiers. Though generally supplied in individual boxes for single batches, bulk quantities are also available.

CIRCLE NO. 257



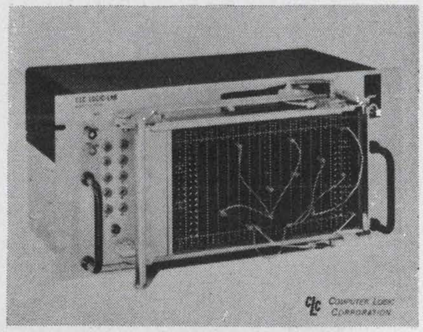
Reactive solvent dissolves urethane

Dynaloy Inc., 408 Adams St., Newark, N. J. Phone: (201) 622-3228. Price: from $6.95/gal.

Cured urethane resins can be removed from electronic components by a reactive solvent called Uresolve HF. The clear, yellow-brown liquid is said to completely dissolve the urethane potting without damaging other plastic components or metals. Uresolve is also offered as an aid in packaging. Its slow etching action on DAP and anhydride-cured epoxies aids the adhesion properties of epoxies and other encapsulants.

CIRCLE NO. 258

ON READER-SERVICE CARD CIRCLE 73

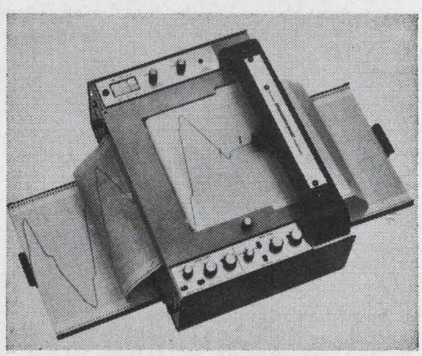


Digital problem-solver called "universal"

Computer Logic Corp., 1528 20th St., Santa Monica, Calif. Phone: (213) 451-9754. Price: $1240.

Applications such as generating and checking of word, code and format, interface problem-solving, proving system timing, even digital computation are cited for two "universal" logic instruments. Logic-Lab LL-350, for IC logic cards, and LL-150 for discrete cards are both fully assembled and tested. The basic frame includes the cover, patchboard, patchcords, terminals and connectors.

CIRCLE NO. 259



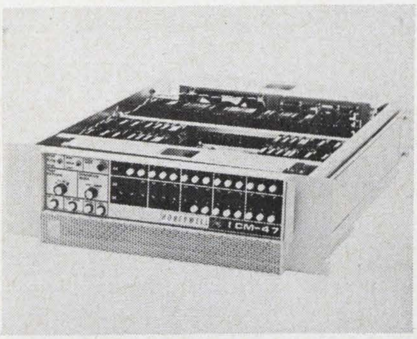
Incremental plotter operates bidirectionally

Houston Omnigraphic Corp., 4950 Terminal Ave., Bellaire, Texas. Phone: (713) 667-7403. P&A: $2850; 4 wks.

A record that you can read like a book, rather than a scroll, is provided by the model 6650 bidirectional incremental plotter. The recorder uses fan-fold paper that can be separated at perforated lines into standard-size pages. Recorder accuracy is 0.002-in. and the independently moveable pen and paper move at speeds to 18,000 increments per minutes.

CIRCLE NO. 260

ON READER-SERVICE CARD CIRCLE 74

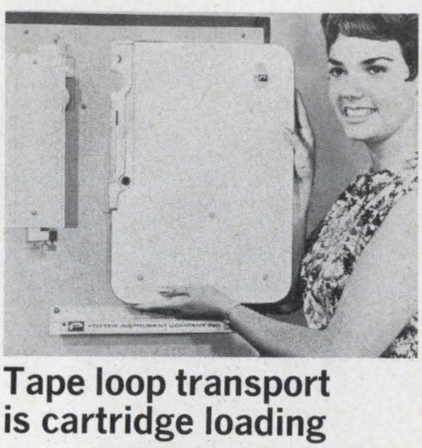


IC core memory rated 750 nsec

Honeywell, Computer Control Div., Old Connecticut Path, Framingham, Mass. Phone: (617) 879-2600.

Especially designed for OEM applications, the ICM-47 μ-Store memory has a full-cycle time of 750 nsec. The basic design of the ICM-47 eliminates the adjustments and controls required by other memories, limits application of "Murphy's Law" and simplifies maintenance. For 4096 and 8192 word memories, max word length is 28-bits per module. In 16,384-word systems, lengths up to 14-bits are available.

CIRCLE NO. 261



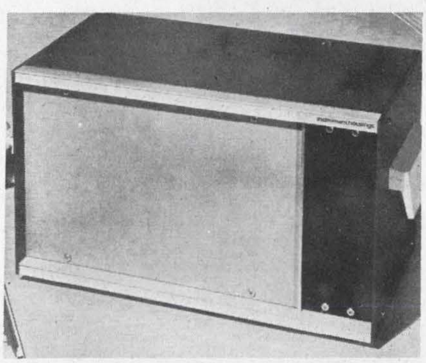
Tape loop transport is cartridge loading

Potter Instrument Co. Inc., 151 Sunnyside Blvd., Plainview, N. Y. Phone: (516) 681-3200.

Especially designed for correlation of data and real-time analysis in geophysics, aircraft and shipboard applications, the modular LT=1500 tape loop transport features interchangeable cartridge loading. The package operates from a 12-V battery drawing 300 W and provides six speeds through a single capstan drive system. Storage is rated 35 Mbits with transfer at 192,000 ch/s.

CIRCLE NO. 262

PRODUCTION EQUIPMENT

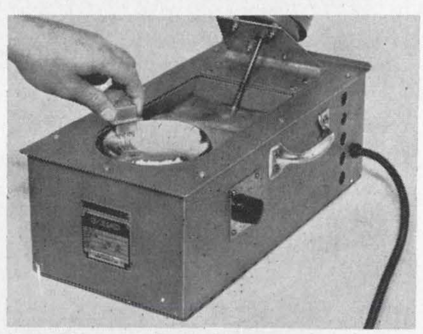


Instrument housings allow 500 variations

T. Foxall & Sons Ltd., Maylands Ave., Hemel Hempstead, Hertfordshire, England.

A line of British instrument housings include 13 basic designs in a total of 57 sizes. Variations in trim and split panels bring the selection to 500. The housings use 1/8-in. aluminum alloy panels which are said to provide more stability than the usual thin-gage steel in these applications. A variety of finishes are offered.

CIRCLE NO. 263

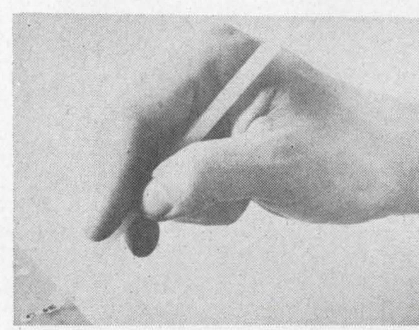


Solder "wavedipper" eliminates skimming

Electrovert Inc., 86 Hartford Ave., Mt. Vernon, N. Y. Phone: (914) 664-6090. P&A $750; stock.

You don't have to interrupt dip-soldering to remove the oxide layer with the Wavedipper soldering unit. By pumping solder upwards through the reservoir from a circular nozzle, a 4-in. diameter raised solder surface is formed. Through this constant recirculation, the active area is always dross-free and held at constant temperature settable from 400° to 600°C.

