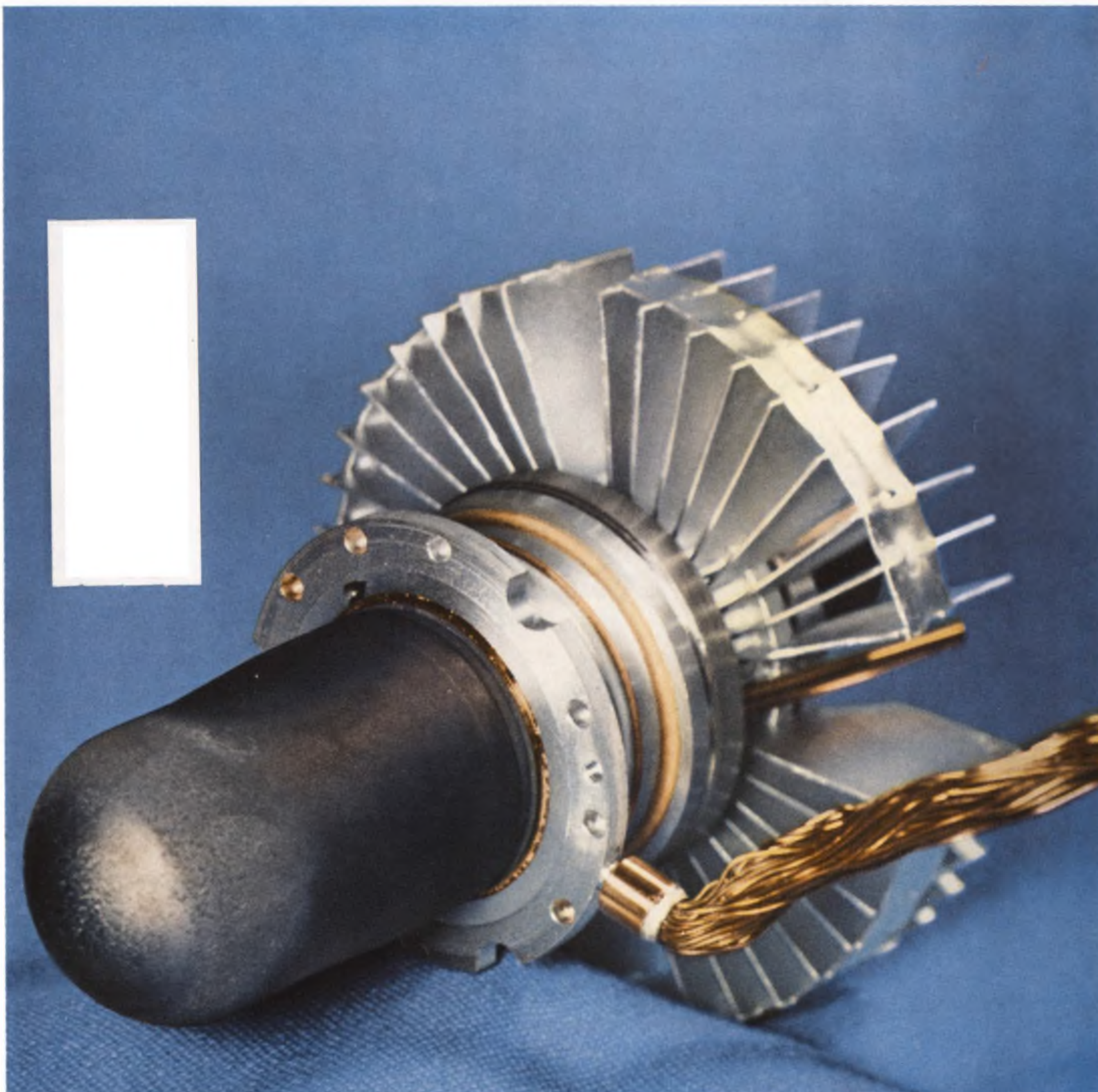
VOL. 14, NO.

# Electronic Design 16

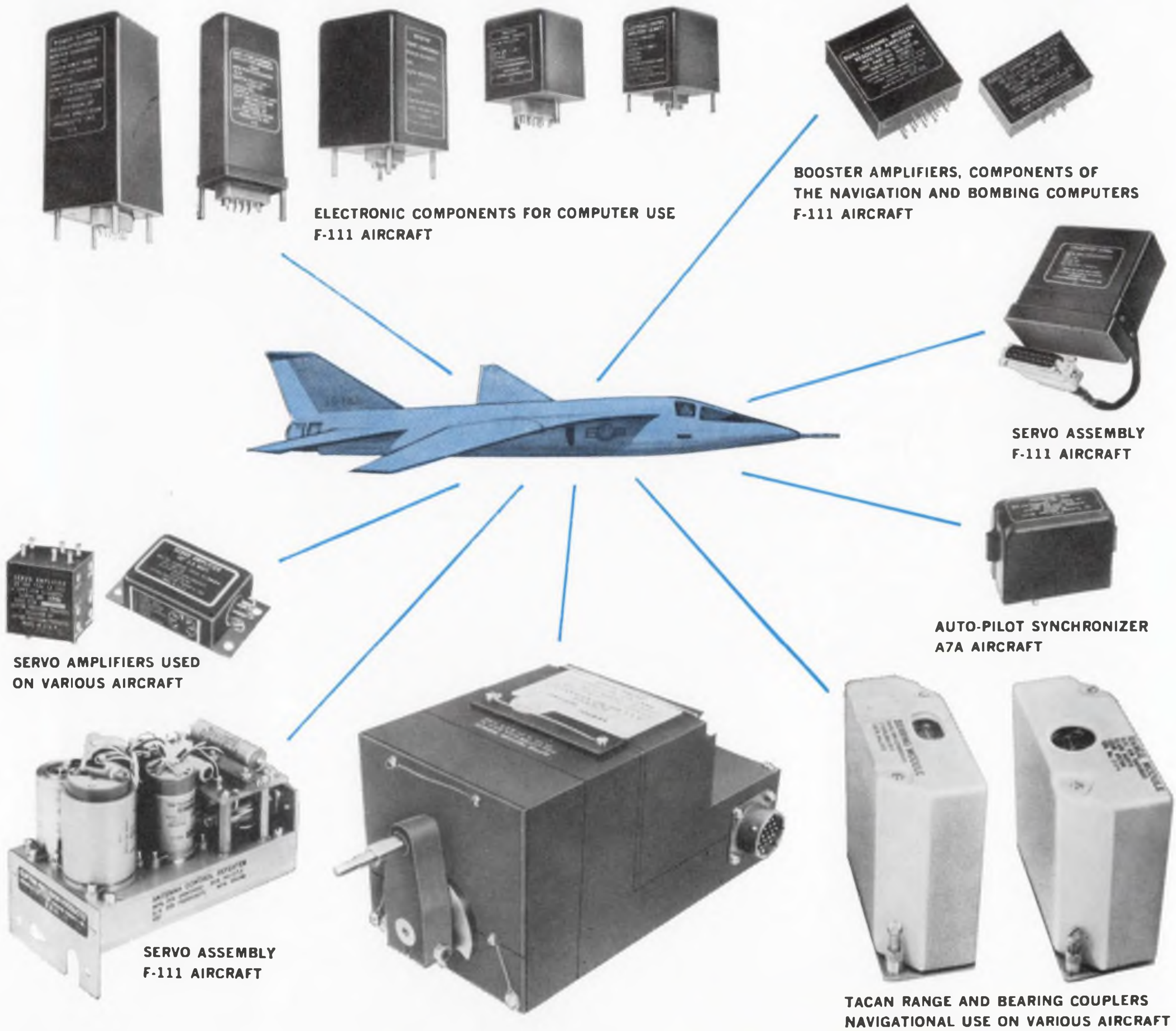
THE MAGAZINE OF ESSENTIAL NEWS, PRODUCTS AND TECHNOLOGY

JULY 5, 1966

**Thermionic activity heats up** as new advances promise silent power for the Army, high power for long-range space flight. A 100-watt thermionic diode is shown below. • New heat pipe allows greater efficiency in heat source-to-diode coupling. • Coming: A 3-kW generator with a 36-diode array. (See page 17.)



# ✓ Check CLIFTON for Servo Packages




*All units shown ⅓ actual size.*

We have been designers and manufacturers of flight controls and special aircraft devices for the past 10 years. A great many engineers and purchasing people think of Clifton only as a leader-manufacturer of rotating components, synchros, servo motors and resolvers. We would like to point out that we also develop, design and produce servo sub-assemblies, to the most exacting requirements. These precision-engineered modules are now flying, or will soon fly, in our country's most important aircraft.

These packages are built to Clifton synchro standards of reliability and accuracy . . . and in production quantities. While we can hand build models for you, we excel in "in-line" *quantity* and *quality* production.

Give us the opportunity to discuss your next servo package need! Do it now, today!

Call 215 622-1000 and ask for Mr. E. Fisher, or TWX 215 623-1183.

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DIVISION OF LITTON INDUSTRIES
Clifton Heights, Pa. Colorado Springs, Colorado

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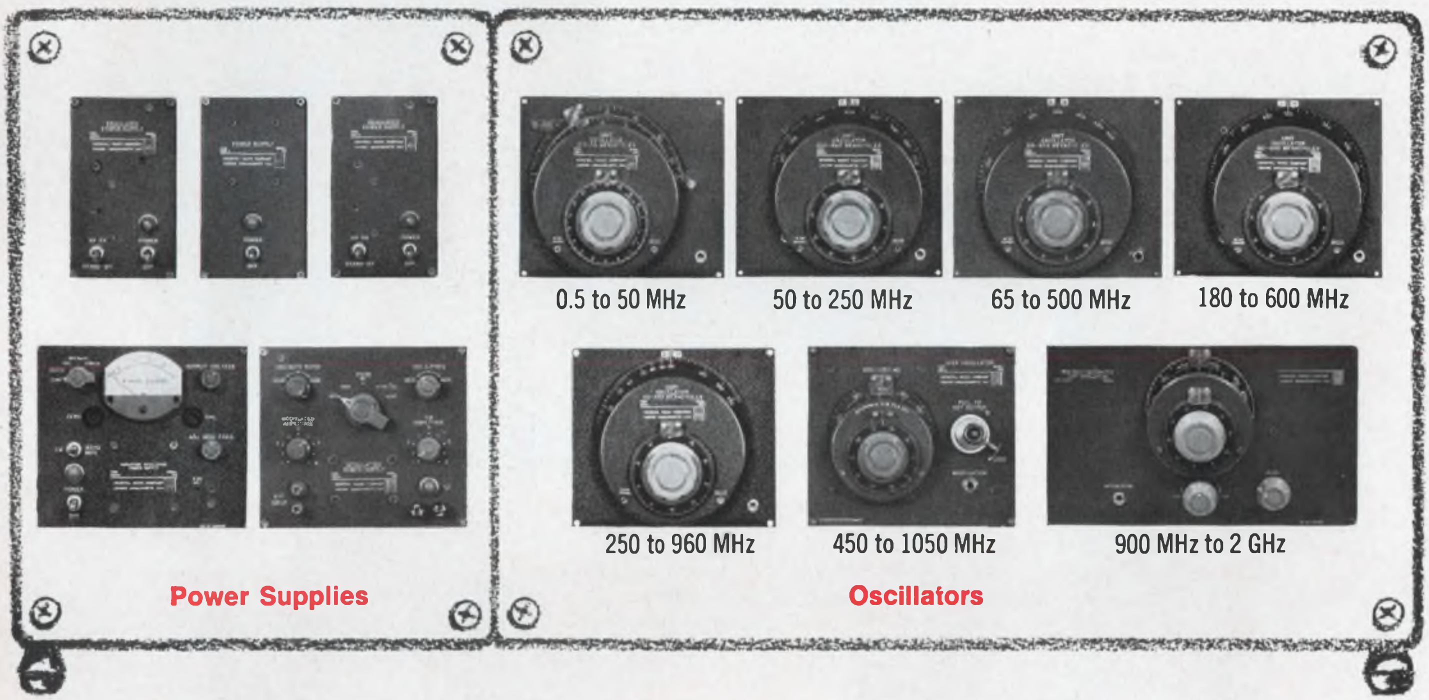
ON READER-SERVICE CARD CIRCLE 212

# Select the oscillator you want,

then choose the power supply that gives the performance you need...power, frequency stability, pulse and/or square-wave modulation, amplitude-regulated output, 115-V or 230-V input.




There are 32 different combinations offered here, each with a different set of features for your measurement needs. The seven oscillators from which you can choose provide continuous frequency coverage from 500 kHz to 2000 MHz and have typical outputs of several hundred milliwatts. All but two of these can be mated with any of five power supplies to provide a variety of operating conditions. Prices for oscillator/power-supply combinations range from $355 to $1104 in the U.S.A.

*Please write for complete information.*

**Typical Oscillator/Power-Supply Combination**

**Type 1361-A4 .... $680**

450- to 1050-MHz oscillator with a power supply that provides stable CW and 100% square-wave and pulse modulation, bench model. This oscillator also usable with any of the other four power supplies, for bench use or rack mounting.

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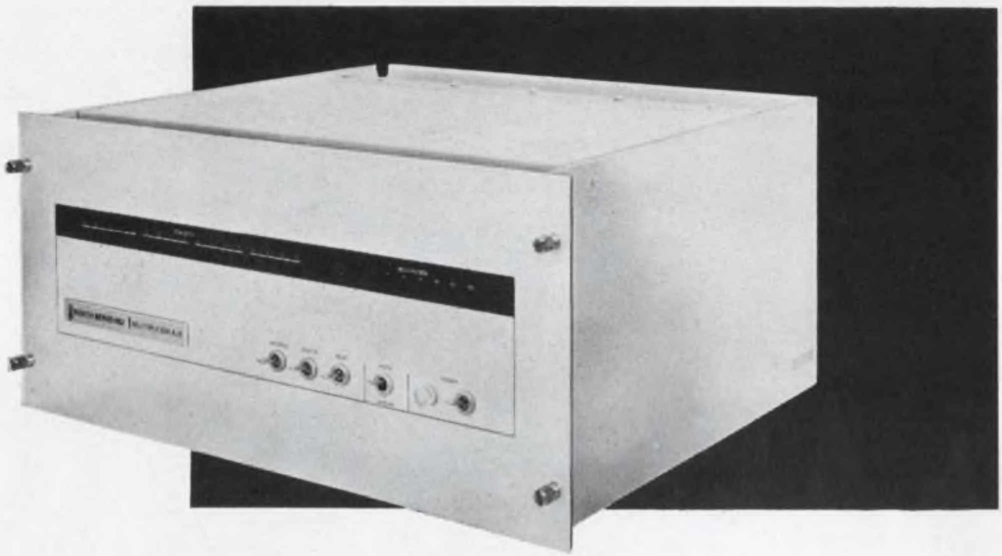
**GENERAL RADIO**

WEST CONCORD, MASSACHUSETTS

ON READER-SERVICE CARD CIRCLE 215

# ARE YOU OVERLOOKING REDCOR'S 663 series A to D converter (15 bit accuracy) and MULTIPLEXER (up to 256 channels) SYSTEMS?



## CHECK THESE FEATURES

☐ SYSTEM REPEATABILITY AND RESOLUTION — ±0.01% ± ½ L.S.B., 3 sigma error distribution (15 bit binary or 17 bit BCD).

☐ SYSTEM THROUGHPUT RATES — 43 kc at 13 bits and 36 kc at 15 bits.

☐ DIFFERENTIAL SAMPLE AND HOLD — Aperture time less than 100 nanosecs; 5 $\mu$secs settling time. (0.01%)

☐ HIGH INPUT IMPEDANCE — 100 megohms for both differential and common mode signals (selected or unselected channels).

☐ ANALOG-DIGITAL GROUND ISOLATION is obtained by differential amplifiers with high common mode rejection maintaining a system accuracy of 0.01%.

☐ OVERLOAD RECOVERY — Each input is clamped so that the system will recover from a 100 V overload in one channel time.

☐ "NO COST" OPTIONS include true and false digital outputs, positive or negative logic levels from 6 V to 12 V, Absolute Value and Sign or complement output coding, internal-external bit clock, and internal-external reference.

☐ AUTOMATIC — sequential or random access multiplexer address, internal-external bit clock. MANUAL by front panel multiplexer advance and A-D start.

☐ EXTRA CARD SLOTS for expansion of the basic system using compatible REDCOR modules to meet specific customer total data acquisition systems requirements.

☐ MULTIPLEXER EXPANDABLE from 1 to 256 channels in 1 channel increments (1 plug-in microelement per channel).

☐ INTEGRATED CIRCUIT DESIGN AND ALL SILICON DESIGN increases system reliability and overall performance; reduces physical size; lowers system power consumption.

☐ MTBF — Calculated per MIL handbook 217 — 3500 hours. Actual experience in excess of 36 machine months operation with no failures.

☐ TOTAL PLUG-IN FEATURES including power supply and front panel assembly provides unique ease of maintenance.

☐ PLUG-IN MICROELEMENTS allow inexpensive spares provisioning and minimizes total troubleshooting costs.

☐ BUILT-IN FILTER AND ATTENUATOR — No reduction in number of channels necessary.

☐ EXTERNAL REFERENCE — The A-D Converter can be slaved to an external reference voltage if desired.

☐ PATCHABLE number of sequence positions or channels.

☐ TEST POINTS on the integrated circuit modules eliminates the necessity of back-plane probing.

☐ COMPLETE FUNCTIONS are contained on individual 8"x 12" modules for ease of maintenance. The system consists of only 5 different types of modules including power supply.

For complete specifications, write for Brochure 663.

*complete systems compatibility* **REDCOR**

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VOL. 14, NO.

# Electronic Design 16

THE MAGAZINE OF ESSENTIAL NEWS, PRODUCTS AND TECHNOLOGY

JULY 5, 1966

## NEWS



## TECHNOLOGY



## PRODUCTS



## Departments



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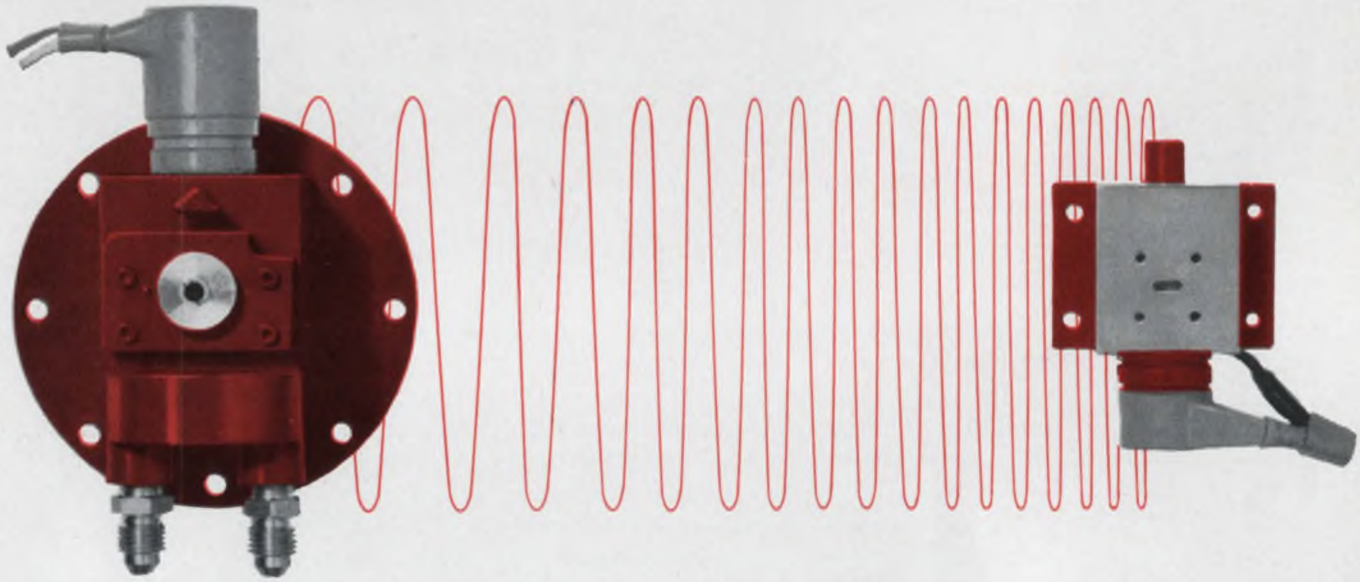
# Spanning the range of low-noise klystron oscillator capabilities



| C BAND | VA-521 |
|---|---|
| Frequency | 5.5 to 7.0 GHz |
| Mechanical Tuning | 100 Mc |
| Power Output | Up to 5 Watts |
| AM Noise Performance (Bench) | Better than 125 db below the Carrier (in a 1 Kc bandwidth 10 Kc from the Carrier) |

| Ka BAND | VA-531 |
|---|---|
| Frequency (Fixed) | 26.5 to 33.0 GHz |
| Power Output | Up to 1 Watt |
| FM Noise Performance Under Environment | (Random Vibration or Sinusoidal) |
| FM Vibration Sensitivity | Less than 200 Hz per G at the vibration frequency |

When ultra-low spectral noise is a critical factor in your oscillator requirements, Varian offers you proven, total capability from C band through Ka band.
Measuring low noise is standard procedure at Varian, and has been for many years. Noise measurements are made under both laboratory AND stringent environmental conditions.

For more information about Varian's low spectral noise capabilities, write the Palo Alto Tube Division, 611 Hansen Way, Palo Alto, California. In Europe: Varian A.G., Zug, Switzerland. In Canada: Varian Associates of Canada, Ltd., Georgetown, Ontario.

varian

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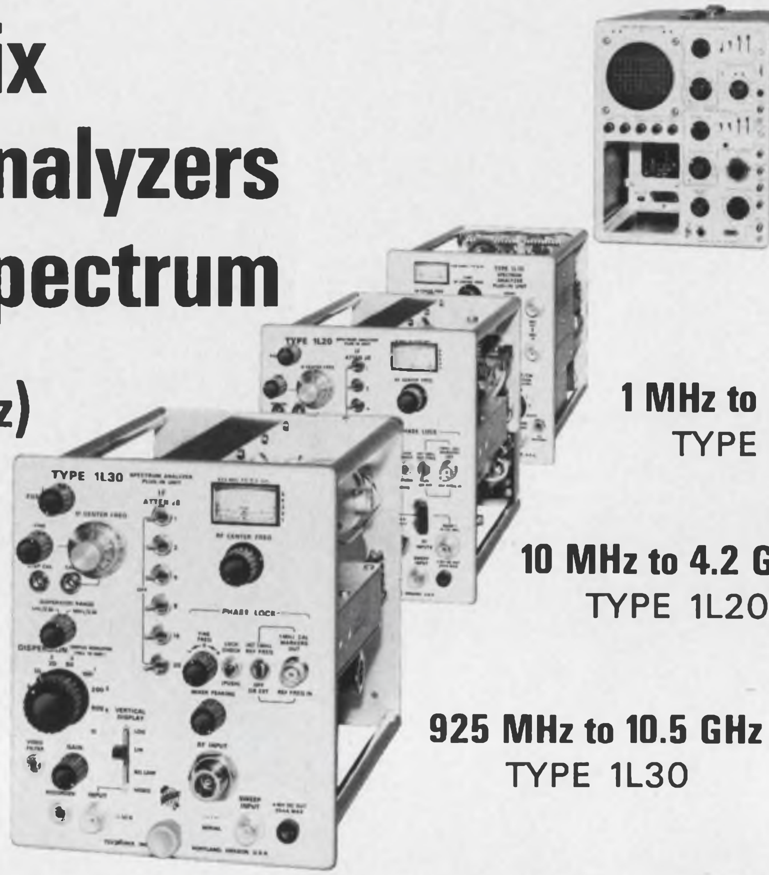
# Tektronix spectrum analyzers cover the spectrum

## (1 MHz to 10.5 GHz)



**1 MHz to 36 MHz**
TYPE 1L10

**10 MHz to 4.2 GHz**
TYPE 1L20

**925 MHz to 10.5 GHz**
TYPE 1L30

## They're all designed by Tektronix specifically for use in Tektronix oscilloscopes

### Features of Tektronix Spectrum Analyzers

(Types 1L20 and 1L30)

- Internal phase lock
- 100 MHz calibrated dispersion
- 1 kHz resolution
- ±1.5 dB display flatness

With any Tektronix oscilloscope that accepts letter and 1-series plug-ins, plus one of these spectrum analyzer plug-ins, you can extend the measurement capability of your laboratory to include spectrum analysis in the frequency range between 1 MHz and 10.5 GHz.

The Tektronix combination of spectrum analyzer and oscilloscope lets you make simple and accurate frequency measurements directly from the CRT display. The availability of many other plug-ins makes the oscilloscope an even more versatile laboratory measurement instrument.

Tektronix offers an outstanding measurement value in an oscilloscope-spectrum analyzer package, particularly when its cost is compared with a typical single-purpose spectrum analyzer.

*TEKTRONIX SPECTRUM ANALYZER CHARACTERISTICS*

| | TYPE 1L10 | TYPE 1L20 | TYPE 1L30 | TYPE 3L10 (for use in Type 561A, 564 and 565 oscilloscopes) |
|---|---|---|---|---|
| | (for use in Tektronix oscilloscopes accepting letter and 1-series plug-in units) | | | |
| Frequency Range | 1 MHz to 36 MHz | 10 MHz to 4.2 GHz | 925 MHz to 10.5 GHz | 1 MHz to 36 MHz |
| Sensitivity | —100 dBm | —110 dBm to —90 dBm | —105 dBm to —75 dBm | —100 dBm |
| Calibrated Dispersion | 2 kHz/cm to 10 Hz/cm | 10 MHz/cm to 1 kHz/cm | | 2 kHz/div to 10 Hz/div |
| Resolution | 1 kHz to 10 Hz | 100 kHz to 1 kHz | | 1 kHz to 10 Hz |
| Incidental FM | IF: 5 Hz LO: 25 Hz + 1 Hz/MHz dial frequency | With internal phase lock, less than 300 Hz | | IF: 5 Hz LO: 25 Hz + 1 Hz/MHz dial frequency |
| Display | Log, linear, linear X10 and video | Log, linear, square law and video | | Log, linear and video |
| Price | $1100 | $1825 | $1825 | $1200 |

For a demonstration, call your nearby Tektronix field engineer, or write:
Tektronix, Inc.,
P. O. Box 500,
Beaverton, Oregon 97005.

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

## *Tektronix, Inc.*

*If you are interested in helping advance the state-of-the-art in oscilloscope design, write D. A. Thompson, professional placement manager.*

ON READER-SERVICE CARD CIRCLE 5



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ON READER-SERVICE CARD CIRCLE 217 ➤

# Chances are about 100 to 1 that one of these three frequency synthesizers will do your job better...and for less too! Cover the frequency range of 50 Hz to 11 MHz with the Model 304A; the 50 Hz to 1.1 MHz band with the Model 303A...and from 10 Hz to 110 KHz with the Model 302A. If one of these won't do, we can probably make a special that will; give us a call.

Fluke/Montronics frequency synthesizers use direct synthesis. Because phase locked oscillators aren't used, the output is extremely pure and phase stable. These synthesizers may be remotely programmed. Readout is illuminated inline.

Each band is covered in 1 Hz steps. Modular construction means 0.1 or 0.01 Hz steps on order. The search oscillator can be used to vary continuously the output frequency. Oscillator voltage is controlled from either front panel calibrated dial or an external source.

Long term stability and accuracy equal that of the input source. Switching time from one frequency to any other is less than 1 millisecond. Price of the Model 304A is $6,950; the Model 302A $4,250; and the Model 303A, $4,825.

For full information, call your Fluke/Montronics representative or write.

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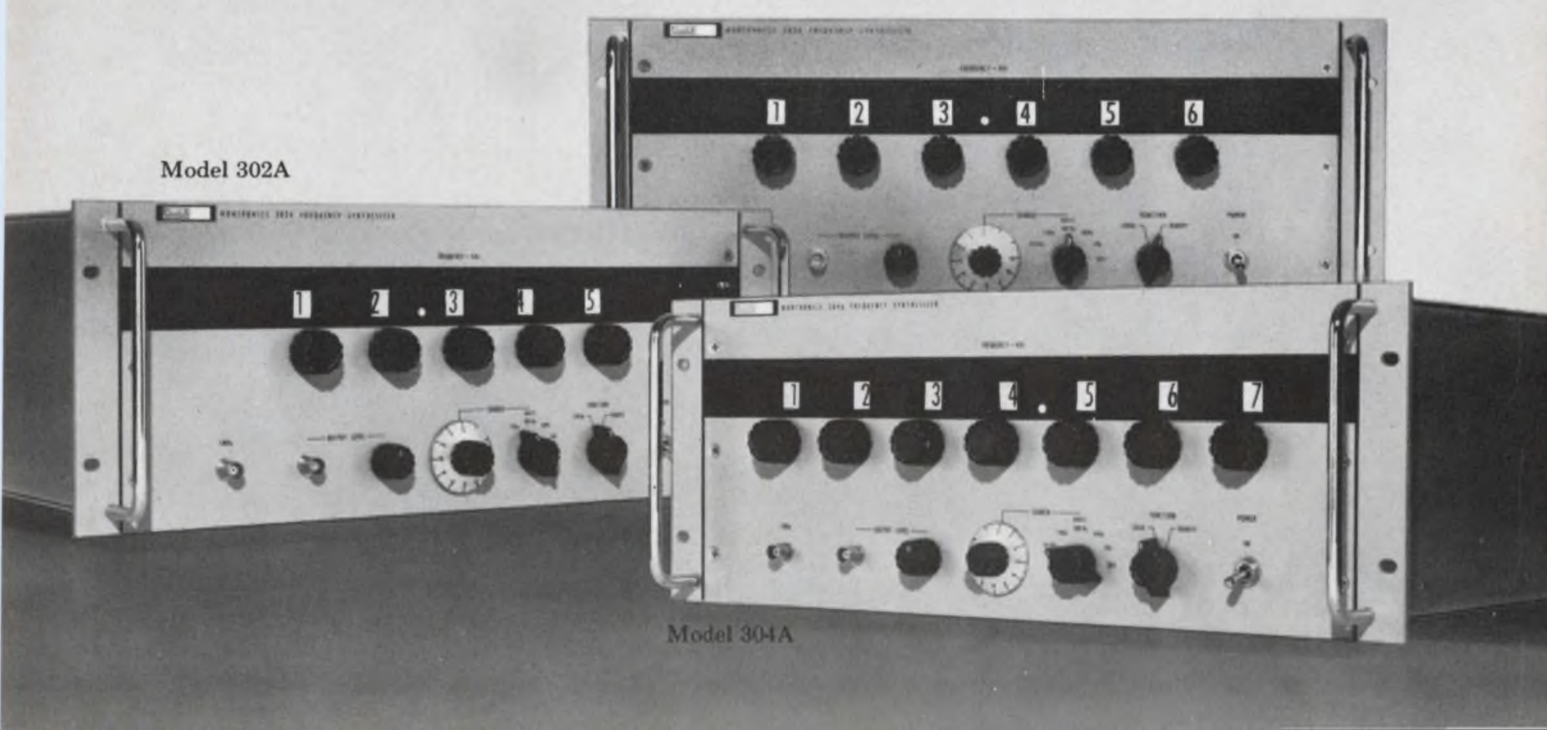
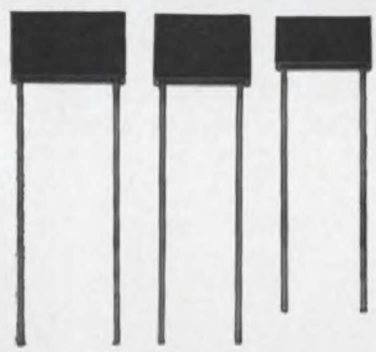
Model 303A




Model 302A

Model 304A

# Small and stable –capacitors for a filter man's thinking



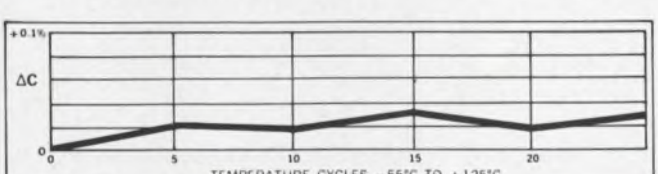
ACTUAL SIZE

**KEMET Flat-Kap: Parylene dielectric extended-foil capacitors with excellent stability in a very small plug-in conformal design. Available with tight tolerances.**

Typical retrace stability is 0.1% from cycling, use, or storage, over the full operating range from $-55°$ to $+125°C$, with nominal T.C. $-200$ ppm/°C. They are available in any value from 0.001 to 0.100$\mu$F, 50 VDC, with tolerances as tight as $\pm1\%$. Insulation resistance is 1,000,000 megohms, minimum, at 25°C. Flat-Kap capacitors are up to 95% smaller than glass, mica, porcelain or polystyrene.

The reason: A remarkable new dielectric from Union Carbide research called Parylene. Vacuum-vapor-deposited in micron-range thickness on aluminum foil, Parylene offers, in minimum capacitor volume, the very stable characteristics demanded by today's precision circuitry.

Even if you're not a filter designer, you'll probably think of circuit problems the Flat-Kap capacitor can solve. For technical details, mail the coupon.




Superior capacitance stability of Flat-Kap capacitors.

Regional Sales Offices

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Union Carbide Corporation
Linde Division, Dept. ED-71
270 Park Avenue, New York 10017

Please send Engineering Bulletin #22, on KEMET Flat-Kap film-foil capacitors

Name____________________

Title____________________

UNION CARBIDE

ELECTRONICS

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# Did you know Sprague makes...?

## UNICIRCUIT® RCTL INTEGRATED CIRCUITS

(8X actual size)

Sprague Series US-0100 . . . a complete line of monolithic digital building blocks featuring low power consumption (2 mW typ.)

ON READER-SERVICE CIRCLE 101

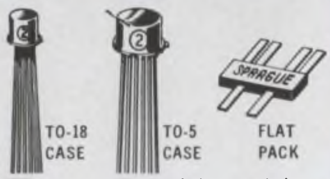
## UNICIRCUIT® mW RTL INTEGRATED CIRCUITS

TO-5 CASE

Types US-0908 through US-0921 . . . Fully interchangeable mW digital building blocks featuring power consumption of 4 mW/node and propagation delay of 40 nsec

ON READER-SERVICE CIRCLE 102

## DIFFERENTIAL AMPLIFIER TRANSISTOR PAIRS

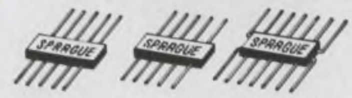


TO-18 CASE | TO-5 CASE | FLAT PACK

NPN or PNP • Matched characteristics.
$h_{FE}$ = 10-20%. $\triangle V_{BE}$ = 5-20 mV.
$\triangle V_{BE}$/Temp = 5-20$\mu$V/°C.

ON READER-SERVICE CIRCLE 103

## MULTIPLE TRANSISTORS (NPN-PNP PAIRS/QUADS)

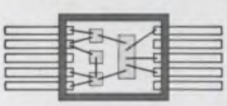


AMPLIFIERS SWITCHES CHOPPERS

| Pairs | Quads |
|---|---|
| 2 NPN | 4 NPN |
| 2 PNP | 4 PNP |
| 1 NPN—1 PNP | 2 NPN—2 PNP |

ON READER-SERVICE CIRCLE 104

## UNICIRCUIT® CUSTOM HYBRID CIRCUITS



Combine monolithic silicon circuits with tantalum or Ni-Cr alloy resistors. Close resistance tolerances, low temperature coefficient. Resistor matching, ±½%.