CIRCLE NO. 264



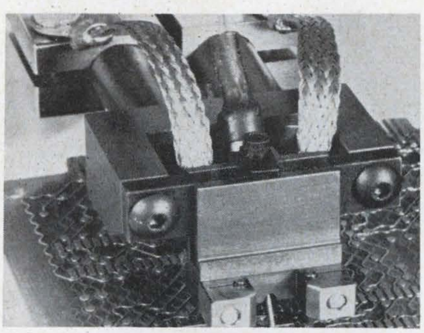
Nylon tool preforms leads

Hunter Tools, 9851 Alburtis Ave., Santa Fe Springs, Calif. Phone: (213) 692-7281. Price: $1.16.

Designed to form component leads before they are placed on printed circuit boards, tool #51FN is formed entirely of nylon. One end is shaped like a pencil point for forming radius leads and the other is like a slot screwdriver to smooth the leads after insertion and trimming. The nylon construction insures that neither leads nor board will be nicked or marred.

CIRCLE NO. 265

ON READER-SERVICE CARD CIRCLE 76

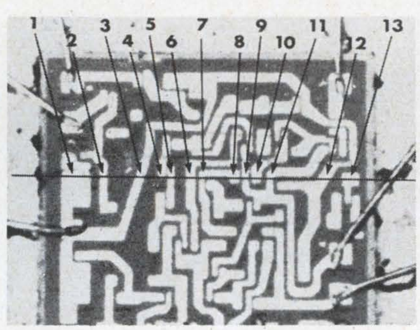


Soldering head handles 7 leads

Development Assocs. Controls, 123 W. Padre St., Santa Barbara, Calif. Phone: (805) 963-3708. Price: $295.

In a single operation, the 3007 soldering head attaches up to seven leads of a flat-pack module. A heated element, processed to prevent voltage differentials between leads, applies solder on pretinned leads to solder plated pads. A thermocouple control and self-aligning design are provided to prevent damage to the component or the board.

CIRCLE NO. 266

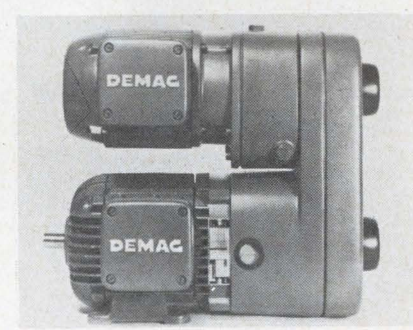


Instrument measures chip's profile

Clevite Corp., 37th and Perkins, Cleveland, Ohio. Phone: (216) 361-3315.

An actual, undistorted surface profile of an IC chip is enlarged to 30 in. by an instrument called a Surfanalyzer (which has nothing in particular to do with oceanography). By a combination of microphotography and the rectilinear output of a surface gage, profiles can be determined accurately without damage to the chip. Profile indications range down to 50 Å with repeatability.

CIRCLE NO. 267

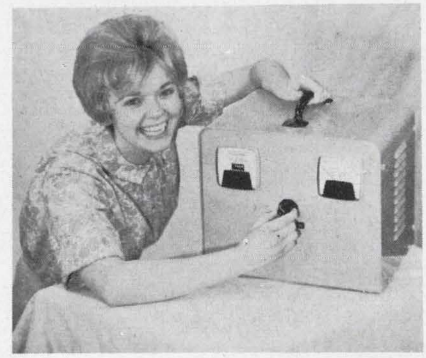


Indexing drive can speed or creep

Demag Hoists & Cranes Corp., 4410 13th St., Wyandotte, Mich. Phone: (313) 386-7133.

This indexing drive permits a programed selection of a fast speed followed by a creep cycle for accurate indexing. Outputs from 0.5 through 30 horsepower continuous or 50 horsepower intermittent are possible with speed ratios from 2:1 to 500:1. Variations available include reduction gearing, multipolarity and choice of pickaback or inline configurations.

CIRCLE NO. 268

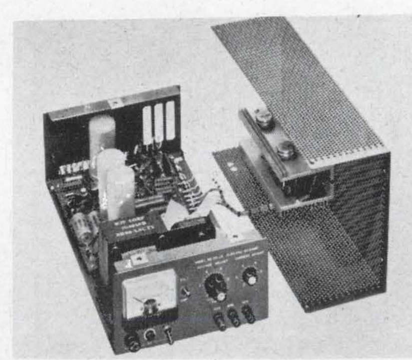


Frequency changer uses rotary converter

Kato Engineering Co., 1415 First Ave., Mankato, Minn. Phone: (507) 388-2941.

A rotary converter provides the ac output in a new frequency changer. The input power is converted to dc which in turn drives a rotating converter which delivers 50 or 60 Hz output. Power capabilities are available in 225 W to 5 kW. Input can be any ac line frequency, the system of rectifiers and transformers is designed to use.

CIRCLE NO. 269

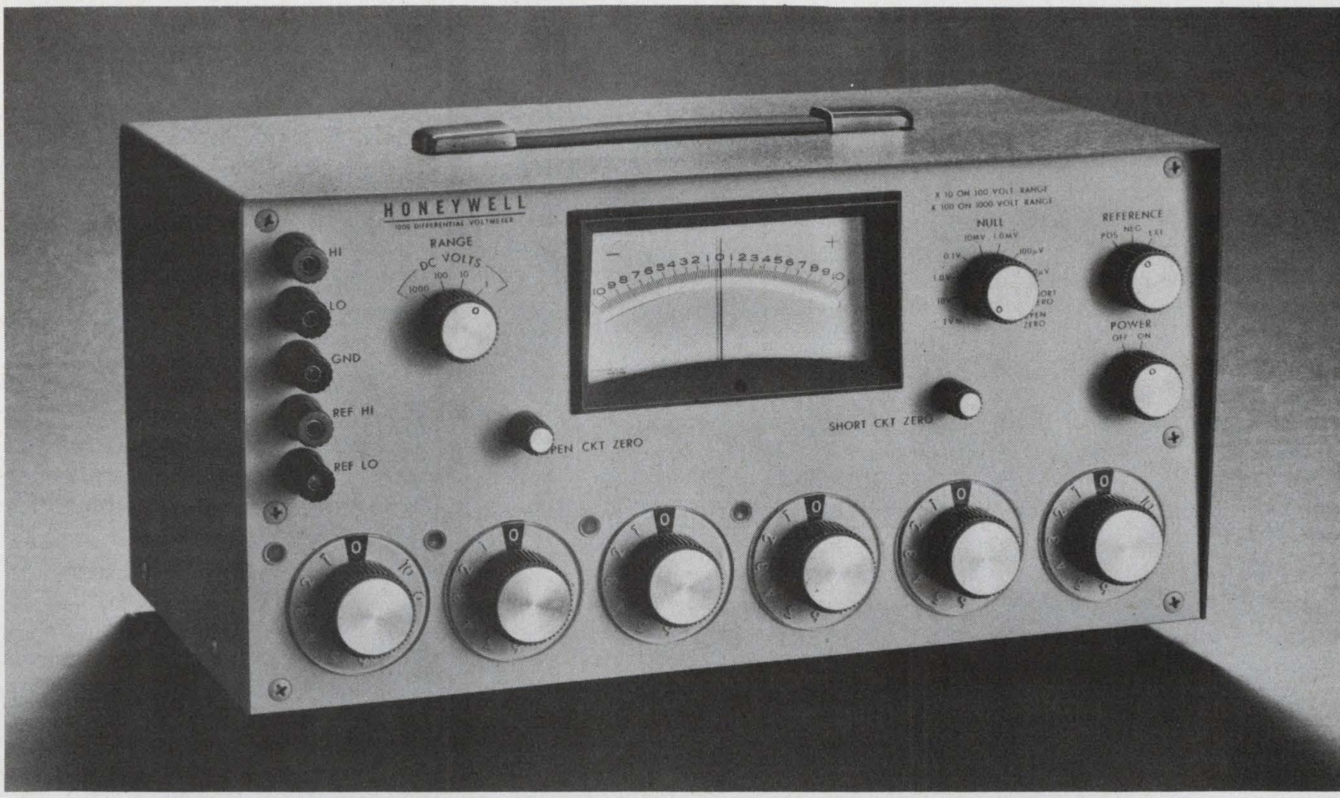


Regulated supply packaged half-rack

NJE Corp., 20 Boright Ave., Kenilworth, N. J. Phone: (201) 272-6000.