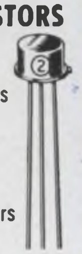
ON READER-SERVICE CIRCLE 105

## LOW-COST HERMETICALLY-SEALED PLANAR TRANSISTORS

**TQ SERIES (PNP)**
Low Level Amplifiers
High Gain Switch/Amplifiers
High Speed Switches

**TN SERIES (NPN)**
High Voltage Switches
Low Level Amplifiers
High Speed Switch/Amplifiers
Choppers
Power Amplifiers
Core Drivers

TO-18 CASE



TO-5 CASE

ON READER-SERVICE CIRCLE 106

## SILICON ALLOY REPLACEMENT TRANSISTORS

***FULL PLANAR RELIABILITY***

| | | |
|---|---|---|
| 2N327A | 2N945 | 2N1026 |
| 2N328A | 2N946 | 2N1469 |
| 2N329A | 2N1025 | 2N1917 |

Sprague makes 82 standard high-emitter-voltage full planar silicon alloy replacement types.

ON READER-SERVICE CIRCLE 107

## DIGITAL-TO-ANALOG CONVERSION CIRCUITS

UT-1000—Four-bit ladder network
UT-4001—Ladder switch for driving resistor ladder networks
UT-4024—Buffer amplifier

ON READER-SERVICE CIRCLE 108

## TW-3000 MICROPOWER PNP SILICON HIGH-SPEED SWITCHING TRANSISTORS

Fastest switching transistor available in the 1 to 100$\mu$A range

$C_{ib}$ = 0.7 pF typ., 1.5 pF max.

$C_{ob}$ = 1.5 pF typ., 2.5 pF max.

TO-18 CASE

ON READER-SERVICE CIRCLE 109

For complete technical data on any of these products, write to:
Technical Literature Service
Sprague Electric Company
347 Marshall Street
North Adams, Mass. 01247

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INTEGRATED CIRCUITS
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ELECTRIC WAVE FILTERS
CERAMIC-BASE PRINTED NETWORKS
PACKAGED COMPONENT ASSEMBLIES
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FUNCTIONAL DIGITAL CIRCUITS

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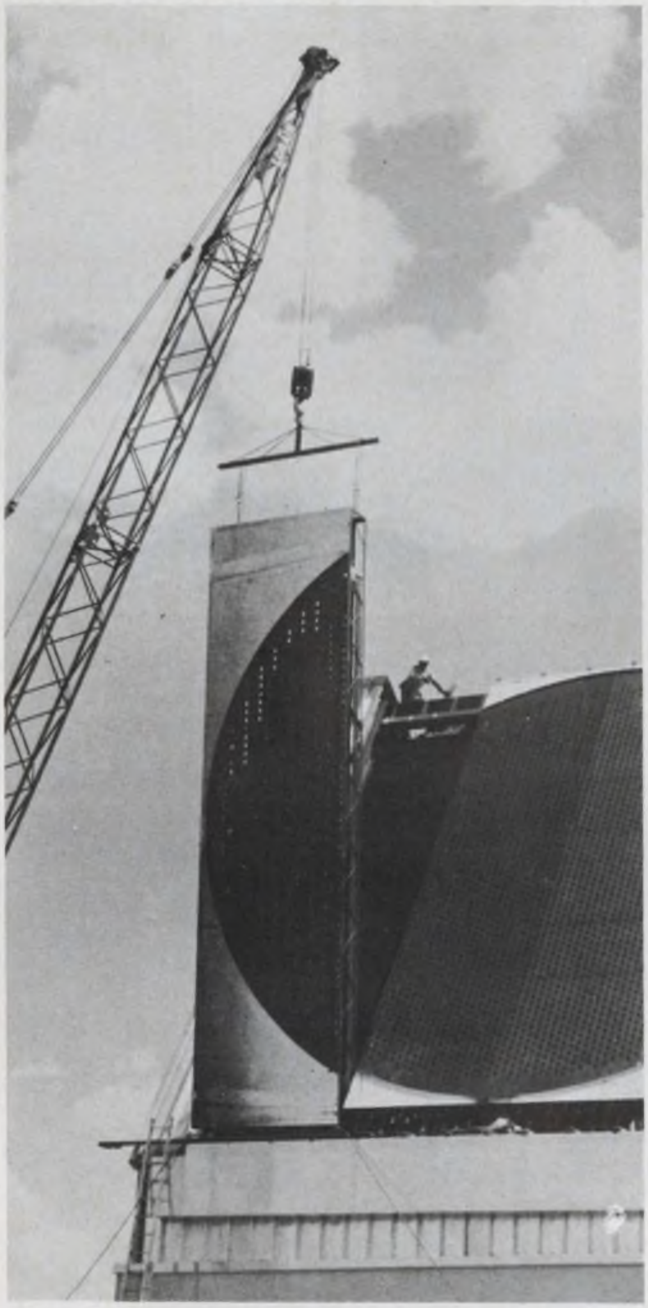
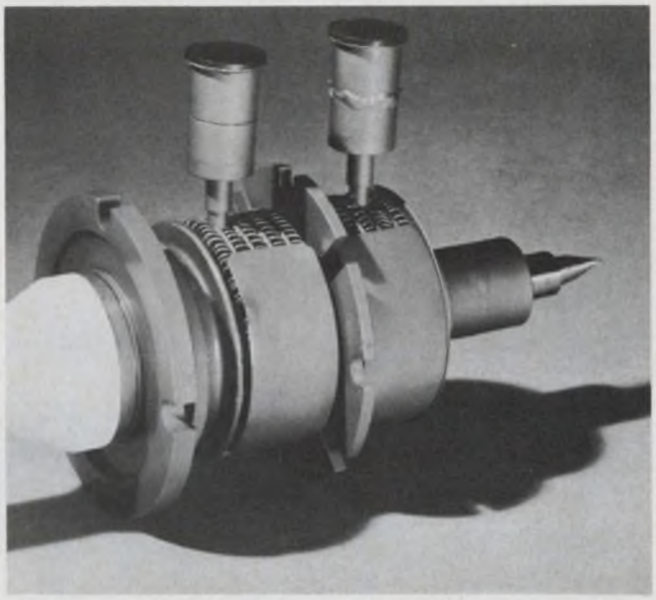
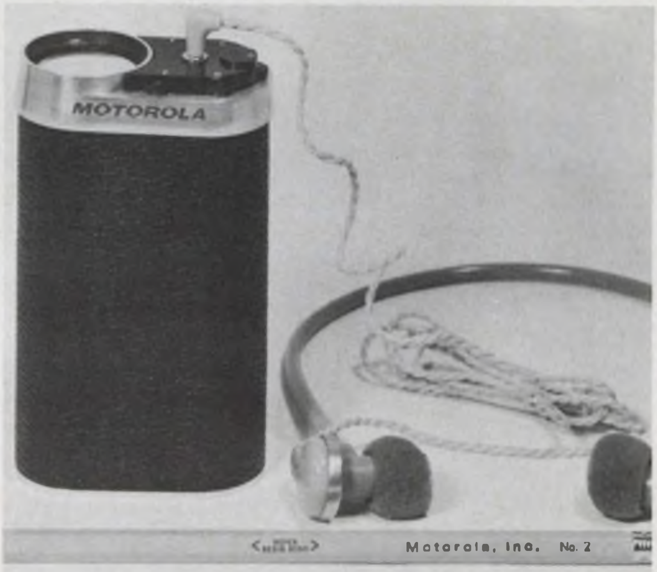
# News



Phased-array antennas are today ushering in a new era in radar design. Page 20.



**Recent developments** stimulating renewed interest in thermionic converters. Page 17.




**Pocket-television** may not be practical, but the technical capability exists. Page 24.

**Phased-array antennas** are today ushering in a new era in radar design. Page 20.

## Also in this section:

**Aircraft may soon be fitted** with hearing aids. Page 28.

**News Scope**, Page 13 . . . **Washington Report**, Page 31 . . . **Editorial**, Page 35.

# Plug in to the Industry's Most Advanced Counter Line


Systron-Donner's system for *direct readout* of microwave frequencies from 0-15 GHz provides an unprecedented simple and low cost solution — features no other Gc counting system offers. Further, S-D's "think ahead" design provides even greater flexibility. As you can see, an ever-growing number of plug-ins can be used interchangeably in the basic 50 and 100 MHz counters. When your digital measuring needs change, you change plug-ins, not counters. That way you always have a state-of-the-art-counter.

EXCEPTIONAL STABILITY—Another exclusive feature of S-D's counter line is a high stability oscillator with an aging rate of better than

**1 part in $10^9$ per 24 hours!**

NEW INSTRUMENT STYLING—In addition to unmatched performance and flexibility in counting instrumentation, new styling refinements have been added to the entire line of S-D counters: die cast front panel, wrap-around cabinetry, tilt stand, and a simplified method for bench or rack installation.

*ACTO: Automatic Computing Transfer Oscillator plug-ins. For fully automatic microwave measurements with counter accuracy and instantaneous direct readout.

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ON READER-SERVICE CARD CIRCLE 7

# News Scope

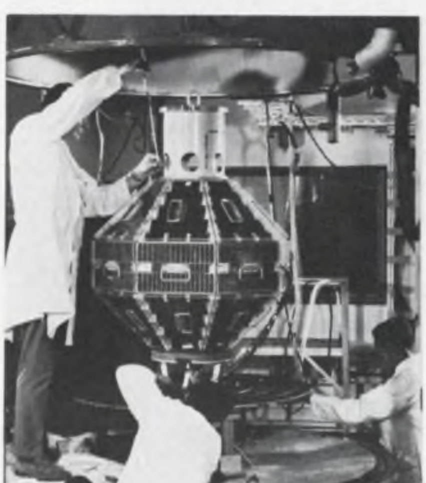
## Solar-powered satellites spring into orbit

Market for satellite batteries takes a dip.

On Thursday, June 16, 1966, a Titan III-C lifted eight exclusively solar-cell-powered satellites into an orbit around the equator and ejected them one by one.

Built for the Air Force, the satellites are to provide a global emergency communications system known as IDCSP (Initial Defense Communication Satellite Program). They contain no storage cells, but though these orbiting relay stations can operate only in sunlight, eight scattered randomly in the equatorial plane ensure global coverage 97% of the time.

Eight-to-one shot



Philco scientists at work

The satellites were held in a tubular frame dispenser on the booster and ejected by springs at intervals of a few seconds. Though initially close together, they drifted slowly apart in orbit because they were ejected at slightly different velocities.

Seven of them were made by Philco's Western Development Laboratory in Palo Alto, Calif., and the eighth by General Electric.

The 36-inch-diameter Philco satellites, after ejection, were made to spin at 150 rpm by cold nitrogen gas squirted out of them through small nozzles. This gives them enough angular momentum to maintain a constant attitude.

The General Electric satellite does not spin. It telescopes out two 52-foot arms. The arms have mass and extend in opposite directions from the satellite's central hub. The satellite orbiting in the earth's gravitation field acts somewhat like a weak dipole, aligning itself along an axis from the earth's center. This is because the gravitational field is not uniform, but rather, has a measurable gradient: It attracts the nearer arm more strongly than the farther arm. Gravity-gradient alignment has worked at low altitudes before, but this time it is being checked at approximately 18,200 nautical miles distance.

A single satellite at this altitude can relay radio signals between ground stations 9000 miles apart. Because all eight units operate on the same X-band frequencies they can transmit a signal from one to another all around the earth.

Each Philco satellite contains one wideband amplifier, a solid-state local oscillator/varactor multiplier train and two traveling-wave tube amplifiers. These are all contained in a 12-inch cylinder through the middle of the nearly spherical satellite. The whole assembly with its outer skin of solar cells weighs 100 pounds. The GE satellites function in a similar manner.

In an actual emergency, the satellites would transmit scrambled, coded digital information.

Two emergency-satellite-launching programs will follow this. The next be known as ADCSP (Advanced Defense Communication Satellite Program).

## FORTRAN gets nod as language standard

FORTRAN has become the first computer programing language to be approved and accepted as a standard by The American Standards Association. It is to be published as ASA Standard X3.9-1966.

An abbreviated version, called basic FORTRAN, has also been approved and will be published as ASA Standard X3.10-1966. Basic FORTRAN is suitable for implementation and use on small computers having limited storage and operating capability.

## Meteorologists to marry satellites and balloons

A new method of gathering meteorological data for long-range weather forecasting will be tested jointly by the space agencies of the United States and France. Designated Eole (the French word for Aeolus, god of the winds in Greek mythology), the project will seek to demonstrate the value and technical feasibility of collecting meteorological data on a global scale by means of constant-altitude balloons and an Earth-orbiting satellite.

The purpose of the Eole project is to obtain data on the circulation of the atmosphere at one or more levels over a large oceanic area.

Pressure, temperature and location data from the drifting balloons will be telemetered to, and recorded in, the satellite memory for later transmission to ground stations.

Agreement for the Eole project is contained in a recently concluded Memorandum of Understanding between the French National Center for Space Studies (CNEE) and NASA. The agreement provides that CNEE will be responsible for the development and launching of the balloons and their payloads and for the design, fabrication and testing of the proposed satellite. NASA will provide the launching rocket, perform the launching and train French personnel, as required.

## New avionics system contract flies to Sperry

ILAAS to control A-7 . . .

A $17.9 million contract to develop, produce and test four prototypes of the Navy's integrated light attack avionics system (ILAAS) has been granted to Sperry Gyroscope. The ILAAS will be the first fixed-wing-aircraft avionics system to integrate fully the functions of navigation, central control, communications, weapons delivery and displays through a computer control complex.

Two redundant computers, weighing less than 45 pounds each, will be used to enhance system reliability. In addition, the principle of functional modularity will be employed in the system, so that subsystem functions can be added or removed without affecting the rest of the system. This will provide growth potential and allow ILAAS to be adapted to changes in weapon technology or other mission applications. Present plans include the ILAAS in an advanced version of the Navy's A-7 aircraft.

## Congress asked to soften antitrust restrictions

In a report to Congress, a top-level study group has requested legislation to allow sweeping mergers among U.S. international communications companies. The report states that mergers, or restructuring, could lead to "more efficient use of plant, reductions in cost and therefore rates, and an increased ability to make overseas telecommunications a more effective instrument of national policy." Present antitrust laws prevent such restructuring.

The report notes that various Government agencies, which are heavy users of international communications, are concerned at the impact of the industry's present structure on their "national security and foreign relations responsibilities". This problem relates "both to the speed with which necessary facilities are installed and to the security and reliability of communications, which under present operating conditions are often routed through areas that are vulnerable in emergencies."

The report also noted that many foreign users of U.S. communications services are "Government-controlled monopolies, having a superior negotiating position and opportunities to play off one U.S. carrier against another."

Most companies that would be affected by the proposed legislation are withholding comment pending closer study of the report. However, Howard R. Hawkins, president of RCA Communications, comments: "This has been advocated by RCA for some time in view of the dynamic developments in global communications. We need new procedures attuned to the realities of the space era."

The study group that prepared the report comprised representatives of the Federal Communications Commission, and the State, Justice and Defense departments.

## USAF may counter USSR radar with big missiles

A U.S. Air Force response to a Soviet anti-missile, anti-bomber network presently under construction in the northwest part of the Soviet Union may cost this country several billion dollars.

According to an article in the New York Times (June 20, 1966, p. 1), the Air Force is considering development of a giant missile called ICM—Improved-Capability Missile. It will also speed up programs to develop advanced Polaris and Minuteman missiles.

A spokesman at the Pentagon indicated that, although the Air Force has made no explicit statements about a new ICM program, information on improved versions of both Polaris and Minuteman (to be called Minuteman III) has appeared in Congressional testimony, posture statements by Defense Secretary McNamara, budget hearings and Senate investigations of strategic preparedness. The Pentagon source indicated that the term ICM might be some reporter's term for Minuteman III.

## Compatibility keynotes communications meeting

The keynote of this year's International Communications Conference in Philadelphia was compatibility. The speakers noted that contemporary technology made a vastly improved global communications system possible. But the major obstacle to direct international television broadcasting and telephone dialing, for instance, was differences in national standards. Until these were regularized, full advantage of present possibilities could not be taken. "How would the Danes, who have no "W" on their dials, manage to call a WAlnut exchange in the U.S.?" asks L. W. Wimgert, vice president of AT&T's Long Lines Division.

## Floating satellite surveys land across oceans

Another floating star, actually the Pageos I aluminum-skinned balloon satellite, has joined the Echo series in the heavens. The new balloon, launched into a polar orbit from Vandenberg Air Force Base, Calif., June 23, has a far different mission though.

It will allow scientists to survey points across large bodies of water. The distance between distant points on separate continents can be measured with a trangulation technique between at least three ground stations and the balloon. This will assist map-makers and ICBM-aimers. Pageos' orbit is about 2600 miles high, and it glows as brightly as the North Star.

# A BRUTE

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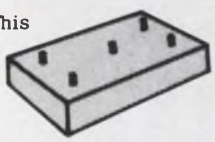
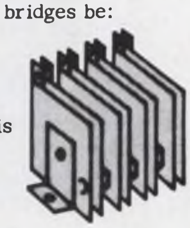
### CASE HISTORY

Bob has the job of designing power supplies for his company, an electronic equipment manufacturer. Requirements vary considerably from one piece of equipment to the next, with ratings all the way from 1 to 10 amps in both single and three phase configurations. He had a dilemma--what should the physical arrangement of his bridges be:

This

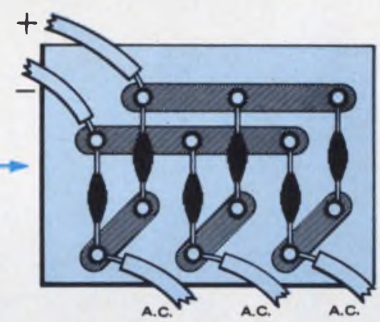


or this



Both were bulky, and--worse yet--each was a custom design requiring long vendor lead times, not to mention the expense. One day, a Compar salesman suggested that if Bob used Unitrode UT 4000 series diodes, he could make his own bridges with only this comparative space required...

...TO GET 10 AMPS AT 500 VOLTS without additional heat sinking.




Space and lead time were both saved. In addition, Bob's production department could produce the bridges using individual diodes for far less than vendors were charging for special bridge assemblies ...and the work stayed in-house.

Also Bob could supplement his small laboratory stock by drawing on Compar's substantial inventory of Unitrode semi-conductors. No more weeks of waiting. Now he could instantaneously breadboard any bridge he needed.

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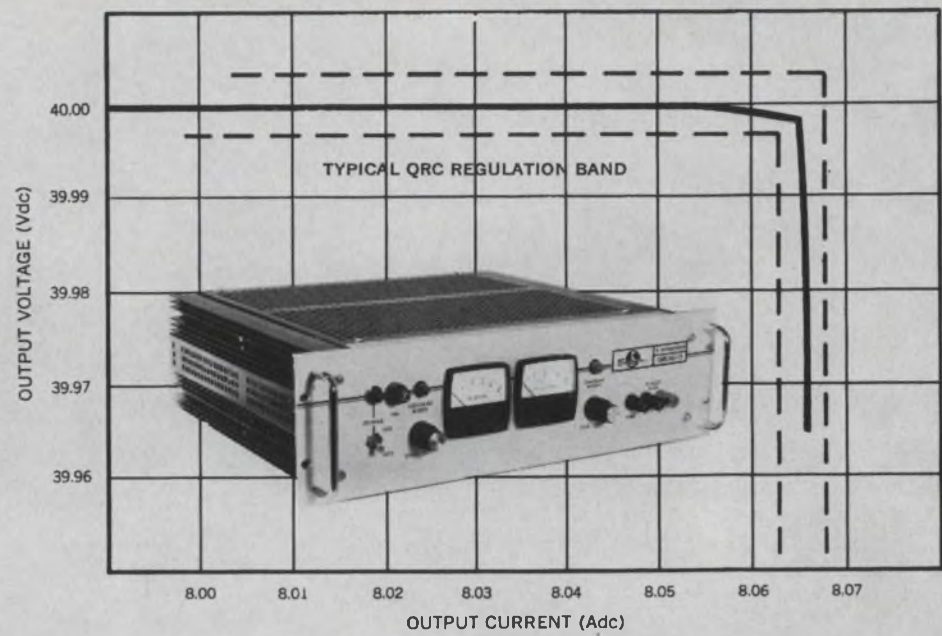


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|---|---|---|---|---|---|---|---|---|
| QRC20-08A | 0-20 | 0-8 | ± .005% or ± 1 mv | 1 mv | ± .05% or ± 4 ma | 1 ma | 3½ | $410.00 |
| QRC20-15A | 0-20 | 0-15 | ± .005% or ± 1 mv | 1 mv | ± .05% or ± 8 ma | 2 ma | 5¼ | 525.00 |
| QRC20-30A | 0-20 | 0-30 | ± .005% or ± 1 mv | 1 mv | ± .05% or ± 16 ma | 4 ma | 7 | 700.00 |
| QRC40-4A | 0-40 | 0-4 | ± .005% or ± 1 mv | 1 mv | ± .05% or ± 3 ma | 1 ma | 5 † | 315.00 |
| QRC40-8A | 0-40 | 0-8 | ± .005% or ± 1 mv | 1 mv | ± .05% or ± 4 ma | 1 ma | 3½ | 450.00 |
| QRC40-15A | 0-40 | 0-15 | ± .005% or ± 1 mv | 1 mv | ± .05% or ± 8 ma | 2 ma | 5¼ | 575.00 |
| QRC40-30A | 0-40 | 0-30 | ± .005% or ± 1 mv | 1 mv | ± .05% or ± 16 ma | 4 ma | 7 | 775.00 |

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# Interest renewed in thermionic converters

## Army is developing 3-kW devices for field use. Nuclear-fuel 200-W converters are also under test.

**Howard Bierman**
Editor

Renewed efforts to evolve thermionic diodes for direct conversion of heat into electricity are in progress now that heat-coupling and material problems appear to have been overcome. The Army is developing a compact 3-kW generator and NASA is proving the feasibility of a 200-watt nuclear-fueled thermionic converter for space service.

Key to the new interest in thermionic devices is the heat-pipe design concept, originated at the Los Alamos Scientific Laboratory. Basically, the heat pipe is a long, evacuated enclosure containing a capillary structure along its inside walls. The capillaries are filled with a fluid that has substantial vapor pressure at the desired operating temperature. When heat is applied to the input end of the pipe, some fluid is evaporated and transferred by pressure differential to the output end where it condenses and releases its heat of vaporization. The condensed fluid then returns to the evaporator through the wick by capillary action. Since operation of the heat pipe does not depend on gravity, the device can operate in the weightless environment of outer space And because the heat pipe requires only a slight temperature difference for condensation (about 1° C), it may be considered a constant-temperature device with little or no thermal loss.

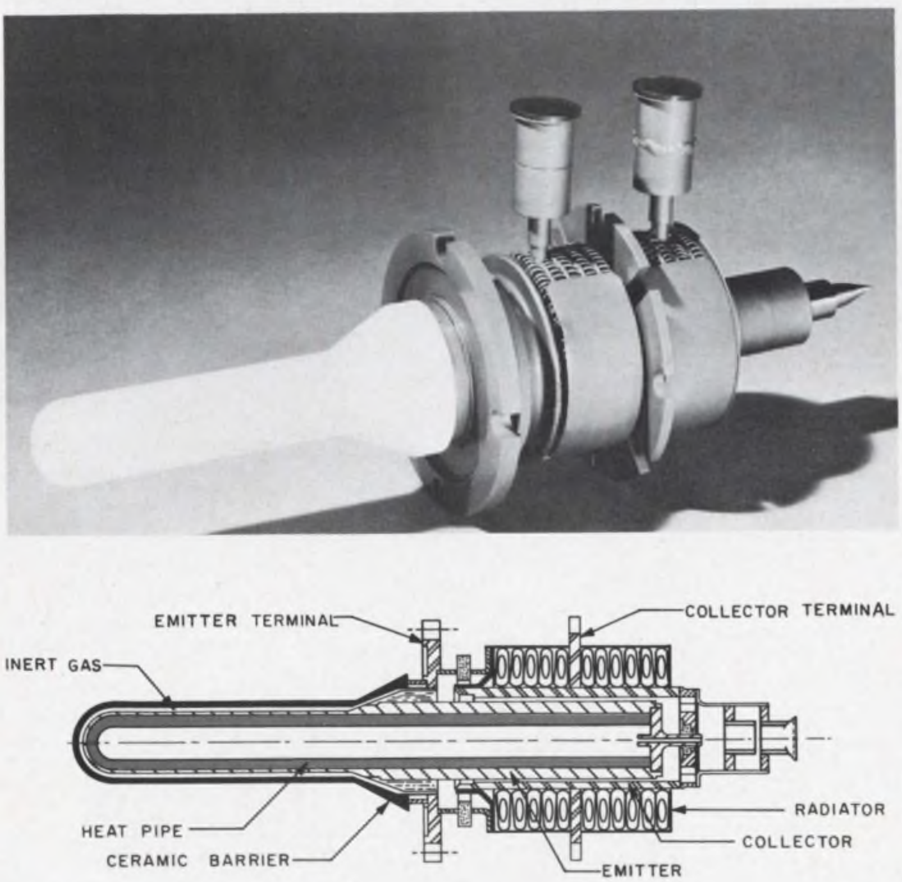
A heat source and a thermionic diode with dissimilar power-density characteristics can be matched with the heat pipe by adjusting the heat input and output areas. For example, a burner producing 15 watts per square centimeter at maximum efficiency can be matched to a thermionic converter requiring an input of 30 watts per square centimeter if the input area is designed to be double the output area.

### 3-kW generator being developed

A 3-kW hydrocarbon-fueled thermionic supply, comprising 36 individual converters, represents the most ambitious program to date. Under development by RCA and the U.S. Army Engineering R&D Labs., the 150-pound generator will be packaged in three 1-kW building blocks; each module will house 12 diodes delivering 4 volts dc to a solid-state power conditioner, which will provide 28 volts dc or ac at either 50-60 Hz or 400 Hz. Between six and seven per cent over-all efficiency is anticipated for the 3-kW generator, according to G. Y. Eastman, RCA project manager.

The molybdenum-alloy heat pipe (see Fig. 1) uses lithium as the heat-transfer fluid to couple thermal energy from the burner to the emitter of each thermionic diode. The capillary structure is a wick formed of several wraps of woven molybdenum mesh. The nine-inch-long heat pipe, less than 0.75 inch in diameter, will sustain a heat flow exceeding 1000 thermal watts at 1350°C with less than 1°C temperature difference. The effective thermal conductivity achieved by this approach would be more than 8000 times that of an equivalent copper bar, if copper were useful at this temperature, Eastman reported.

The cylindrical thermionic converter is mounted at the heat-delivery end of the heat pipe. Waste heat from the collector is rejected with




1. **This thermionic-converter design uses a molybdenum-alloy heat pipe to concentrate heat** from the flame-heated burner to the converter emitter. Thirty-six of these diodes, built by RCA, will be combined to develop a 3-kW generator for Army field use.

(**converters,** *continued*)

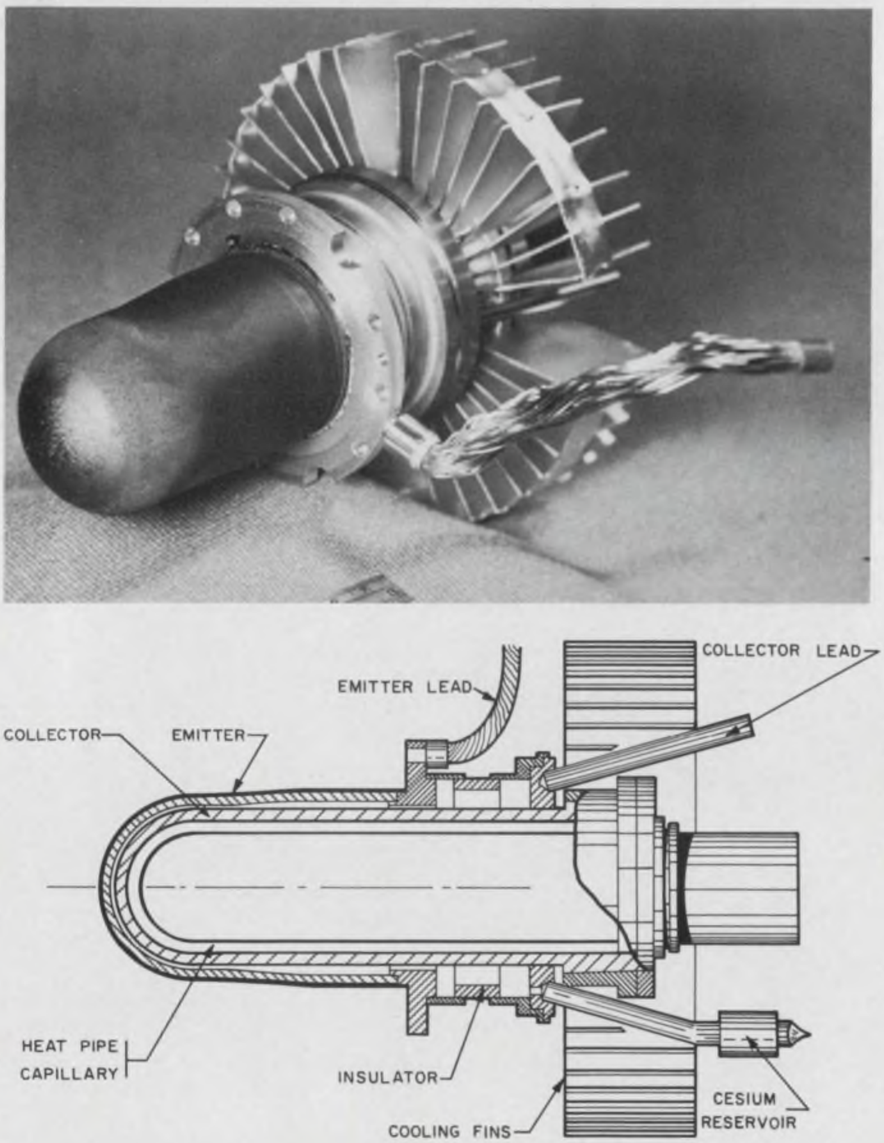
the aid of a cooling blower. The converter-heat-pipe assembly is expected to provide 100 watts at an efficiency of 13 per cent; to date, a maximum of 86.5 watts has been achieved with a flame-heat source.

The Army is investigating the compact generator—each 1-kW module occupies only 1.3 cubic feet—for applications in the field.

## Bonded shell-emitter is durable

Another approach embodying the heat-pipe-thermionic-converter combination has a nickel structure and uses potassium as the working fluid to transfer heat from the diode collector to a finned structure where heat can be rejected by convection. With this, auxiliary cooling devices are unnecessary. The emitter (the hemispherical end of the diode shown in Fig. 2) is coated with silicon carbide for protection against the combustion products of the flame. The bonded shell-emitter, according to L. J. Lazaridis, manager of Hydrocarbon Thermionics, Thermo Electron Engineering Corp., Waltham, Mass., makes it possible to construct a practical and usable flame-heated thermionic converter that combines durability with a capacity for extensive cycling.

The principal parts of the converter are the emitter shell, an insulating assembly, the collector and the collector cooling fins. Using a tungsten emitter and nickel collector with a spacing of 0.01 inch, the thermionic diode is designed to deliver 100 watts when operating at 1400°C. Heat is rejected by convection from its main body and the finned structure.




2. **In this thermionic converter, a heat pipe conveys the heat** rejected by the collector to external cooling fins. Designed by Thermo Electron Engineering Co., the device will deliver 100 watts when the hemispherical end is placed in a 1400°C flame-heated burner.

## Nuclear devices have space use

Many problems involved with matching isotope sources to thermionic diodes have been solved by the heat-pipe concept, according to B. I. Leefer of NASA. At the high temperatures involved (1400°C), material problems ensue if the isotope and converters are joined; heat-transfer problems result if they are separated. For space applications, he explained, many isotope fuels have power densities too low to operate thermionic diodes; other isotopes have decay half-lives much shorter than required for practical mission durations. The heat pipe now permits the use of low power-density isotopes for relatively long space missions.

An experimental converter has been developed by RCA and NASA with electrode materials and structural members made of vacuum arc-cast molybdenum. The heat pipe is made of a molybdenum alloy, TzM, and the capillary structure consists of a molybdenum mesh; lithium is the working fluid.

Using computer-aided design, the device has been optimized for maximum efficiency—rather than maximum power—to obtain the highest system power-to-weight ratio. The design will have the converter supply about 185 watts at 1450°C with 16.5 per cent efficiency. If maximum power output is the prime objective, the design shows that 225 watts could be delivered at an efficiency of 13 per cent. Three converters have been built and early test results indicate that the required output power and performance characteristics are being met.

Advances in fuel cells, primary and secondary batteries and solar cells were discussed at the Power Sources Conference held May 24-26 in Atlantic City, N. J. The Proceedings will be available in October and copies may be ordered, at $15 each, from the PSC Publications Committee, P. O. Box 891, Red Bank, N. J. 07701. ■ ■

# Phased Arrays Break the Inertia Barrier

## Computer, ferrite and semiconductor technology contribute to new era of radar design.

**Neil Sclater**
East Coast Editor

New procurement of electronically scanned radars has hastened the merger of radar with computer and semiconductor technology. The phased-array antenna, in existence for more than 20 years, has received new emphasis because of military and space demands. Development of this antenna concept is accelerating because of the impact on radar of computers, microcircuitry, semiconductors, and ferrite technology.

Improvements in the effectiveness of these complex antennas and reductions in cost and weight resulting from the merger are making them feasible for all types of radar.

The full theoretical possibilities of microwave physics can now be brought to bear on the problems of detecting and identifying large numbers of aircraft, satellites and even ICBMs. Microsecond reaction time is especially critical in the case of ballistic missiles.

Integrated circuitry, semiconductors, ferrites and computers, used to some extent in conventional radars with rotating or oscillating antennas, have made the striking improvements in phased-array performance possible. The benefits of this merger are just as apparent in new concepts for airborne radar and satellite communication systems as they are in existing large ground-based or shipboard systems.

The theories of electronic beam scanning have been well-known for many years, but it required a combination of factors, some technical and some economic, to set off the current wave of activity. The primary cause was the inability of conventional, mechanically scanned radar to collect and handle data at the required rate to deal simultaneously with many high-velocity aircraft, ballistic missiles and satellites.

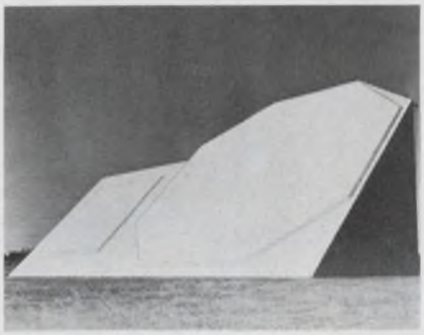
Many farsighted engineers, both in industry and government, had long seen the advantages of electronic scanning but were frustrated by the lack of funding and the inability of the radar engineer to take advantage of the results of computer techniques. While radar technology dawdled in doldrums some years ago because of the lack of funding for new programs, computers and their allied technology were leaping forward. When the need existed and the funds became available, the merger took place.

### The phaser seesaw

Significant in the future of phased-array antenna designs is the current research and development controversy between ferrite and diode phase shifters. These components steer the RF beam and direct return signals on computer command. Better comprehension of basic theory and vast improvements in ferrite and diode materials have led to phasers covering most of the microwave spectrum with low losses. Unfortunately, neither ferrite nor diode types can cover all the frequency bands with equal effectiveness.

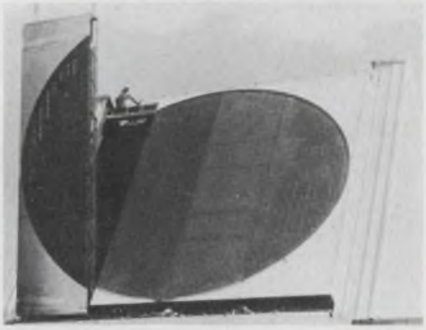
Phase shifters can be reciprocal or nonreciprocal, analog or digital, and ferrite or diode. For modern arrays, the reciprocal digital type is preferred. Analog devices produce phase shifts proportional to an applied voltage or current while digital devices produce shifts in binary increments. These shifts, generally including 180°, 90°, 45° and 22-1/2°, can be programed in digital computer format. The computer selects the appropriate combinations of increments required for beam steering. Because they have two stable states, the switching action is referred to as latching.