Operation for either constant voltage or constant current is possible with the half-rack RB-36-2 supply. This supply incorporates full-range adjustability, 0-36 V, 0-2 A, and uses series transistor regulators driven by feedback amplifiers. Regulation is 0.01% and 1 mV for line and load respectively and current changes 1 mA/V in output, 0.5 mA operating constant-current.

CIRCLE NO. 270



Honeywell's new 5 in 1 Instrumentation Package:

own this Model 1000 Differential Voltmeter, and you also own a Differential Ratiometer, a Decade Voltage Divider, a Precision Voltage Reference Source, and an Electronic Null Detector!

Here's the most versatile single instrument any lab can own – five essential measuring functions combined in one neat, fully portable package! Let's look at the new Honeywell Model 1000, function by function.

As a **Precision Differential Voltmeter,** the Model 1000 provides ±0.0025% accurate measurements to your DC signals. And you get 7 digit resolution from 6 decades with 10% overrange (also eliminates time consuming dial manipulation). Potentiometric input impedance to 11V provides errorless measurements to standard cells or high source impedance signals. Polarity is reversible from the front panel.

As a **Differential Ratiometer,** the 1000 gives you precise DC ratio measurements with ±0.001% accuracy. External reference signal level may range up to ±100 VDC. All Voltmeter mode convenience features are applicable when the 1000 is used as a Ratiometer.

As a **Decade Voltage Divider,** the 1000's precision, 6 decade Kelvin-Varley divider network gives accurate voltage level divisions to ±0.001%. AC power not required in this mode.

As a **Precision Voltage Reference Source,** calibrated voltage levels of 6 digit resolution are provided at the 1000's rear panel. Output levels are selected by front panel dials. Levels vary from 0 to 11 VDC, and may be used for calibration of potentiometric instrumentation. Accuracy: ±0.0025%.

As an **Electronic Null Detector,** the 1000 offers high sensitivity for use with balance type instrumentation or other circuitry. Silicon field effect transistors eliminate electro-mechanical choppers and assure drift-free operation. Changes as minute as 10 nanovolts or an input current of 10^{-15} amperes may be detected.

Other features of this versatile instrument include: complete cancellation of common mode, standoff voltages; high superimposed noise rejection; Zener reference supply with 2-3 ppm stability; 4 full-scale ranges of 1, 10, 100, and 1000 VDC; ratio ranges of 1:1, 10:1, and 100:1; recorder outputs on rear panel, and silicon solid-state circuitry throughout. Ask your Honeywell Representative for a demonstration of the Model 1000, or mail coupon for literature.

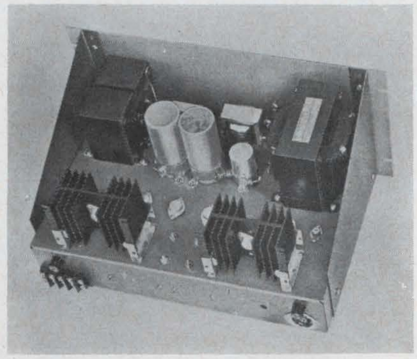
Honeywell, Test Instruments Div. 12-11
Denver, Colorado 80217
Please send Model 1000 Literature to:

Name__________
Company__________
Address__________
City______ State______ Zip______

LABORATORY STANDARDS
Honeywell

HONEYWELL IS WORLDWIDE · Sales and service offices in all principal cities of the world. Manufacturing in Brazil, Canada, France, Germany, Japan, Mexico, Netherlands, United Kingdom, United States.

ON READER-SERVICE CARD CIRCLE 78

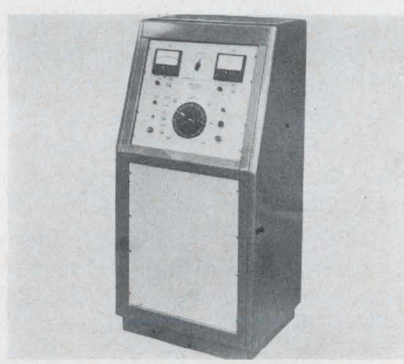


Ac power converters designed for stability

Metric Engineering, 5221 E. Simpson Rd., Mechanicsburg, Pa. Phone: (717) 766-0741. P&A: $595; 6-8 wks.

Designed to provide stable ac for speed control of synchronous motors, PC2100 converters handle from 25 to 2500 watts. Any frequency from 50 Hz to 15 kHz is available. Typical output voltage is 120 V rms, ±0.5% no-load to full-load. Frequency stabilities range from ±0.01% to 0.00001% or better. Ac line or battery units up to 128 Vdc can be specified.

CIRCLE NO. 271

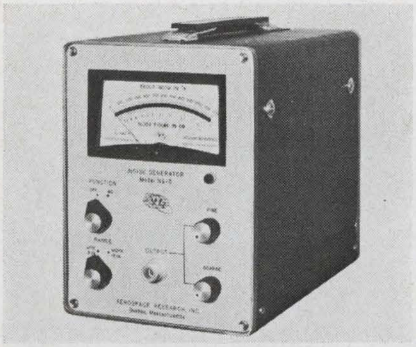


High voltage supply for lab and industry

Cober Electronics Inc., 7 Gleason Ave., Stamford, Conn. Phone: (203) 327-0003. Price: $3,000.

Brute-force dc power supplies of the model BF20-300 pictured are offered as a low-cost source of high power for lab and industrial applications. Overvoltage and overcurrent protection is provided through meter relays. The BF20-300 has an output continuously variable from 0 to 20 kV dc with currents from 0 to 300 mA, positive or negative.

CIRCLE NO. 272

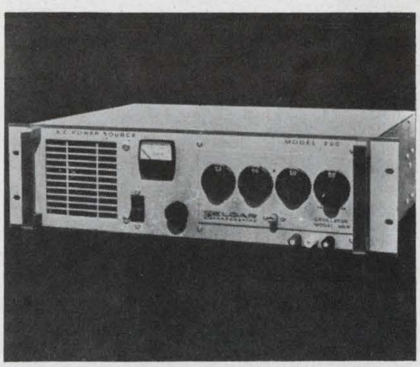


White-noise source independent of line

Aerospace Research, Inc., 130 Lincoln St., Boston (Brighton), Mass. Phone: (617) 254-7200.

A servo-stabilized RF random noise generator is said to provide white noise output virtually independent of line voltage changes and change in ambient temperature. A resonant-line output-coupling circuit insures low vswr over the full 1 to 500 MHz range. The output is continually variable from 0-16 dB in two ranges. The meter is also calibrated in degrees K from 0-12,000° above KTB.

CIRCLE NO. 273

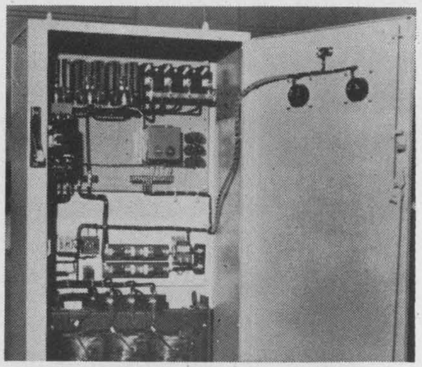


Ac power source varies 45 Hz to 5 kHz

Elgar Corp., 8046 Engineer Rd., San Diego, Calif. Phone: (714) 279-0800.