The most popular phasers are yttrium-iron-garnet ferrites and pin-type semiconductor diodes. Ferrites can be used in both reciprocal and non-reciprocal shifters of either analog or digital varieties. However, diodes so far have been of the recip-



**Space Track Radar** AN/FPS-85, the first phased-array space surveillance system, uses many power tubes with separate transmit array (left). Receive array (right) is over 140 ft high.

**Multi Function Array Radar,** MAR is prototype for systems to direct Nike-X. MAR will benefit from R&D efforts to assure maximum capability and reliability at reasonable cost.



**HAPDAR** phased-array radar shown during final assembly. Its 30-ft. dia. planar lens, illuminated by a single power tube, has successfully tracked reentry vehicles.

rocal digital type.

Diode devices which work best at the lower frequency bands are considered to be limited in their ability to perform without undue losses at frequencies much higher than 5 GHz (C-band). Ferrite phase shifters, on the other hand, dominate in higher frequencies because of their low magnetic losses. However, they present an unresolved weight problem.

Regardless of their handicaps and power or frequency capability, each version has its own advocates. Carl Blake, an antenna scientist at MIT's Lincoln Laboratory, favors the ferrite phase shifters and believes that ferrite thin films will meet the weight problem raised in connection with their use in aircraft or satellites. In his view, diodes and ferrites rate about even in power-handling ability and insertion losses at S-band, but ferrites are superior in performance at C-band and higher frequencies.

Another advocate of ferrite phase shifters, Julian Brown, an engineering section head at Sperry's Clearwater, Fla, Microwave Division, stresses high-power, long-range arrays (see ED 14, June 7, 1966, pp. 34-38).

Sperry Gyroscope's Gerard Hanley, a research section head and diode man, is optimistic about the diodes' future. He predicts that they will be developed with cutoff frequencies approaching 1000 MHz for use in low-loss phase shifters operating at frequencies up to 16 GHz (see ED 13, May 24, 1966, pp. 46-52).

Progress is being made on reciprocal shifters, especially necessary in reflecting arrays. Dr. Lawrence Whicker, engaged in ferrite development at Westinghouse's Baltimore Defense and Space Center, says, however, that results so far lag behind those of nonreciprocal devices by four to five years.

There is general agreement among all phaser specialists that the see-saw contest will last well into the 1970's but that both types have their place in systems depending upon the mission.

### Where the phased arrays are

Major contractors participating in phased-array programs are General Electric, Hughes, ITT Gilfillan, Raytheon, Western Electric, West-

(**phased arrays,** *continued*)
inghouse, Bendix and Sperry.

Despite security wraps, enough information on two significant large-scale projects is available to permit a view of trends.

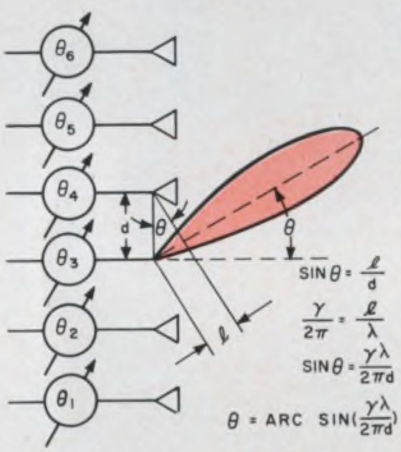
The Space Track Radar, AN/FPS 85, built by Bendix under sponsorship of the Air Force's ESD and RADC, is the first space surveillance system. Located at Eglin, Fla., the site was recently rebuilt after a destructive fire. It is designed to track and catalog accurately all orbiting satellites. Known satellites can be identified from new satellites and the presence of ICBMs can be determined.

The system's computer will use a series of tracking data points to determine the orbit or trajectory of targets. Many low-power, identical RF generators, rather than one large RF power source, will form the transit beam. The receive array, separate from the transmit array, has many redundant receiver modules.

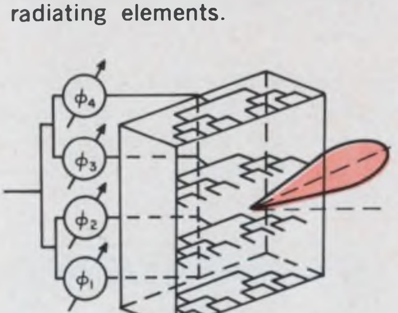
Henry Dantzig, Bendix senior engineer, says that this design offers higher reliability than is possible with other radars because failure of individual power amplifiers or receiver modules will have little effect

## Basic Electronic Scanning Concepts

Three basic techniques exist for electronically scanning an electromagnetic beam: phase, frequency and feed. In phase scanning, the most popular, the beam is positioned by varying the phase of the energy fed to the separate elements of an array (Fig. 1). Feeding a number of radiating elements equally spaced along a straight line with in-phase currents yields a broadside beam. The beam direction is an arc sine function of the interelement phase shift. For one-dimensional pencil beam scanning, the beam is focused in the unscanned dimension by a reflector or by radiating elements supplied from the phasing network (Fig. 2). Two-dimensional scanning can be obtained by various combinations and modifications of one-dimensional scanning. One important type (Fig. 3a) employs a lens having a cellular structure with a ferrite or diode digital R-F phase shifter in each cell. This scanning method is obtained by combining the phase increment associated with the vertical and horizontal beam-positioning in each module.




1. **Phase scanning** occurs at a constant frequency. Beam direction is determined by phase shift between radiating elements.




2. **Pencil beam** obtained with planar array is provided by vertical and horizontal feeds.

### Feeding the antenna

Various methods are used to divide and feed R-F power to phase shifters. Typically, the feed network is bilateral so that received energy is combined and sent to the receiver with the same network. Two basic categories are the confined feed and the space or optical feed.

In confined feed, RF power is contained within a waveguide, coaxial cable, or a strip line. Corporate feed, shown in Fig. 2, is the most widely used example.

In space feed, the RF power is radiated from a horn with the division of energy following the inverse square law. Dispersed energy must be collected again at each element, sent to the element phase shifter, and then radiated.

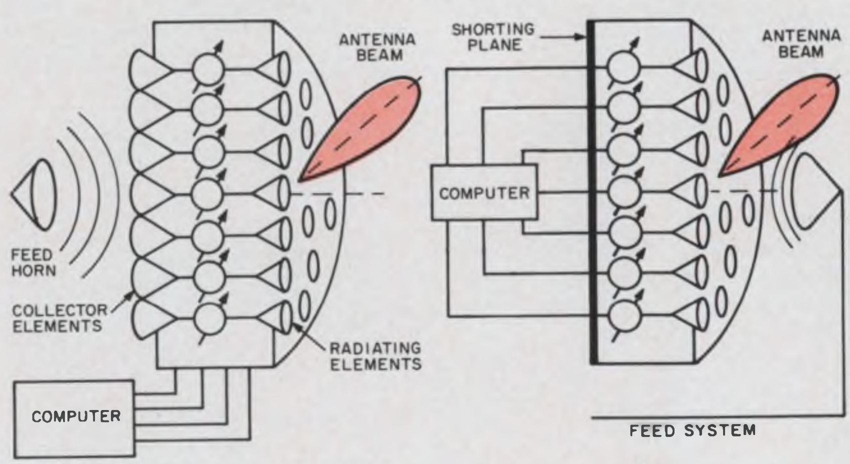
Lens and the reflector feeds are shown in Fig. 3. The lens can use reciprocal or nonreciprocal phase shifters. Reflecting arrays must use reciprocal types.

### Tapering the beam

Phased arrays make better tapering of the illumination pattern possible to reduce side lobes because radiating elements can be individually controlled. Both amplitude and space taper may be used.

**Acknowledgement:**

A detailed discussion of these different arrays was covered in the *Sperry Engineering Review, Winter 1965.*

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3. **Optical feed systems**. A lens array is shown in (a) and a reflector array is depicted in (b). These arrays eliminate need for power-distribution networks. Array phase shifters are computer controlled.

on system performance.

Sperry's hard-point demonstration array radar, HAPDAR, uses a different design approach. A planar optical array, it produces a pencil beam in two dimensions. The system employes one RF power source and a passive diode phase-shifting network in a novel antenna design. Now operating at the U.S. Army Missile Command's White Sands, N.M., range, HAPDAR is being used to evaluate designs for high-performance, low-cost, phased arrays. This information is vital in planning large-scale hardened anti-missile radar sites.

A Univac 1218 digital computer controls the diode phase-shifting network and gives HAPDAR its rapid scanning and multiple-target acquisition and tracking capability. In addition, it provides data-recording, self-test, and simulation functions.

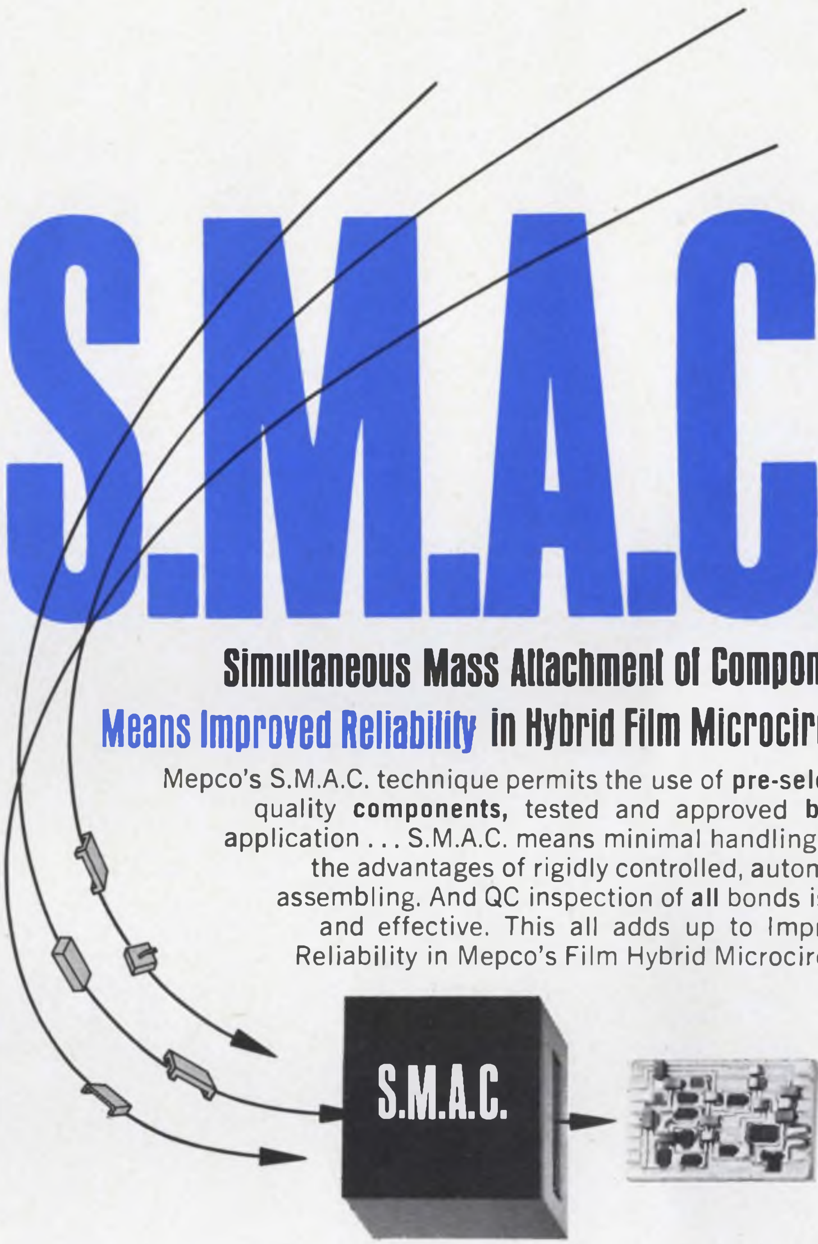
Peter Kahrilas, HAPDAR engineering manager, reports that the system has already successfully acquired and tracked numerous Agena re-entry vehicles at the White Sands Range.

### Arrays with wings

Airborne phased arrays so far are in the design concept and prototype-model stage, according to Ed Shubel, an antenna engineer at Maxson Electronics Corp. This, he said, is due to problems of weight, complexity and cost effectiveness. In Mr. Shubel's opinion, use of micro-circuitry can make phased arrays serious competitors of the airborne mechanical dish. Future systems can perform the functions of at least two conventional aircraft radars.

### Arrays from blocks

Texas Instruments reports that it is building microminiature modules containing solid-state RF power sources and receive and phase-shift functions. The design goal is to produce modules which are essentially miniature radar sets. These can be combined to form a phased-array system. At X-band, for example, the modules must be smaller than one cubic inch because of the geometry associated with maximum scan angle. Integrated circuit techniques, according to the TI report, offer the only realistic method of achieving this goal. ■ ■



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MC931F, MC831F
MC931G, MC831G
MC945F, MC845F
MC945G, MC845G
MC948F, MC848F
MC948G, MC848G

**GATE EXPANDERS**
MC933F, MC833F
MC933G, MC833G

**MULTIPLE GATES**
DUAL 2-3 INPUT "NAND/NOR" GATES
MC930G, MC830G
DUAL 2-3 INPUT POWER GATES
MC944G, MC844G
DUAL 4-INPUT "NAND/NOR" GATES
MC930F, MC830F
DUAL 4-INPUT POWER GATES
MC944F, MC844F
TRIPLE 3-INPUT "NAND/NOR" GATES
MC962F, MC862F
TRIPLE 1-2-2- "NAND/NOR" GATES
MC962G, MC862G
QUAD 2-INPUT "NAND/NOR" GATES
MC946F, MC846F
QUAD INVERTER
MC946G, MC846G

**DUAL BUFFERS**
MC932F, MC832F
MC932G, MC832G

Suffix "F" denote Flat Package   Suffix "G" denotes Can

ON READER-SERVICE CARD CIRCLE 122

# MRTL*

**MC900 SERIES • MC800 SERIES**
**MC700 SERIES • MC908 SERIES**

*Performance Ratings (typ)*

| | MRTL | mW MRTL |
|---|---|---|
| • Propagation Delay (Gates) | 12 nsec | 25 nsec |
| • Power Dissipation/Node | 12 mW | 2.5 mW |
| • Toggle Frequency | 8 MHz (min) | 3 MHz (min) |
| • Fan-Out | 5 (min) | 4 (min) |
| • Supply Voltage | 3 V ± 10% | 3 V ± 10% |

- Temperature Range
  - MC900, MC908 Series — −55°C to +125°C
  - MC800 Series — 0°C to +100°C
  - MC700, MC708 Series — +15°C to +55°C*

*Supply Voltage 3.6 V ± 10%

**FLIP-FLOPS**
MC902G, MC802G, MC702G
MC916G, MC816G, MC723G
MC926G, MC826G, MC726G

**LOGIC GATES**
3-INPUT GATES
MC903G, MC803G, MC703G
4-INPUT GATES
MC907G, MC807G, MC707G
5-INPUT GATES
MC929G, MC829G, MC729G
DUAL 2-INPUT GATES
MC914G, MC814G, MC714G
DUAL 3-INPUT GATES
MC915G, MC815G, MC715G
QUAD INVERTER
MC927G, MC827G, MC727G

**HALF ADDERS†**
MC904G, MC804G, MC704G

**BUFFERS†**
MC900G, MC800G, MC700G

**DUAL BUFFERS**
MC999G, MC899G, MC799G

**COUNTER ADAPTERS**
MC901G, MC801G, MC701G

**HALF-SHIFT REGISTERS**
MC905G, MC805G, MC705G
MC906G, MC806G, MC706G

† MC908 Series — also includes Gate Expander and Adder Circuits

ON READER-SERVICE CARD CIRCLE 123

**MOTOROLA Semiconductors**

*—where the priceless ingredient is care!*

Speed Inquiry to Advertiser via Collect Night Letter

# Prototype shirt-pocket TV set demonstrated

In the near future, millions of teen-agers may be walking about with a tiny TV set tucked in their shirt pocket. Such a possibility was envisioned by the Advanced Engineering Laboratory of Motorola's Consumer Products Division during the June 13-14 Broadcast and TV Receiver Conference in Chicago.

The 29-transistor, 14-diode receiver (see Fig. 1) was designed and built in 1964 and so does not include integrated circuits. Weighing only 12.5 oz. and occupying 13 cubic inches, the tiny prototype, demonstrated during the conference, receives one vhf channel; a miniature multi-section switch could have been included but was considered inessential for the feasibility project. Half the volume is filled by the 1-1/8-inch-diameter, 4-inch-long electrostatic-deflection picture tube; the receiver circuits are packed into a three-layer module taking up a total space of 1.2 cubic inches. Average input power is about 1.5 watts.

Power for the set is provided by four penlight cells which drive a dc-to-dc converter that delivers 11 V, 100 V, 275 V, 1200 V and 3000 V to various sections with no need for dropping resistors. Interference from switching transients in the dc-to-dc converter is reduced to an acceptable level by operation close to the horizontal scanning frequency. The close proximity of the picture tube and batteries make it impossible to locate the converter module in a position where interference would be partially self-canceling.

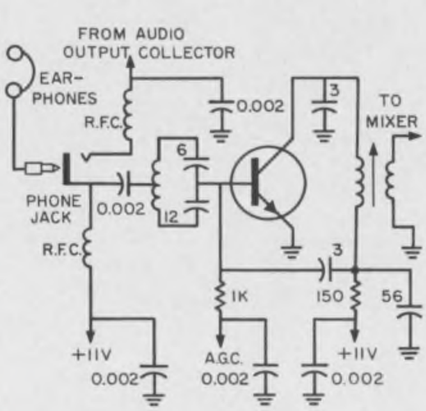
A clever element of the design is the use of the earphone lead as the receiver antenna (see Fig. 2). The RF chokes permit the audio to reach the earphones and prevent the RF signals from shorting to ground. The 0.002-$\mu$F capacitor couples the RF to the input coil while blocking the dc. To obtain sensitivity comparable to present portable sets, the signal chain includes an RF stage, mixer, three IF stages, and a two-stage video amplifier. Reverse agc is used with bias obtained from the first video amplifier rather than the conventional video detector take-off.

The vertical and horizontal outputs are the same—200 volts peak-to-peak—even though the aspect ratio is 3:4. This is because the horizontal deflection plates are closer to the electron gun assembly.