At any frequency from 45 Hz to 5 kHz, the model 200 power source delivers 200 VA. Front panel plug-in oscillator modules are available to select fixed frequencies with accuracy from ±1% to 0.0001%. Two- and three-phase output is obtained by stacking units. Line and load regulation as well as distortion are held to less than 1%.

CIRCLE NO. 274

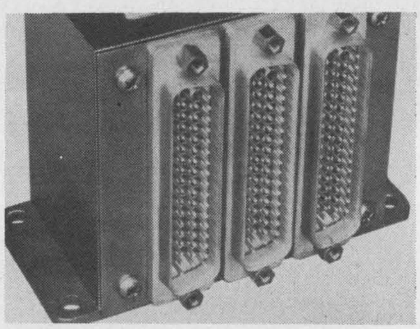


Regulated dc supplies fill industrial needs

Magnetics Inc., Butler, Pa. Phone: (412) 285-4711.

Wherever dc power is required on large scale, these packaged units provide solid-state design and SCR control. At ratings of 2 to 80 kW at 125 Vdc or 250 Vdc, power control is effected by SCRs regulated by a magnetic amplifier. Voltage adjustment is 0 to 100% by means of a control potentiometer. Voltage control is ±1% for 10% line variation and 2% rms ripple.

CIRCLE NO. 275

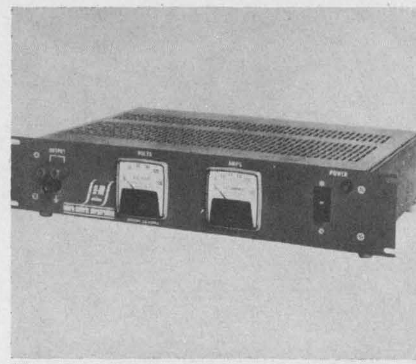


Voltage reference accurate to ±0.0025%

General Resistance Inc., 430 Southern Blvd., Bronx, N. Y. Phone: (212) 292-1500. P&A: $985; stock.

Housed in an easily transportable case, the DAS-46L dialable voltage source features an accuracy of ±0.0025% from 1 μ V to 10 V. The unit combines a "Dial-A-Volt" reference with a chopper-stabilized operational amplifier to provide totally isolated voltages. IR drops in interconnecting harnesses are automatically compensated. Output regulation is 5 ppm and stability is 10 ppm.

CIRCLE NO. 276

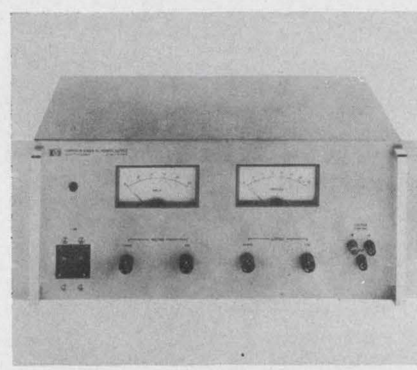


Frequency converters rated to 750 VA

Astro-Metrics Corp., 1123 Mission St., South Pasadena, Calif. Phone: (213) 799-1509. P&A: $495; stock to 2 wks.

For applications demanding high-level ac without high-level cost, a new line of converters includes ratings from 100 to 750 VA. Operation is at 60 to 400 Hz, single- or three-phase. All three-phase units maintain specs with load unbalance as high as 50%. The rack-mount units are fully solid-state.

CIRCLE NO. 278

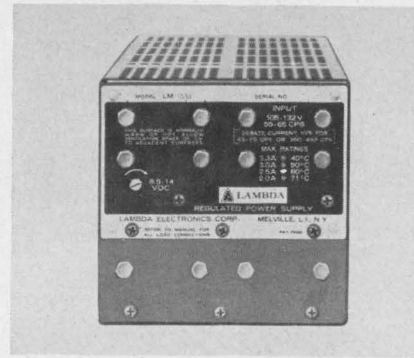


Low-level rack supply is RFI shielded

Hewlett-Packard, 100 Locust Ave., Berkeley Heights, N. J. Phone: (201) 464-1234. P&A: from $350; 1-6 wks.

A rack power-supply line consists of 10 transistor-regulated models with outputs from 0-10 to 0-60 V and power to 2 kW. All are RFI shielded in accordance with MIL-I-6181D. An optional over-voltage protection "crowbar" is available. Regulation is 0.01%, ripple is 1 mV at 2 kV and short recovery is below 50 μs. Operation is constant/voltage/current.

CIRCLE NO. 277

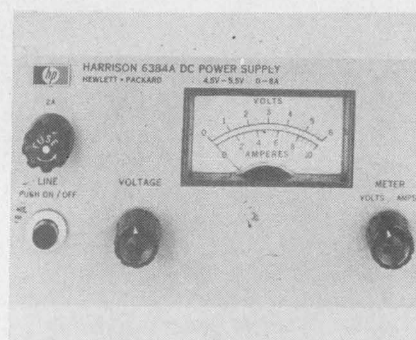


Fixed-level supplies packaged 1/3rd rack

Lambda Electronics Corp., 515 Broad Hollow Rd., Melville, N. Y. Phone (516) 694-4200. Price: $169.90 up.

A total of 21 fixed-voltage supplies comprise the LM line of CC-packaged power supplies. These modular units are convection-cooled and have multiple current ratings based on 40°, 50°, 60°, and 71°C. Standard models are offered at 21 levels from 3 to 150 Vdc with a ±5% adjustment. On special order, voltages between the standard ratings are also available.

CIRCLE NO. 279

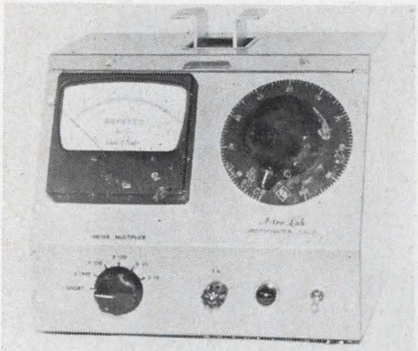


Low-voltage supplies safeguard ICs

Hewlett-Packard, 100 Locust Ave., Berkeley Heights, N. J. Phone: (201) 464-1234. P&A: $220; stock.

Designed specifically for use with integrated circuits, a new series of low voltage power supplies pays particular attention to the danger of over-voltage. A "crowbar" protection circuit monitors the voltage and shorts the output within 10 us when an over-voltage condition arises. The first of the series of five, the 6384A provides 4 to 5.5 V at 0 to 8 A.

CIRCLE NO. 280

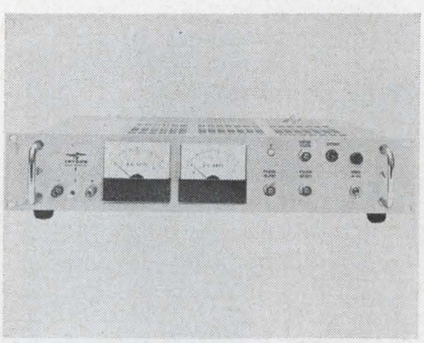


Adjustable ac source meters to 1000 amps

Astro Lab, 9371-D Kramer Ave., Westminster, Calif. Phone: (714) 839-0741. P&A: $225; stock to 60 days.