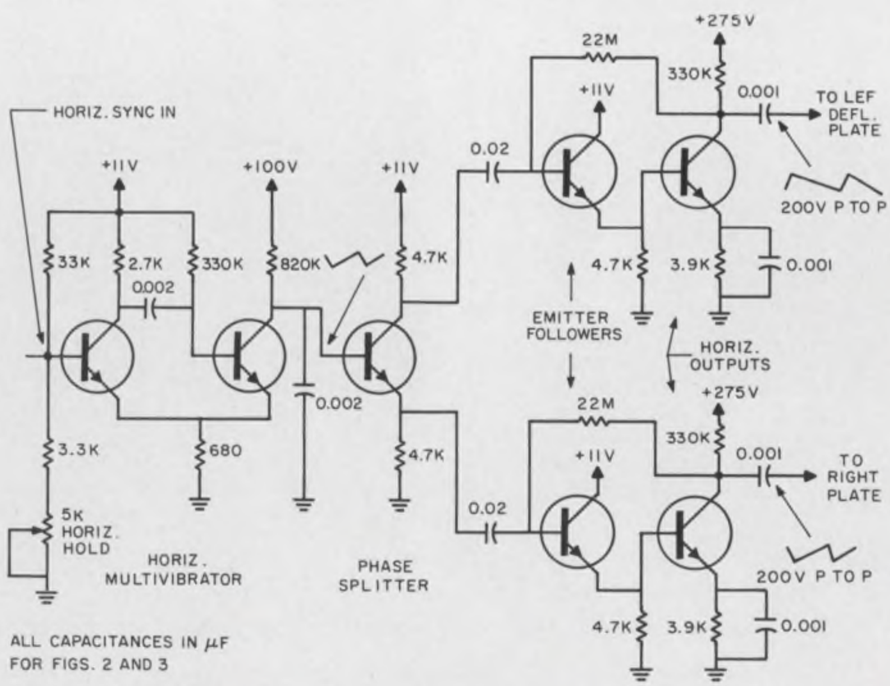
Motorola flatly states that they have no intention at this time of marketing the receiver. Should someone be interested in manufacturing such a set, the following improvements were offered:

- To extend battery lifetime, use a low-heater power picture tube.
- Develop a display tube that would fill the entire front of the set. ■ ■


1. **Motorola's experimental TV set** is powered by four penlight cells.

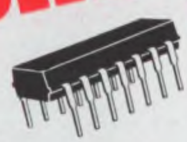



2. **The earphone lead serves as the antenna** in the tiny set. RF chokes prevent RF grounding.




3. **Horizontal deflection for electrostatic deflection** is obtained from an emitter-coupled multivibrator feeding phase shifters which drive push-pull amplifiers.

# Signetics SP600 Monolithic Plug-in DTL Circuits Less than 60¢ Per Gate Function From Your Distributor



"Off the Shelf" DISTRIBUTOR PRICES

**SIGNETICS INTEGRATED CIRCUITS**

A subsidiary of Corning Glass Works
811 East Arques Avenue, Sunnyvale, California
Tel.: (408) 739-7700 TWX: (910) 339-9220

| Type | | 1000-2499 Mixed | 100-999 One Type | 100-999 Mixed | 25-99 Mixed | 1-24 |
|---|---|---|---|---|---|---|
| SP616A | Dual 4-Input NAND/NOR | 2.35 | 2.45 | 2.60 | 2.95 | 3.70 |
| SP620A | J-K Binary Element | 2.65 | 2.80 | 2.95 | 3.35 | 4.20 |
| SP629A | RS/T Binary Element | 2.65 | 2.80 | 2.95 | 3.35 | 4.20 |
| SP631A | Quad-2 Gate Expander | 2.35 | 2.45 | 2.60 | 2.95 | 3.70 |
| SP659A | Dual 4-Input Driver | 2.65 | 2.80 | 2.95 | 3.35 | 4.20 |
| SP670A | Triple 3-Input NAND/NOR | 2.35 | 2.45 | 2.60 | 2.95 | 3.70 |
| SP680A | Quad 2-Input NAND/NOR | 2.35 | 2.45 | 2.60 | 2.95 | 3.70 |

ON READER-SERVICE CARD CIRCLE 12

# Low-cost hearing aid protects aircraft

A simple, budget-priced airborne listening system will soon be saving lives and costly aircraft in Viet Nam. Sniper fire from concealed Viet Cong, always a serious risk, is even more of a menace when an aircrew is unaware that it is being fired upon. The noise of the engines masks the sound of gunfire and the flight crew often knows that its craft is a target only after bullet holes appear or, worse yet, vital systems are damaged or casualties sustained. The new listening device will permit pilots to take evasive action, and to some degree even locate their attackers.

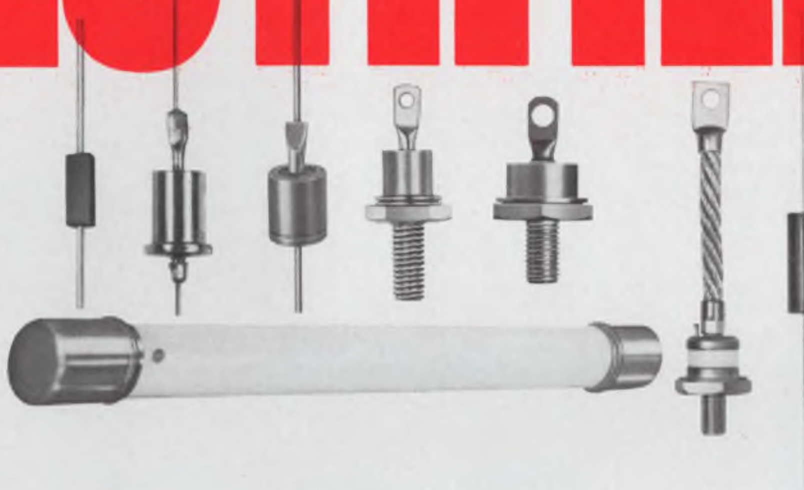
Basic parts of the system are dual microphones located on opposite sides of a drop-shaped nacelle below the fuselage, an acoustic filter and a solid-state amplifier. The filter eliminates fundamental engine and propeller or rotor noise and the amplifier raises the received sound of gunshots. The output of the hearing device is fed directly to the pilot's communication headset. A stereo effect, due to the positioning of the listening microphones, makes it possible for the pilot to determine the approximate position of the sniper.

### Proven components used

A development of the Air Force Cambridge Research Laboratories, Bedford, Mass., the hearing aid is the essence of simplicity. The components are all readily available, relatively inexpensive and of proven reliability. The electronic components of the system can be packaged into about 10 cubic inches and the complete installation in production quantities will cost approximately $100.

Prototype models of the "aerophone" have been jointly tested by Air Force and Army electronics engineers at Eglin, Fla., and at Fort Devens and Camp Edwards in Massachusetts. Pilots experienced in flying over combat zones have proved the system's effectiveness in tests performed on the H-13 helicopter, the C-47 and other light observation-type aircraft. ■ ■

# RECTIFIERS



# IRC expands rectifier line

## Wide choice of MIL and industrial devices

Now, IRC is offering an even larger selection of silicon rectifiers. These devices are immediately available from stock to fill the vast majority of your MIL and industrial requirements. Most IRC rectifiers are also available in reverse polarity.

- Ratings from .045 to 250 amps, and 50 volts to 100 Kv
- MIL types meet all performance and environmental requirements of MIL-S-19500
- Subminiature, high-voltage types to 4000 volts
- 100 and 250 amp controlled avalanche units for industrial use
- Fast recovery types—200 nsec—in five package choices

If you specify or buy silicon rectifiers, you should know about the money-saving advantages of IRC's silicon rectifier line. For new semiconductor catalog, prices and samples, write: IRC, Inc., Semiconductor Division (formerly North American Electronics), 71 Linden St., West Lynn, Massachusetts 01905.

**ZENER DIODES**

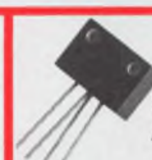
MIL and industrial regulator types, silicon reference diodes, 1-watt DO-7, and solid construction Poly-Sil packaging.

**AXIAL LEAD RECTIFIERS**

AR16 thru AR24 replaces 363 JEDEC devices for 50 to 1000 V/.25 to 1A needs. Costs less than stud-mounted types.

**SCR's**

MIL and industrial devices, including fast-switching types. Choice of power ratings and package shapes.



**SPECIAL ASSEMBLIES**

Rectifier stacks, potted bridges and high voltage assemblies. Available in prototype or production quantities.

IRC®

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ON READER-SERVICE CARD CIRCLE 14

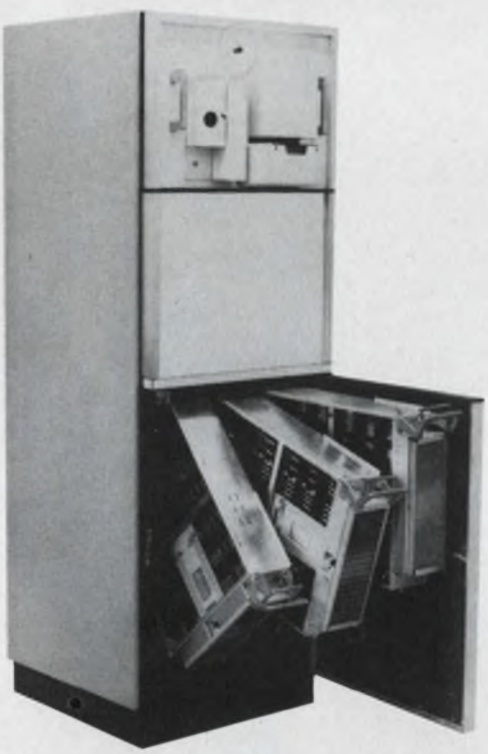
## ONLY 3C OFFERS...

# A CHOICE OF 1 μSEC I/C CORE MEMORIES WITH 4K TO 32K WORDS IN 5¼" UNITS


Standard ICM-40 mounts horizontally, provides ¼ million bits of economical high speed storage in a single compact 5¼" high unit which pulls out, swings, and tilts for easy access.

1 μsec cycle time, 500 nsec access time — capacities from 4K x 4 bits to 32K x 84 bits. Extensive features of ICM-40† Core Memories include proven I/C reliability, adjustment-free operation, and compact packaging with unique ready access to all components.

ICM-40's are designed and built for critical computer level speeds and reliability at minimal user cost. All logic, addressing, decoding, control, line driving, and sensing functions utilize 3C μ-PAC integrated circuit logic modules. (Discrete active components employed only in the core stack selection switch.) All modules are interchangeable; tuning is accomplished by adjusting power supply voltage only. ICM-40's interface comfortably with both discrete component and integrated circuit systems.



Shown: 1½ million bits (98K words) of core memory. Standard 5¼" ICM-40 mounts vertically in standard 19" x 24" cabinet. Memory module swings out, tilts for easy access to module side or wired side of hardware.

## SPECIFICATIONS

| | |
|---|---|
| **Capacity*** (in a single 5¼" high unit) | 4096 words x 4 – 28 bits<br>8192 words x 4 – 28 bits<br>16,384 words x 4 – 28 bits<br>32,768 words x 4 – 14 bits |
| **Speed** | 1.0 μsec for Clear/Write and Read/Regenerate<br>1.25 μsecs for Read/Modify/Write |
| **Access** | <0.5 μsec |
| **Input logic levels** (other input logic levels on request) | ZERO: 0.0 volts to +1.0 volt<br>ONE: +3.0 volts to +6.5 volts |
| **Output logic levels** (other output logic levels on request) | ZERO: 0.0 volts to +0.4 volt<br>ONE: +4.0 volts to +6.5 volts |
| **Power** | 115 or 230 volts (±15%), 50 or 60 cps (±1 cps) |
| **Weight** | <55 pounds |
| **Environment** | Operating temperature: 0° to 50°C<br>Non-operating temperature: −25° to +80°C<br>Humidity: 95% without condensation<br>Shock and vibration: normal shipping conditions |

†Patent Applied For

*NOTE: System word capacity and bit length can be increased by combining several ICM-40's in a single cabinet.

**Honeywell**

3C COMPUTER CONTROL DIVISION

OLD CONNECTICUT PATH, FRAMINGHAM, MASSACHUSETTS

Speed Inquiry to Advertiser via Collect Night Letter
ON READER-SERVICE CARD CIRCLE 15

# Washington Report

S. DAVID PURSGLOVE,
WASHINGTON EDITOR

## High-speed trains pick up steam

The research-and-development end of the Commerce Department's high-speed ground transportation (HSGT) program has been boosted by the award of a $71,129 R&D contract to Garrett Airesearch Manufacturing Division, Los Angeles. Under its terms Garrett will investigate the possibility of using a linear induction motor to power future high-speed trains. (See also this column in ED 5, Mar. 1) The new contract follows hard on the heels of one awarded to Melpar, Inc., Falls Church, Va., to instrument the high-speed test cars that will begin operating late this summer over the Pennsylvania Railroad's tracks between Trenton and New Brunswich, N. J.

The department is also about to sign contracts for the upgrading of the track to be used for the tests and for the operation of the test cars. Over $950,000 will be spent on the latter; the test track will cost $1.6 million, and the instrumentation and test contract is valued at $1.1 million. Another $2 million in R&D contracts have already been earmarked. And Robert A. Nelson, director of the HDGT Office, has an additional $3 million for R&D in hand, which he says plans have already been made to spend.

In announcing the 12-month Garrett contract the Commerce Department stated only that the project would include "theoretical studies." However, HSGT officials have declared earlier that a contract would include detailed analysis of force-speed, force-weight, efficiency and power-factor characteristics, with both magnetic and nonmagnetic conductors. It would also involve a design study of various motors to evaluate such quantities as pole pitch, slots per pole, stator copper and iron configurations and the rotor conductor configurations. Both multi-fixed-frequency and continuously-variable-frequency power supplies are expected to come under study. Several methods of speed control for different types of vehicles will likely be investigated.

Commerce Under Secretary for Transportation Alan S. Boyd did announce, however, that if Garrett's theoretical studies prove out, "we may authorize development and testing of scale-model motors." Boyd went along with the department's technicians who favor linear induction motors if practicable. They cite such advantages over conventional motors as the elimination of bearings, centrifugal stresses, windage and heating. Above all is the consideration that a vehicle powered by a linear induction motor would carry only half the power plant of a conventional locomotive and hence have a greatly reduced dead load.

## Boom in education technology anticipated

Educators and industrialists alike came away from a recent symposium on the application of technology—especially computers—to education, looking forward to a period of rapid growth involving big money and radical new techniques for the education-technology industry.

The educators were represented by the Defense Department and the U.S. Office of Education which jointly sponsored the "Engineering Systems for Education and Training Conference" in co-operation with the National Security Industrial Association. Industry was represented by some 500 intent observers from scores of electronic, aerospace, computer, copying-machine, software-research and publishing firms.

The main reason for the air of optimism was the Office of Education's repeated emphasis that profit-making industry was now eligible for its R&D support. R. Louis Bright, the office's associate commissioner for research, indicated that, while little money could be spent with industry in Fiscal 1967, Fiscal 1968, which starts next July, may see a large part of USOE business that formerly went to universities and nonprofit organizations being switched to industry.

Before passage of the Elementary and Secondary Education Act of 1965, the USOE's external research program consisted by law almost entirely of support for unsolicited proposals from universities and nonprofit organizations. Ever since the bill was passed, little use has been made of its authority to broaden participation; few contracts have gone to industry.

Now the USOE plans to begin entertaining unsolicited proposals from industry; it even plans to ask selected firms to submit proposals for specific projects.

U.S. Commissioner of Education Harold Howe II said: "Recent legislation has made it possible for the office to contract with profitmaking organizations for the conduct of research and development programs. As yet, we have not taken real advantage of this opportunity, but we can identify several areas —job training, for example—where industry has unique capability to contribute to our efforts."

Both Howe and Bright noted that industry would have to take a "total systems" approach to solutions of problems. Hitherto, Bright pointed out, the hardware sold to schools has originally been designed for some other purpose. He commented: "There is little real evidence that a tape recorder designed for commercial recording studios has all of the characteristics necessary for an effective language laboratory, or that an entertainment system such as home TV is equally effective for education; most certainly, computers designed for business data processing are not ideally suited for computerized classrooms."

Howe and Bright also pointed up the need for new approaches to software. Howe said that while local school districts have so far invested $200 million in equipment ranging from overhead projectors to complex electronic gear to supplement the shortage of teachers, there is considerable doubt that adequate software is available to make the hardware effective. For this reason, he said, the hardware has been earning a bad reputation in some places.

Development of both software and hardware, the USOE feels, is being inhibited by the difficulty of pleasing and selling to the 26,000 separate school districts in the nation. USOE may help industry to overcome this through the new network of regional educational laboratories. Couching what they have to say in the most circumspect terms lest they scare any local school district or incur the wrath of a Congressman, Federal education experts say that the fruits of hardware and software R&D will be tried out in the regional laboratories. When satisfied that the new equipment can make a significant contribution in relation to its cost, the laboratories will demonstrate it to encourage local school districts to adopt new techniques and apparatus.

Is the market worth it to industry? Many electronic firms apparently believe it is. Harvard professor J. Sterling Livingston, who is also executive director of the Sterling Institute, listed a few of the companies that have committed themselves heavily to it.

Livingston said that a new "education technology industry" was coming into being as an offshoot of the information technology industry. He went on: "It is being created by the great electronic equipment firms such as General Electric, R.C.A., Raytheon, IBM, General Telephone, I.T.&T., Sylvania and Litton Industries; by reproduction equipment companies such as Xerox and Minnesota Mining; and by communication companies such as Western Union and American Telephone & Telegraph, often in association with publishing firms such as Time Inc., Random House, D. C. Heath, and Wesleyan University Press" (now American Education Publications).

What do these companies have their eye on? Just to start with, there is Title I of the Elementary and Secondary Education Act, which contains a Congressional authorization to disburse more than one billion dollars a year. And the total potential market for these companies is immense: The U.S., one way and another, is already spending $40 billion a year on education.