For bench testing, metered, adjustable ac up to 1000 A is provided by the Var-I-Amp source. Applications include high-current problems such as determining the fusing current of conductors, testing terminals and connectors and driving high-current soldering equipment. Output is accurate ±3%, metered on 5 ranges, 0 to 1000 A.

CIRCLE NO. 281



System power units long on features

Trygon Electronics Inc., 111 Pleasant Ave., Roosevelt, N. Y. Phone: (516) 378-2800.

The story on L3R and L5R supplies from Trygon is the many standard features: All silicon design with matched differential amps and integrated reference amplifiers . . . 70 A in L5R, 5-1/4-in. rackmount . . . 40 A in L3R, 3-1/2-in. rackmount . . . Full power to 60°C . . . Regulation to 0.005% . . . Stability to 0.01% . . . Ripple below 0.5 mV, 3 mV peak-to-peak . . . Automatic load-share paralleling . . . and others.

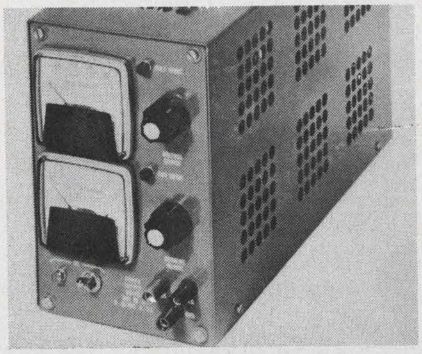
CIRCLE NO. 282

Strip-line oscillator delivers 150 watts

Terra Corporation, 505 Wyoming Blvd., N. E., Albuquerque, N. M. Phone: (505) 255-0157.

A power output of 150 watts, grid pulsed, is provided by the GLJ-1117 strip-line oscillator. For operation at 1.6 GHz, this oscillator features a 25-nsec pulse rise-time and pulse widths down to 100 nsec. The oscillator's size is 1.0 x 2.5 x 0.4-in. and total unit weight is below 2 ounces.

CIRCLE NO. 283



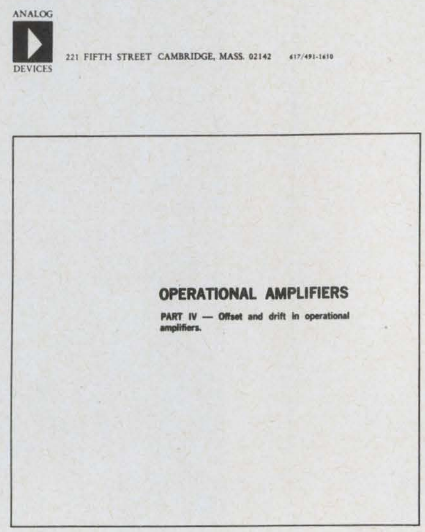
Regulated dc supply operates triple-mode

NJE Corp., 20 Boright Ave., Kenilworth, N. J. Phone: (201) 272-6000.

Operation as either current- or voltage-regulated or both, is possible with the LabRak SVC-40-5. The unit, for lab or system use, is of all-silicon design. Voltage regulation for load and line changes is 0.01% or 1 mV respectively. Current regulation is 0.2 mA/V change and 1 mA in constant current mode.

CIRCLE NO. 284

Application Notes


ANALOG DEVICES
221 FIFTH STREET CAMBRIDGE, MASS. 02142 617/491-1610

OPERATIONAL AMPLIFIERS

PART IV — Offset and drift in operational amplifiers.

Op-amp probed

An application note defines offset as the input bias required to set an amplifier's output to zero when no input signal is applied.

It goes on to explain that offset is made up of separate voltage-offset and current-offset components, each of which must be allowed for in any practical application.

Having defined offset, the note proceeds to elaborate on the effects of changes in voltage-offset, which can be caused by variations in ambient temperature, supply-voltage change, or aging of amplifier components. Analog Devices.

CIRCLE NO. 285

Frequencies compared

A 9-page application note describes how to make frequency comparisons with very high resolution in only a few minutes' time. Such measurements are valuable when adjusting a precision oscillator to match a known standard or in studies concerned with the effects of temperature and aging on precision oscillators. The application note (AN 77-2) discusses how a vector volt-meter is used to quickly compare precision frequency standards with a resolution of parts in 10^{13}. Hewlett-Packard.

CIRCLE NO. 286

S-parameter measurements

An important technique for measuring the characteristics of transistors in the 100- to 1000-MHz range is described in this 12-page application note. The technique involves "scattering" or s parameters; much easier to determine above 100 MHz than conventional h, y and z parameters. The note discusses the nature of s parameters and describes how they are derived from voltage and phase measurements. Several typical measurement examples are given. The note also shows how to re-convert the parameters to h, y or z. Several examples of high-frequency circuit design using the technique complete the discussion. Hewlett-Packard.

CIRCLE NO. 287

Transient data analysis

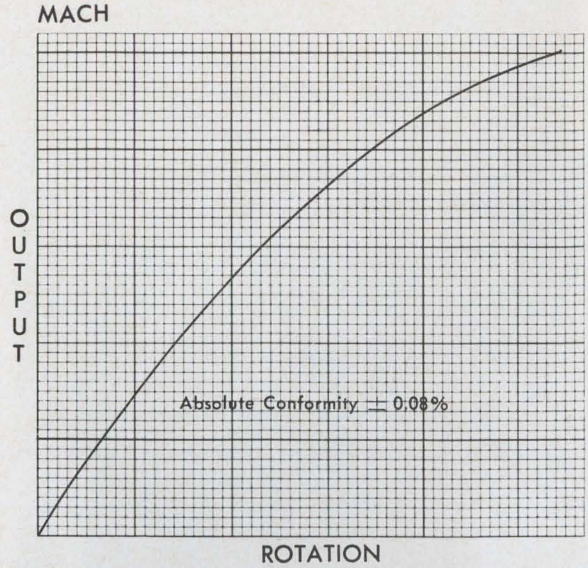
"A New Technique for Transient Data Analysis and Signal-to-Noise Ratio Enhancement" describes a method of using conventional instruments for analyzing transient data with the accuracy and simplicity possible for periodic signals. A discussion of how the technique can be used for detecting transient and periodic signals in noise is included. The method involves converting data to be analyzed to a stable, periodic signal with high duty cycle. The 16-page note is complete with examples and illustrations. S. Himmelstein & Co.

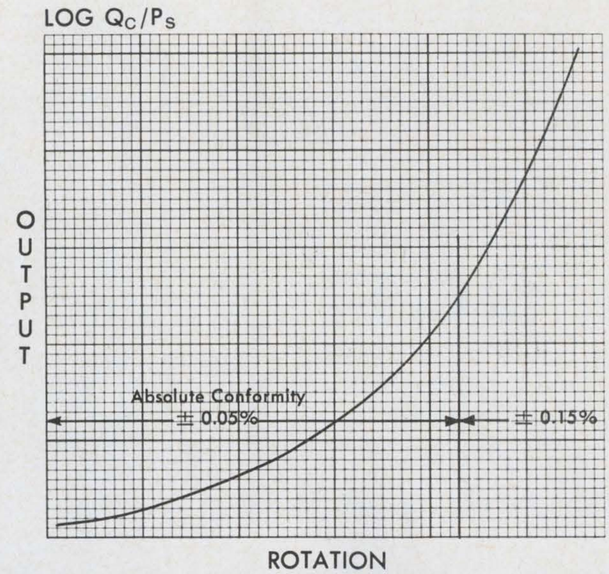
CIRCLE NO. 288

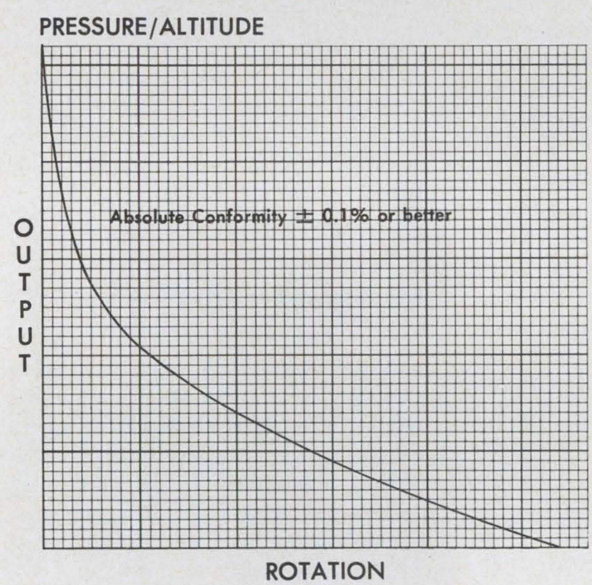
Tuning fork applications

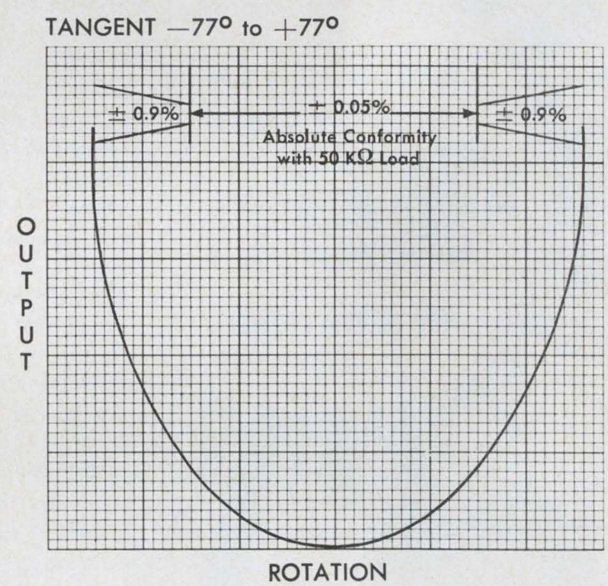
An illustrated technical booklet, "Increasing Application of Tuning Forks in Control Systems," describes features and applications of tuning fork resonators and oscillators. The 12-page brochure details the advantages of the fork oscillator and its parameters, contrasting it to other frequency sources. Sections cover the use of regular and torsional tuning forks as modulators of light or energy beams. The discussion is complete with schematics and photographs. American Time Products, Bulova Watch Co., Inc.

CIRCLE NO. 289

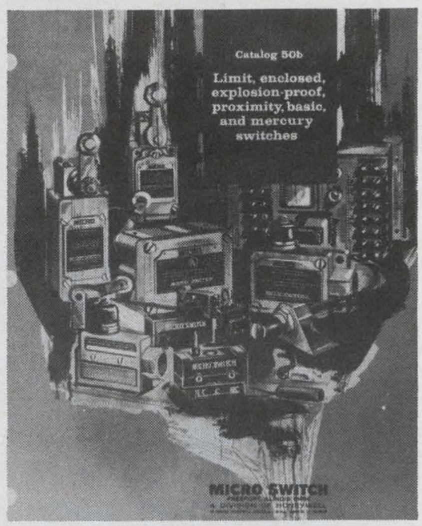

MACH
OUTPUT
Absolute Conformity ± 0.08%
ROTATION


LOG Q_C/P_S
OUTPUT
Absolute Conformity
± 0.05%
± 0.15%
ROTATION


PRESSURE/ALTITUDE
OUTPUT
Absolute Conformity ± 0.1% or better
ROTATION


TANGENT −77° to +77°
OUTPUT
± 0.9%
± 0.05%
± 0.9%
Absolute Conformity
with 50 KΩ Load
ROTATION

New Literature



Switch selection guide

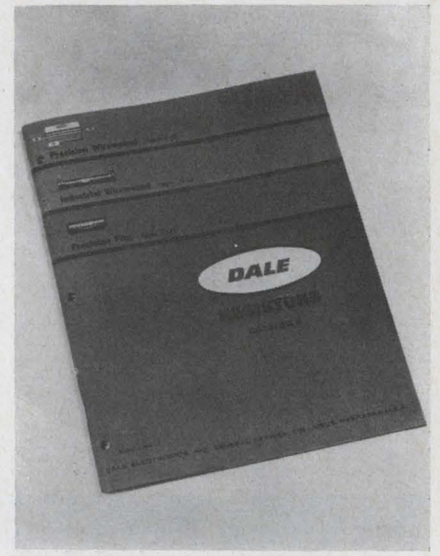
This 72-page switch selection guide is border-indexed for handy reference to the more than 1000 switches covered. The index categories include switch information on limit, enclosed, explosion-proof, proximity, basic, small basic and mercury switches. A reference to lighted and unlighted pushbuttons, toggle, rotary, hermetically sealed and environment-proof switches included in the last section refers you to other available catalogs. Features included are mounting dimensions drawings, horsepower ratings, operating characteristics, contact arrangements, electrical ratings, actuator variations, replacement parts, environment data, pricing and a handy glossary of switch terms. Honeywell, Micro Switch Div.

CIRCLE NO. 290

Zirconium copper

A 20-page technical data booklet on zirconium copper is now available. This metal is a heat-treatable copper alloy developed for applications requiring high conductivity and good strength at high temperature. It is an alloy that develops its strength primarily from cold working. Heat treatment precipitates the Cu_3Zr phase, increasing electrical conductivity, ductility and recrystallization temperatures, while retarding dislocation movements. The booklet contains 16 graphs and ten tables of the metal's properties. American Metal Climax Inc.

CIRCLE NO. 291



Resistor line cataloged

The entire Dale line of wirewound and film resistors is covered in its Catalog A. Color coding of the book allows easy reference to sections on precision wirewounds, industrial wirewounds and precision film-types. Dale Electronics Inc.

CIRCLE NO. 292

Microwave components

This catalog of microwave components takes the form of three standard-size data sheets in a file folder. The data sheets describe a line of low-noise solid-state front ends: preamps, mixer-preamps, and oscillators. Consolidated Airborne Systems, Inc., Microwave Products Group.

CIRCLE NO. 293

NBS bulletins

The National Bureau of Standards, U.S. Department of Commerce, Washington, D. C., offers a group of publications to the engineering society. Below is a list of some that might be useful to electronic design engineers:

1. Silicon attenuators for laser measurements (15¢).
2. Modification simplifies volt box calibration (15¢).
3. Some techniques for measuring small mutual inductances. D. N. Homan (75¢).
4. Notes on the use of propagation-of-error formulas. H. H. Ku (75¢).