## Teamsters may go electronic

Teamsters Union president James R. Hoffa has jumped aboard the auto-safety bandwagon. At a little publicized press conference, Hoffa demonstrated the safety devices that he wants the Interstate Commerce Commission to make mandatory on all interstate trucks. The most unconventional was a system that detects when a driver has begun to doze, sounds an alarm and, if necessary, halts the truck.

The device works on the theory that an alert driver moves his steering wheel ever so slightly but almost constantly. When wheel movement ceases, a buzzer sounds. If this fails to awaken the driver, the device—called Drive-a-Lert—gently applies the brakes. It would sell for $35 for the alarm alone; an additional $85 would cover the braking system.

Hoffa's press conference went almost unnoticed, but some time later, hearings on Capitol Hill suddenly brought the selfsame Drive-a-Lert and two other devices that Hoffa called for into the limelight. Shortly thereafter a group of truckers assembled at a short-notice meeting in Washington, but forcibly ejected newsmen from the room. The topic they discussed? Tactics to keep the total $950 worth of equipment out of ICC regulations.

# Planar Power Selection Guide

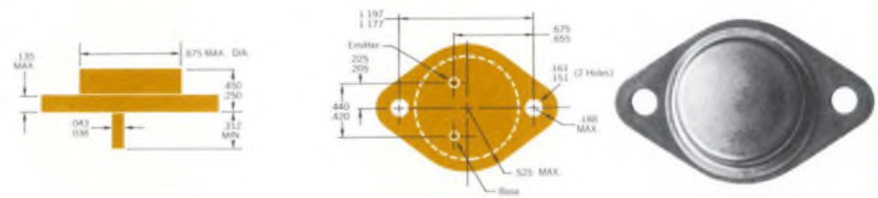
FAIRCHILD SEMICONDUCTOR

# Power Packages

## TO-3

Fig. 1

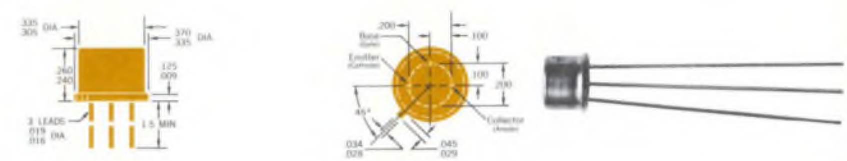
All dimensions in inches
Leads 1 and 2 electrically isolated from case
Case is third electrical connection (Collector)
Leads are nickel-alloy
Package weight is 8.71 grams



## TO-5

Fig. 2

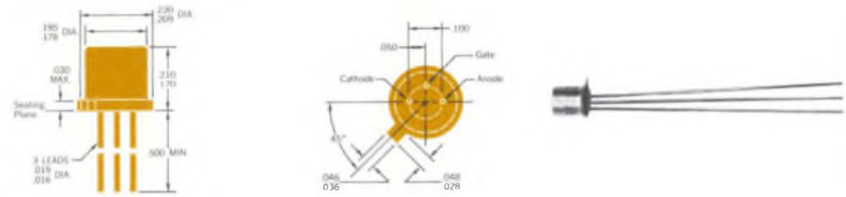
All dimensions in inches
Leads are gold-plated KOVAR*
Collector internally connected to case
Package weight is 1.10 grams



## TO-18

Fig. 3

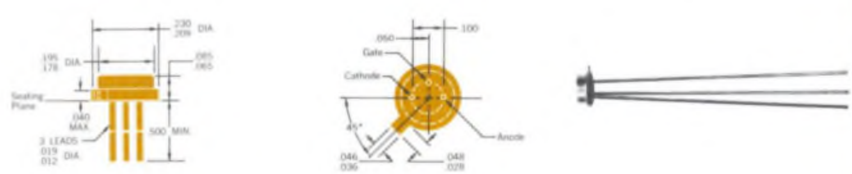
All dimensions in inches
Leads are gold-plated KOVAR*
Collector internally connected to case
Package weight is 0.43 gram



## TO-46

Fig. 4

All dimensions in inches
Leads are gold-plated KOVAR*
Collector internally connected to case
Package weight is 0.36 gram

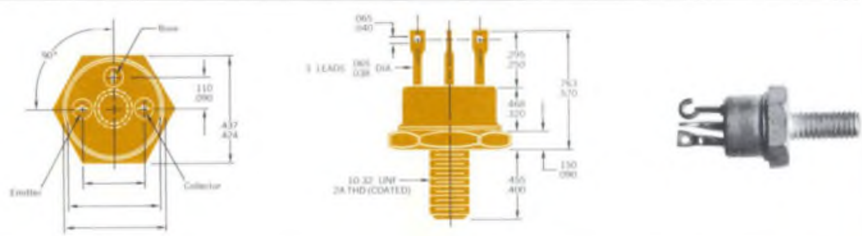


## TO-59

Fig. 5

All dimensions in inches
Collector electrically isolated from case
Package weight is 6.44 grams.

(also available with isolated collector)

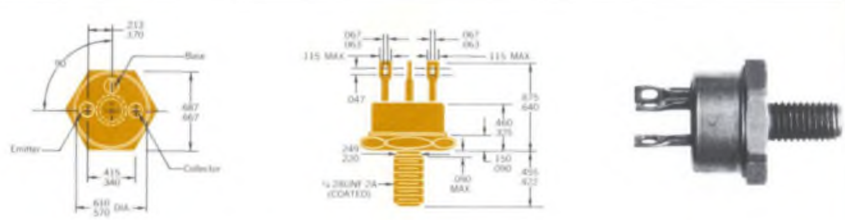


## TO-61

Fig. 6

All dimensions in inches
Stud and header are copper
Cap is KOVAR*
Package weight is 14.1 grams

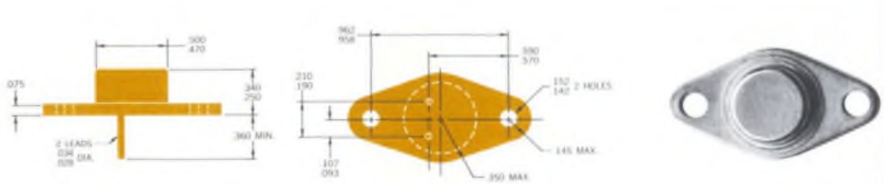
(also available with isolated collector)



## TO-66

Fig. 7

All dimensions in inches
Leads are gold-plated nickel alloy
Identical to "BU" except die mounting
pedestal is copper
Lead 1 and 2 electrically isolated from case
Case is third electrical connection
Package weight is 6.192 grams



*KOVAR is a trademark of Westinghouse Electric Corporation

# Silicon Controlled Rectifiers

FAIRCHILD SEMICONDUCTOR

| | Package: | | $V_{FX}$ & $V_{RX}$ | $V_F$ @ $I_F$ | $I_{GT}$ | Device |
|---|---|---|---|---|---|---|
| 0.5 Amp | TO-18 | (Fig. 3) | 50V | 1.6V @ 0.5A | 200μA | 2N4108 |
| | | | 100V | 1.6V @ 0.5A | 200μA | 2N4109 |
| | | | 200V | 1.6V @ 0.5A | 200μA | 2N4110 |
| | TO-46 | (Fig. 4) | 50V | 1.6V @ 0.5A | 200μA | 2N4096 |
| | | | 100V | 1.6V @ 0.5A | 200μA | 2N4097 |
| | | | 200V | 1.6V @ 0.5A | 200μA | 2N4098 |
| 1 Amp | TO-5 | (Fig. 2) | 50V | 2V @ 1A | 10mA | 2N1595 |
| | | | 50V | 2V @ 1A | 10mA | 2N1595A |
| | | | 50V | 1.4V @ 1A | 50μA | 2N2322 |
| | | | 50V | 1.4V @ 1A | 50μA | 2N2323 |
| | | | 50V | 1.4V @ 1.6A | 200μA | 2N3559 |
| | | | 50V | 2V @ 1A | 200μA | 2N2009 |
| | | | 50V | 2V @ 1A | 200μA | 2N2010 |
| | | | 100V | 2V @ 1A | 10mA | 2N1596 |
| | | | 100V | 2V @ 1A | 10mA | 2N1596A |
| | | | 100V | 1.4V @ 1A | 50μA | 2N2325 |
| | | | 100V | 1.4V @ 1A | 50μA | 2N2324 |
| | | | 100V | 1.4V @ 1.6A | 200μA | 2N3560 |
| | | | 100V | 1.4V @ 1.6A | 200μA | 2N3561 |
| | | | 100V | 2V @ 1A | 200μA | 2N2011 |
| | | | 200V | 2V @ 1A | 10mA | 2N1597 |
| | | | 200V | 2V @ 1A | 10mA | 2N1597A |
| | | | 200V | 1.4V @ 1A | 50μA | 2N2327 |
| | | | 200V | 1.4V @ 1A | 50μA | 2N2326 |
| | | | 200V | 1.4V @ 1.6A | 200μA | 2N3562 |
| | | | 200V | 2V @ 1A | 200μA | 2N2012 |
| | | | 300V | 2V @ 1A | 10mA | 2N1598 |
| | | | 300V | 2V @ 1A | 10mA | 2N1598A |
| | | | 300V | 1.4V @ 1A | 50μA | 2N2328 |
| | | | 300V | 2V @ 1A | 200μA | 2N2013 |
| | | | 400V | 2V @ 1A | 10mA | 2N1599 |
| | | | 400V | 2V @ 1A | 10mA | 2N1599A |
| | | | 400V | 1.4V @ 1A | 50μA | 2N2329 |
| 5 Amp | TO-66 | (Fig. 7) | 200V | 2.8V @ 3A | 15mA | 2N3228 |
| | | | 400V | 2.8V @ 3A | 15mA | 2N3525 |
| | TO-5 | (Fig. 2) | 100V | 2.4V @ 5A | 200μA | 2N3273 |
| | | | 200V | 2.4V @ 5A | 200μA | 2N3274 |
| | | | 300V | 2.4V @ 5A | 200μA | 2N3275 |
| | | | 400V | 2.4V @ 5A | 200μA | 2N3276 |
| 10 Amp | TO-3 | (Fig. 1) | 100V | 2.2V @ 10A | 2-15mA | SE9030 |
| | | | 200V | 2.2V @ 10A | 2-15mA | SE9031 |
| | | | 300V | 2.2V @ 10A | 2-15mA | SE9032 |
| | | | 400V | 2.2V @ 10A | 2-15mA | SE9033 |
| | TO-59 | (Fig. 5) | 100V | 2.2V @ 10A | 200μA | 2N3269 |
| | | | 200V | 2.2V @ 10A | 200μA | 2N3270 |
| | | | 300V | 2.2V @ 10A | 200μA | 2N3271 |
| | | | 400V | 2.2V @ 10A | 200μA | 2N3272 |
| | TO-66 | (Fig. 7) | 100V | 2.2V @ 10A | 2-15mA | 2N4316 |
| | | | 200V | 2.2V @ 10A | 2-15mA | 2N4317 |
| | | | 300V | 2.2V @ 10A | 2-15mA | 2N4318 |
| | | | 400V | 2.2V @ 10A | 2-15mA | 2N4319 |

# Planar Power Transistors

| PNP | Package | $BV_{CEO}$ | $h_{FE}$ | Test Conditions $V_{CE}$ | $I_C$ | $f_T$ | Power Dissipation at case Temperature | Fairchild Device Number |
|---|---|---|---|---|---|---|---|---|
| 1 Amp | TO-59 *(Fig. 5)* *with isolated collector* | 80V | 10 min. | 5V | 1A | 100MHz | 5W @ 75°C | FT55 |
| 5 Amp | TO-59 *(Fig. 5)* *with isolated collector* | 80V | 40 min. | 5V | 5A | 80MHz | 30W @ 100°C | FT400A |
| | | 80V | 20 min. | 5V | 5A | 80MHz | 30W @ 100°C | FT400B |
| | TO-3 *(Fig. 1)* | 80V | 15 min. | 5V | 5A | 80MHz | 30W @ 80°C | SE9541 |
| | | 60V | 20 min. | 5V | 5A | 80MHz | 30W @ 50°C | SE9540 |
| | TO-5 *(Fig. 2)* | 80V | 15 min. | 5V | 5A | 80MHz | 5W @ 25°C | FT400C |

| NPN | Package | $BV_{CEO}$ | $h_{FE}$ | Test Conditions $V_{CE}$ | $I_C$ | $f_T$ | Power Dissipation at case Temperature | Fairchild Device Number |
|---|---|---|---|---|---|---|---|---|
| 150mA | TO-66 *(Fig. 7)* | 300V | 40-240 | 10V | 50mA | 30MHz | 6W @ 75°C | SE7020 |
| | TO-5 *(Fig. 2)* | 300V | 40-240 | 10V | 50mA | 30MHz | 3.5W @ 75°C | FT300B |
| | TO-66 *(Fig. 7)* | 150V | 30-260 | 10V | 150mA | 30MHz | 5W @ 25°C | SE7006 |
| 2 Amp | TO-59 *(Fig. 5)* **indicates isolated collector* | 80V | 30-90 | 2V | 1A | 30MHz | 17W @ 100°C | 2N2892 |
| | | 80V | 50-150 | 2V | 1A | 30MHz | 17W @ 100°C | 2N2893 |
| | | 80V | 30-90 | 2V | 1A | 30MHz | 17W @ 100°C | 2N4075* |
| | | 80V | 50-150 | 2V | 1A | 30MHz | 17W @ 100°C | 2N4076* |
| | | 80V | 40-120 | 2V | 2A | 80MHz | 15W @ 100°C | FT34A |
| | | 60V | 100-300 | 2V | 2A | 80MHz | 15W @ 100°C | FT34B |
| | TO-3 *(Fig. 1)* | 60V | 40-120 | 2V | 2A | 80MHz | 15W @ 75°C | 2N3919 |
| | | 60V | 100-300 | 2V | 2A | 80MHz | 15W @ 75°C | 2N3920 |
| | | 40V | 10 min. | 4V | 2A | 30MHz | 20W @ 50°C | 2N3917 |
| | | 40V | 30-260 | 5V | 0.5A | 30MHz | 10W @ 100°C | SE3035 |
| | TO-5 *(Fig. 2)* | 80V | 30-90 | 2V | 1A | 30MHz | 2.8W @ 100°C | 2N2890 |
| | | 80V | 50-150 | 2V | 1A | 30MHz | 2.8W @ 100°C | 2N2891 |

Planar is a patented Fairchild process

# Planar Power Transistors

FAIRCHILD SEMICONDUCTOR

| NPN | Package: | $BV_{CEO}$ | $h_{FE}$ | Test Conditions $V_{CE}$ | $I_C$ | $f_T$ | Power Dissipation at case Temperature | Fairchild Device Number |
|---|---|---|---|---|---|---|---|---|
| 2 Amp Continued | TO-66 *(Fig. 7)* | 80V | 30-250 | 2V | 1A | 30MHz | 10W @ 100°C | SE9001 |
| | | 60V | 30-250 | 2V | 1A | 30MHz | 10W @ 100°C | SE9002 |
| 5 Amp | TO-59 *(Fig. 5)* **indicates isolated collector* | 80V | 40 min. | 5V | 5A | 70MHz | 30W @ 100°C | 2N4116* |
| | | 80V | 20 min. | 5V | 5A | 70MHz | 30W @ 100°C | 2N4115* |
| | | 60V | 20 min. | 5V | 5A | 70MHz | 30W @ 100°C | FT7207B |
| | TO-3 *(Fig. 1)* | 80V | 20 min. | 5V | 5A | 70MHz | 30W @ 50°C | 2N4113 |
| | | 80V | 40 min. | 5V | 5A | 70MHz | 30W @ 50°C | 2N4114 |
| | | 80V | 15 min. | 5V | 5A | 80MHz | 30W @ 100°C | SE9041 |
| | | 60V | 20 min. | 5V | 5A | 70MHz | 30W @ 50°C | 2N4111 |
| | | 60V | 40 min. | 5V | 5A | 70MHz | 30W @ 50°C | 2N4112 |
| | | 60V | See note 1 | | | 70MHz | 15W @ 75°C | SE3034 |
| | | 60V | 20 min. | 5V | 5A | 80MHz | 30W @ 50°C | SE9040 |
| | TO-5 *(Fig. 2)* | 80V | 40-120 | 2V | 2A | 80MHz min. | 5W @ 25°C | FT34C |
| | | 60V | 100-300 | 2V | 2A | 80MHz min. | 5W @ 25°C | FT34D |
| 7 Amp | TO-3 *(Fig. 1)* | 150V | 10 min. | 1.2V | 7A | 30MHz | 50W @ 25°C | SE9020 |
| 10 Amp | TO-3 *(Fig. 1)* | 60V | 40-120 | 2V See note 1 | 2A | 4MHz | 15W @ 75°C | 2N3919 |
| | | 60V | 100-300 | 2V See note 1 | 2A | 4MHz | 15W @ 75°C | 2N3920 |
| | | 60V | | See note 1 | | 4MHz | 15W @ 75°C | SE3030 |
| | | 60V | | See note 1 | | 4MHz | 15W @ 75°C | SE3032 |
| | | 60V | | See note 2 | | 4MHz | 15W @ 75°C | SE3031 |
| | | 60V | | See note 2 | | 4MHz | 15W @ 75°C | SE3033 |
| | TO-59 *(Fig. 5)* | 80V | | See note 1 | | 4MHz | 15W @ 100°C | FT34A |
| | | 60V | | See note 1 | | 4MHz | 15W @ 100°C | FT34B |
| 12 Amp | TO-3 *(Fig. 1)* | 200V | 10 min. | 1.5V | 12A | 30MHz | 60W @ 25°C | SE9010 |
| | TO-61 *(Fig. 6)* *with isolated collector* | 200V | 10 min. | 1.5V | 12A | 30MHz | 60W @ 25°C | FT301A |

5 Amp — Note 1: $V_{CE}$ (SAT) @ $I_C/I_B$=5A/0.5A = 0.4V max.

10 Amp — Note 1: $V_{CE}$ (SAT) @ $I_C/I_B$=10A/1A = 1.2V
Note 2: $V_{CE}$ (SAT) @ $I_C/I_B$=10A/1A = 1.8V

# Fairchild Suggested Equivalents

This cross-reference list is intended as a guide only. In some instances there will be package, thermal resistance, and safe area differences. The nearest electrical equivalent was selected on the basis of $V_{CEO}$ and $h_{FE}$. Please refer to individual device specifications for additional information.