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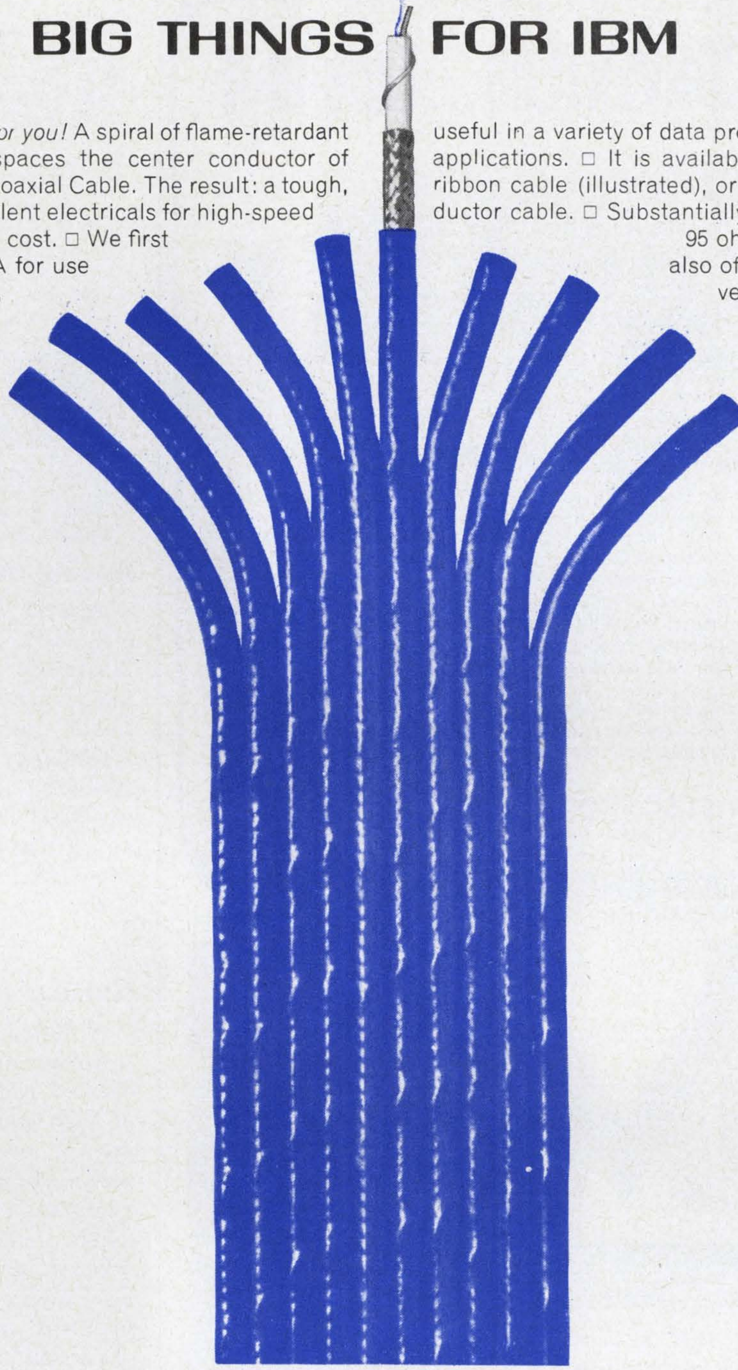

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Shield: #38 AWG tinned copper braid, providing 90% min coverage.

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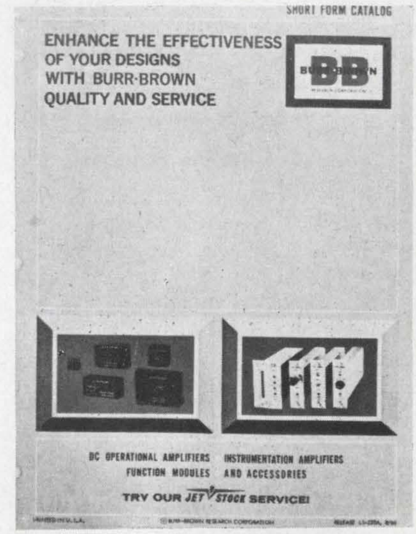


Analog module catalog

Several broad lines of analog modules are described in a 12-page illustrated catalog. Units described include operational amplifiers, functional modules, instrumentation amplifiers, power supplies and accessories. Prices, mechanical and electrical specifications, definitions, and a list of customer services are provided. Burr-Brown Research Corp.

CIRCLE NO. 294

Nuclear accessories

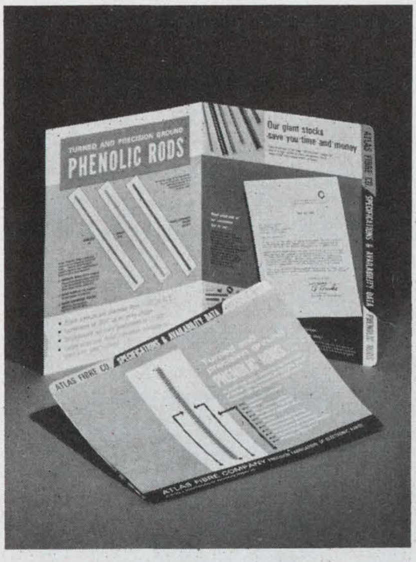
A 50-page catalog of nuclear accessories and detectors offers the user of radioisotopes a wide range of such equipment. Over 200 items include protective clothing, radioactive sources, handling tools, body phantoms and recording instruments among others. Detectors covered include the Molechem low-level counter, Harshaw integral and matched window lines, and Harshaw solid-state detectors. Hamner Electronics Co.

CIRCLE NO. 295

Precision pot catalog

The revised catalog rp 962/D provides detailed specifications on the CIC line of rotary precision film potentiometers. This revised publication includes a new section on electromechanical assemblies and gears. Revised specifications are offered on the single and multi-turn units, their elements and on the electrical and mechanical configurations available. Computer Instruments Corp.

CIRCLE NO. 296



Phenolic rods

This 4-page data folder contains actual samples of 3 basic types of turned and precision-ground phenolic rods for relay and other electronic applications. In addition, this useful, permanent file folder is furnished with complete data sheets listing full specifications, mechanical and physical properties, as well as prices on the entire line. Atlas Fibre Co.

CIRCLE NO. 297

Short-form pot catalog

An 8-page condensed catalog covers over 50 Bourns adjustment potentiometers. The catalog contains the nomenclature, dimensions, specs and prices of wirewound, special, general purpose and non-wirewound units. Information on precision pots, power supplies, voltage sensors, relays, time delays microcomponents and turns-counting dials is also included. Bourns Inc.

CIRCLE NO. 298

Op-amp quiz

For teaching or brushing-up on basic analog techniques, two educational papers on operational amps are now available. Part One is called "An Introductory Laboratory Manual of Operational Amplifier Experiments." Part Two is called "Operational Amplifier Quiz" and is designed to give a one-hour test on one's knowledge of analog operational amplifier use. Nexus Research Lab., Inc.

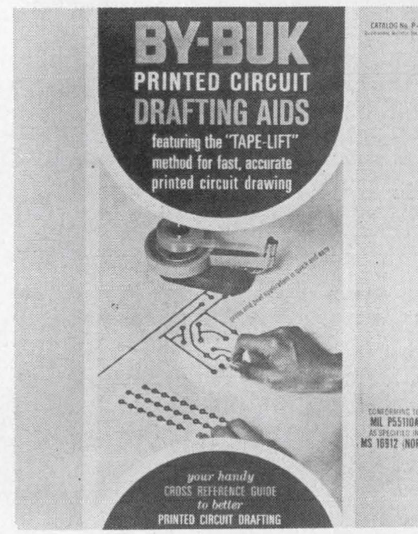
CIRCLE NO. 299

NEW LITERATURE

Thin-metal tubing selector

A 12-page selection guide describes more than 80 metal alloys available in thin-wall tubing and tubular fabrications. Selection tables include nominal chemical composition, melting range, density, coefficients of thermal expansion and electrical resistivity as well as tensile and yield strengths. Uniform Tubes, Inc.

CIRCLE NO. 300



Printed circuit drafting aids

This cross-referenced printed circuit catalog illustrates a line of drafting aids, giving size, shape, price, delivery and notation. Aids such as transistor tri-pads and "tape-lift" shapes are included. By-Buk Co.

CIRCLE NO. 301

Miniature coax connectors

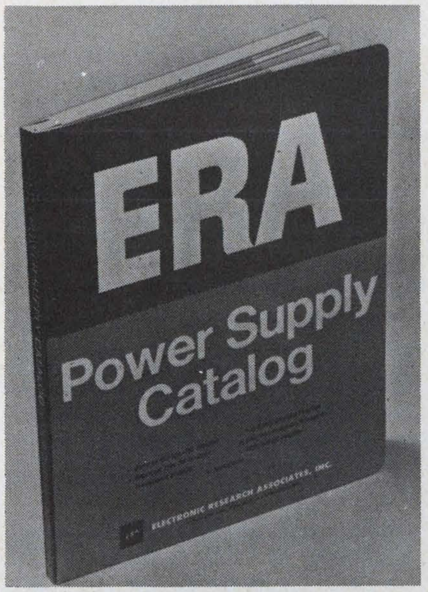
Miniature coaxial connectors for high-impedance systems are described in this catalog. Dimensional drawings for 21 connector varieties are shown. Cutaway drawings explain design features of the connectors. Cinch-Nuline Industries Inc.

CIRCLE NO. 302

Real-time computer

Sigma 2, a small, low-cost, realtime computer, is described in this 16-page brochure. The booklet describes the overall design concept, special design features, software and wired instructions, system interface units and peripheral equipment. Scientific Data Systems.

CIRCLE NO. 303



Power supply catalog

Ac to dc, dc to ac, ac to ac and dc to dc supplies for industrial and military use are featured in this hard-cover catalog. The book lists full data, drawings, block diagrams, price and photos of MIL dc modules, industrial type modules, unregulated modules, variable supplies, inverters, frequency changers and high-voltage supplies. Electronic Research Associates Inc.

CIRCLE NO. 304

Adjustment potentiometers

This catalog contains nomenclature, dimensions, specifications, price listings, and actual size photos of over 50 high performance wirewound, non-wirewound, special, and general purpose adjustment potentiometers. Bourns Inc.

CIRCLE NO. 305

Answer to Puzzle on p. 99

S	T	O	R	A	G	E	U	N	I	T		Q	U	E	U	E
C		P		M			N		N	E	G			R		C
A	R	E	A		P	O	I		C	R			D	A	S	H
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		C		C		N			T	I			P	A	D	
F		O		O	M	I	T		O	N	E			B		F
L		R	I	M		D		C	O	A	X	I	A	L		A
U	S	E		P	H	I		H		L		B		E	N	D
T			M	U		R		R	E	S	U	M	E			E
T	I	P		T	I	E		O		T				F		O
E		U		E		C	O	M	M	A	N	D		L		U
R	I	S	E	R		T		A	F	T		O		O		T
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S	O	P			L	O	O	P		O				T		T
T	R	U	N	K		N		L	I	N	E	N	O	I	S	E
E		L			M	A		A						N		S
P	U	L	S	E		L	I	N	E	O	F	S	I	G	H	T

Did he have wave filters in mind?

Чебышёв

Above is the original Russian spelling of Chebyshev, the name of a nineteenth century mathematician to whom modern network theory owes a debt of gratitude. His well known polynomials were published in "Oeuvres" Vol. 1, St. Petersburg, 1899, for use in studying the construction of steam engines. Obviously, he didn't have wave filters in mind.

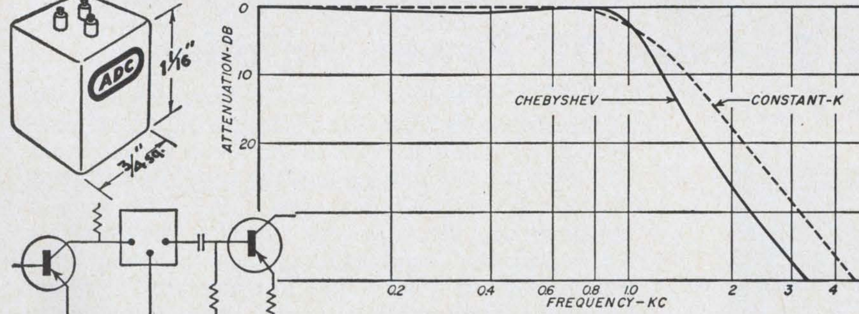
When Chebyshev Polynomials are applied to modern filter synthesis they produce ladder networks with controlled pass band ripple, and roll-off which is more rapid than that produced by "classical" networks such as the image parameter "constant K".

The illustration below shows the improved sharpness at cutoff and increased roll-off rate for a one section Chebyshev Filter. Admittedly, this is a simplified example, but it provides an easily understandable comparison between "old" and "new" design methods.

When the use of more sophisticated tools such as elliptic functions and Bessel Polynomials are added to the Chebyshev Polynomials, Modern Network Synthesis becomes a powerful vehicle for the realization of today's computer and space oriented filtering problems.

ADC staff specialists are skilled in the art of Modern Network Synthesis. The classicial, modern or computer approach to network design is used as each may fit a particular application. Facilities include those for design, prototype sampling, testing, and production.

COMPARISON OF ONE SECTION CHEBYSHEV FILTER WITH CLASSICAL "CONSTANT K"



If modern network theory and its application interests you, we'll be glad to send you a copy of "General Approaches to Wave Filter Design"—no charge, no obligation.

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NEW LITERATURE

Speed measurement

A 28-page booklet "Speed Measurement and Control," contains information on ac and dc tachometer systems. Included are instruments available, various methods of mounting and indicator devices. Weston Instruments. **CIRCLE NO. 306**

Reprints Available

The following reprints are available free and in limited quantities. To obtain single copies, circle the number of the article you want on the Reader-Service Card.

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Nov. 29-Dec. 2

AIAA Third Annual Meeting and Technical Display (Boston) Sponsor: AIAA; Vincent J. Coates, Jr., Avco Everett Research Lab., 2385 Revere Beach Pkwy., Everett, Mass. 02149

Nov. 27-Dec. 1

Energy Systems Exposition and Winter Annual Meeting (New York) Sponsor: American Society of Mechanical Engineers; Marvin D. Frankel, Muller, Jordan & Herrick, Inc., 545 Fifth Ave., New York. 10017

Dec. 7-9

15th Annual Wire and Cable Symposium (Atlantic City, N. J.) Sponsor: Army Electronics Command; J. Spergel, Wire and Cable Symposium, U.S. Army Electronics Command, Fort Monmouth, N. J. 07703

Dec. 7-9

International Scientific Radio Union (URSI) (Palo Alto, Calif.) Sponsor: U.S. National Committee of the International Scientific Radio Union; Prof. R. A. Helliwell, Radioscience Lab., Stanford University, Stanford, Calif. 94305

Dec. 26-31

133rd Meeting of the American Association for the Advancement of Sciences (Washington, D. C.) Sponsor: AAAS; Mrs. Thelma C. Heatwole, 5110 W. Franklin St., Richmond, Va. 23226

Jan. 4-7, 1967

Winter Meeting of the National Society of Professional Engineers (San Juan, P. R.) Sponsor: NSPE; Kenneth E. Trombley, National Society of Professional Engineers, 2029 K. St., N.W., Washington, D. C. 20006

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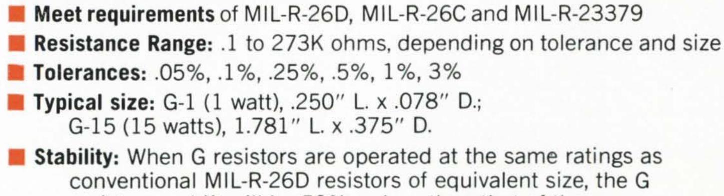

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