| EIA | Fairchild |
|---|---|
| 2N389 | 2N1724 |
| 2N424 | 2N1724 |
| 2N547 | 2N2890 |
| 2N548 | 2N2890 |
| 2N1047 | 2N4115 |
| 2N1047A | 2N4115 |
| 2N1047B | 2N4115 |
| 2N1048 | 2N4115 |
| 2N1048A | 2N4115 |
| 2N1048B | 2N4115 |
| 2N1049 | 2N4115 |
| 2N1049A | 2N4115 |
| 2N1049B | 2N4115 |
| 2N1050 | 2N4115 |
| 2N1050A | 2N4115 |
| 2N1050B | 2N4115 |
| 2N1067 | SE9002 |
| 2N1068 | SE9002 |
| 2N1069 | SE9002 |
| 2N1070 | SE9002 |
| 2N1208 | 2N4115 |
| 2N1209 | 2N4115 |
| 2N1210 | 2N4115 |
| 2N1211 | 2N4115 |
| 2N1212 | 2N4115 |
| 2N1250 | 2N4115 |
| 2N1483 | SE9002 |
| 2N1484 | SE9002 |
| 2N1485 | SE9002 |
| 2N1486 | SE9002 |
| 2N1487 | SE9041 |
| 2N1488 | SE9041 |
| 2N1489 | SE9041 |
| 2N1490 | SE9041 |
| 2N1511 | FT8207A |
| 2N1512 | FT8207A |
| 2N1513 | FT8207A |
| 2N1514 | FT8207A |
| 2N1616A | 2N1724 |
| 2N1617A | 2N1724 |
| 2N1618A | 2N1724 |
| 2N1620 | FT8207A |
| 2N1647 | 2N4115 |
| 2N1648 | 2N4115 |
| 2N1649 | 2N4116 |
| 2N1650 | 2N4116 |
| 2N1690 | 2N4115 |
| 2N1691 | 2N4116 |
| 2N1701 | SE9002 |
| 2N1702 | SE9040 |
| 2N1703 | SE9040 |
| 2N1718 | FT7207B |
| 2N1719 | FT7207B |
| 2N1720 | FT7207A |
| 2N1721 | FT7207A |
| 2N1722 | 2N1724 |
| 2N1723 | 2N1724 |
| 2N1724 | 2N1724 |
| 2N1725 | 2N1724 |
| 2N1768 | FT7207B |
| 2N1769 | FT7207B |
| 2N1886 | FT7207B |
| 2N2015 | 2N4113 |
| 2N2016 | 2N4113 |
| 2N2018 | SE7006 |
| 2N2019 | SE7006 |
| 2N2020 | SE7006 |
| 2N2021 | SE7006 |
| 2N2032 | 2N4115 |
| 2N2033 | FT34C |
| 2N2034 | FT34C |
| 2N2035 | FT34A |
| 2N2036 | FT34A |
| 2N2150 | 2N4115 |
| 2N2151 | 2N4115 |
| 2N2201 | 2N3916 |
| 2N2202 | 2N3916 |
| 2N2203 | 2N3916 |
| 2N2204 | 2N3916 |
| 2N2239 | SE9002 |
| 2N2304 | SE9002 |
| 2N2305 | SE3035 |
| 2N2308 | 2N3919 |
| 2N2338 | 2N4111 |
| 2N2339 | 2N4075 |
| 2N2632 | FT1724 |
| 2N2633 | FT1724 |
| 2N2634 | FT1724 |
| 2N2657 | FT7207C |
| 2N2658 | FT7207C |
| 2N2697 | 2N4115 |
| 2N2698 | 2N4116 |
| 2N2811 | FT1724 |
| 2N2812 | FT1724 |
| 2N2813 | FT1724 |
| 2N2814 | FT1724 |
| 2N2828 | FT7207C |
| 2N2829 | 2N4115 |
| 2N2849-2 | 2N4115 |
| 2N2850-2 | 2N4115 |
| 2N2851-2 | 2N4115 |
| 2N2852-2 | 2N4115 |
| 2N2853-2 | 2N4115 |
| 2N2854-2 | 2N4115 |
| 2N2855-2 | 2N4115 |
| 2N2856-2 | 2N4115 |
| 2N2857 | FT7207C |
| 2N2858 | FT7207C |
| 2N2859 | FT7207C |
| 2N2877 | 2N4115 |
| 2N2878 | 2N4115 |
| 2N2879 | 2N4115 |
| 2N2880 | 2N4115 |
| 2N2881 | 2N4030 |
| 2N2882 | 2N4031 |
| 2N2890 | 2N2890 |
| 2N2891 | 2N2891 |
| 2N2892 | 2N2892 |
| 2N2893 | 2N2893 |
| 2N2911 | 2N2890 |
| 2N3021 | SE9540 |
| 2N3022 | SE9540 |
| 2N3023 | SE9540 |
| 2N3024 | SE9540 |
| 2N3025 | SE9540 |
| 2N3026 | SE9540 |
| 2N3054 | 2N3919 |
| 2N3055 | 2N4111 |
| 2N3163 | FT400A/B |
| 2N3164 | FT400A/B |
| 2N3165 | FT400A/B |
| 2N3166 | FT400A/B |
| 2N3167 | FT400A/B |
| 2N3168 | FT400A/B |
| 2N3169 | FT400A/B |
| 2N3170 | FT400A/B |
| 2N3171 | SE9540 |
| 2N3172 | SE9540 |
| 2N3173 | SE9540 |
| 2N3174 | SE9540 |
| 2N3175 | FT400A/B |
| 2N3176 | FT400A/B |
| 2N3177 | FT400A/B |
| 2N3178 | FT400A/B |
| 2N3179 | FT400A/B |
| 2N3180 | FT400A/B |
| 2N3181 | FT400A/B |
| 2N3182 | FT400A/B |
| 2N3183 | SE9540 |
| 2N3184 | SE9540 |
| 2N3185 | SE9540 |
| 2N3186 | SE9540 |
| 2N3187 | FT400A/B |
| 2N3188 | FT400A/B |
| 2N3189 | FT400A/B |
| 2N3190 | FT400A/B |
| 2N3191 | FT400A/B |
| 2N3192 | FT400A/B |
| 2N3193 | FT400A/B |
| 2N3194 | FT400A/B |
| 2N3195 | SE9540 |
| 2N3196 | SE9540 |
| 2N3197 | SE9540 |
| 2N3198 | SE9540 |
| 2N3199 | FT55 |
| 2N3200 | FT55 |
| 2N3201 | FT55 |
| 2N3202 | 2N4030 |
| 2N3203 | 2N4030 |
| 2N3204 | 2N4032 |
| 2N3205 | FT55 |
| 2N3206 | FT55 |
| 2N3207 | FT55 |
| 2N3208 | 2N4030 |
| 2N3232 | 2N4111 |
| 2N3233 | 2N4111 |
| 2N3234 | 2N4111 |
| 2N3235 | 2N4111 |
| 2N3236 | 2N4111 |
| 2N3237 | 2N4111 |
| 2N3238 | 2N4111 |
| 2N3239 | 2N4111 |
| 2N3240 | 2N4111 |
| 2N3418 | FT7207C |
| 2N3419 | FT7207C |
| 2N3420 | FT7207C |
| 2N3421 | FT7207C |
| 2N3429 | 2N4115 |
| 2N3430 | 2N4115 |
| 2N3439 | FT300B |
| 2N3440 | FT300B |
| 2N3441 | SE7020 |
| 2N3442 | SE9020 |
| 2N3445 | FT8207A |
| 2N3446 | FT8207A |
| 2N3447 | FT8207A |
| 2N3448 | FT8207A |
| 2N3487 | FT1724 |
| 2N3488 | FT1724 |
| 2N3489 | FT1724 |
| 2N3490 | FT1724 |
| 2N3491 | FT1724 |
| 2N3492 | FT1724 |
| 2N3583 | SE7020 |
| 2N3584 | SE7006 |
| 2N3585 | SE7020 |
| 2N3597 | FT1724 |
| 2N3598 | FT1724 |
| 2N3599 | FT1724 |
| 2N3744 | 2N4115 |
| 2N3745 | 2N4115 |
| 2N3746 | 2N4115 |
| 2N3747 | 2N4115 |
| 2N3748 | 2N4115 |
| 2N3749 | 2N4115 |
| 2N3750 | 2N4115 |
| 2N3751 | 2N4115 |
| 2N3752 | 2N4115 |
| 2N3771 | SE9020 |
| 2N3772 | SE9020 |
| 2N3773 | SE9020 |
| 2N3850 | 2N4115 |
| 2N3851 | 2N4115 |
| 2N3852 | 2N4115 |
| 2N3853 | 2N4115 |

# Planar Power Advantages

FAIRCHILD SEMICONDUCTOR

Reliability of a transistor depends on many factors. It is a mistake to consider a single factor, such as operating junction temperature, as the overall determinant of the transistor's reliability and life expectancy. There are at least two significant areas, usually neglected by the power transistor buyer, where Planar construction can add materially to the reliability of the device: 1. Long-term drift, and 2. Ambient influences.

**Long-Term Drift and Stability**: Planar devices are inherently more stable and are affected less by long-term drift as a function of temperature and time. This is due to the passivated junctions of Planar transistors.

**Ambient Influences**: Reliability depends on the susceptibility of a given junction to ambient influences within the encapsulation. The passivation techniques used in the Planar process prohibit external influences from contaminating and degrading the junction surface.

### Secondary Breakdown

Secondary breakdown frequently shows itself as localized spot heating which melts through the base region and causes a collector-to-emitter short. Take away the localized heating (or the concentration of currents which cause it) and you have removed the major cause of secondary breakdown. Fairchild does this by introducing nickel-chromium thin film resistors in series with the emitters. This prevents concentration of currents in any one spot. Here's how it works:

All power transistors can be represented mechanically as thousands of separate transistors placed in parallel. Theoretically, the same amount of current flows through each. But in reality, because each transistor has slightly different characteristics, one will draw more than its share of current. This causes localized heating, which in turn causes the transistor to "hog" yet more current, which causes more heating. If this unpleasant cycle continues unchecked, the result is secondary breakdown.

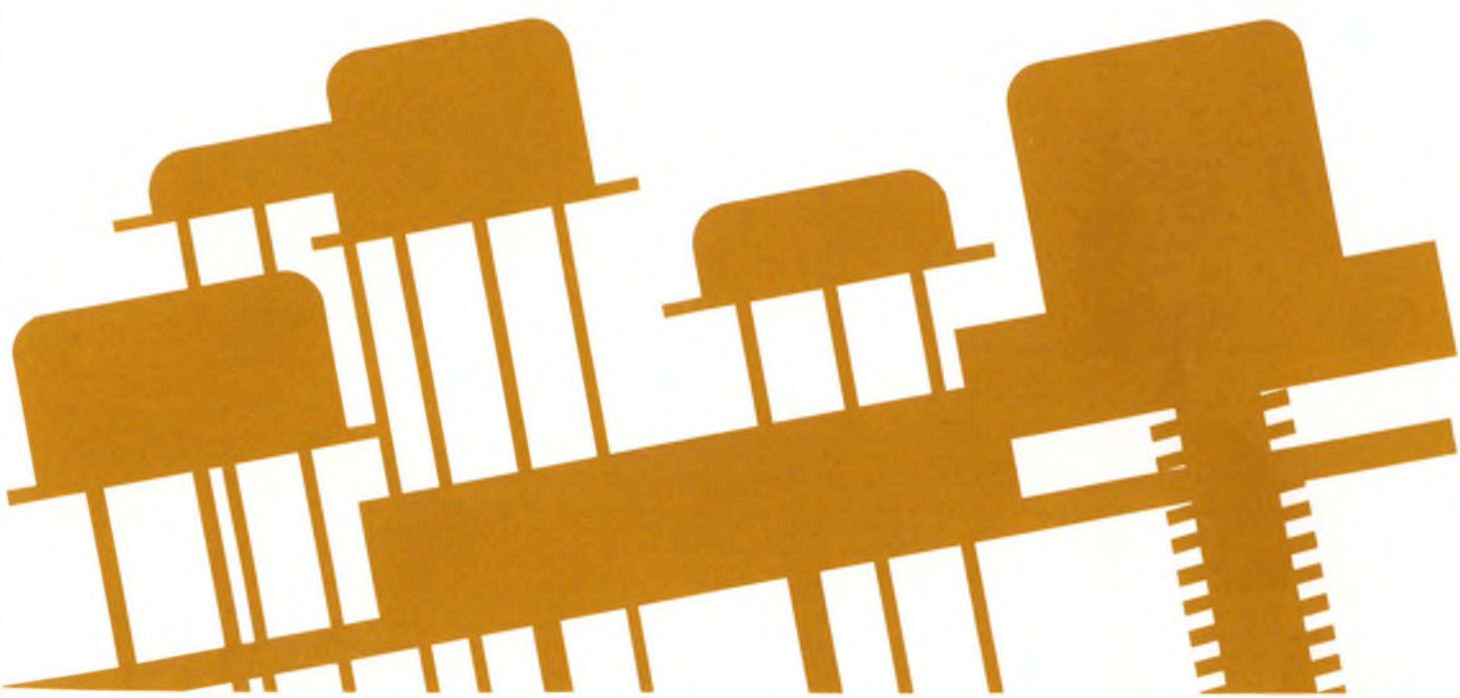
The NICR resistors, placed in series with the emitters, prevent this from happening. When a transistor tries to "hog" more than its share of current, the resistor induces a negative feedback which pulls it right back into the safe zone.

Thus, the key to solving secondary breakdown is not wider base areas, and/or lower frequencies. Fairchild power transistors, such as 2N4111 through 2N4116, have the resistors diffused right into the chip, and assure current sharing over the entire emitter periphery. This technique is highly successful in preventing secondary breakdown, while maintaining the superior performance of Planar technology.

### Test Planar Power

To help you prove to yourself the reliability of Fairchild Planar power, we have prepared two sample kits of Fairchild power devices. One kit contains our latest power transistors, the other contains our SCR's. These kits are offered at a fraction of their retail value, so that you may put the devices to the test on your own breadboards. But hurry. The offer expires July 30th, 1966. So call a Fairchild Distributor (listed on the back page) and ask for the FAIRCHILD POWER PACK.

Planar is a patented Fairchild process



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Tel: 514-381-9127



MANUFACTURED UNDER ONE OR MORE OF THE FOLLOWING U.S. PATENTS:
2981877, 3015048, 3025589, 3064167, 3108359, 3117260; OTHER PATENTS PENDI

# Letters

## Holiday road death rate questioned

Sir:

Wayne Willie of the National Safety Council (*sic*) is merely unbelievable! His "statistical" juggling of holiday vs nonholiday traffic deaths [ED 11, May 10, 1966, p. 33] is hilarious—typical of the distorted and meaningless data that emanate from his organization.

The two rates are only comparable if the relevant vehicle and/or passenger miles are known; in other words, how much more driving is done over holiday weekends than on nonholiday ones. I'll wager that, if these data were added, the NSC might be in for a surprise about how safely people drive during holidays.

Let's try a few other NSC "statistics" while we're about it. How about the "75% (or some such figure) of all accidents occur within 15 miles of home"? What percentage of all driving is done within 15 miles of home? Then there's that "80% of all deaths occur at under 35 mph" claim, which is again suspect unless we know what percentage of all driving is done at under 35 mph. As for that hoary old "Speed Kills" dirge, I guess they'd better not tell the astronauts who have survived 18,000 mph. In Los Angeles, slowness kills on the freeways, since the traffic there has a way of removing the slow and obstructive driver who impedes traffic, usually in the left lane.

As a matter of record, some well researched experiments have proved that speeding up traffic has reduced accidents, but this kind of information has a way of getting buried—it doesn't get votes or swell a city's coffers with violation money.

John Joss
1060 Los Altos Ave.
Los Altos, Calif.

Sir:

A recent letter from Wayne Willie of the National Safety Council [ED 8, May 10, 1966, p. 33] manipulated some figures for last Labor Day weekend auto deaths, finally settling on 765. If 78 hours is the base for total deaths due to auto accidents, this yields a rate of 9.8 deaths per hour.

Will Willie or someone please add up the deaths for the 54-hour weekend preceding Labor Day, including those who died later, and tell me the rate of deaths per hour? Only then can we make a comparison unobscured by columns of verbiage.

Jon P. Ramer
7219 Ravenna Ave.
Orlando, Fla.

Sir:

I thoroughly agree with J. W. Streater [ED 8, Apr. 12, 1966, pp. 39-40]. People just are not interested in safety in cars. Nine times out of ten, seat belts are not used even when they are installed.

Walter A. White
Engr.
Sylvania Electronic Systems
Buffalo, N. Y.

## More support for the siemens

Sir:

In recent issues of ED voices have been raised against the use of the siemens as the unit of conductance. One argument [ED 4, Feb. 15, 1966, p. 42] was that even in Germany companies hesitate to use it. This, however, just is not so; publications, data sheets, handbooks, etc. prove the contrary. Here it is a generally used unit. I cannot believe that anyone writing or reading S, mS or $\mu$S is thinking of a competitive firm.

Another argument was that nobody knows who Siemens was. Siemens' discovery of the dynamoelectric principle exactly 100 years ago was not inferior to the ideas of James Watt, who one century earlier showed the narrow correlation between progress in the technical and physical fields.

Let siemens be the unit—and Siemens a pioneer for all!

Dr. Werner Muschler
Max-Planck-Institut
für Aeronomie
3411) Lindau/Harz
West Germany

Sir:

For purely personal reasons, of course, it is disheartening to learn of Howard Cook's [ED 4, Feb. 15, 1966, p. 42] and Thomas Parsons' protest against the substitution of the siemens for the mho. Being a relatively modest person, I must heartily agree with Parsons that Siemens does not belong in the company of Faraday, Henry and Ohm. But I must retain the hope that springs eternal that surely *someone* knows who I am. As for the question, "What did he do?" maybe it would be better that it remain unanswered rather than have my employer join in asking it, too.

While I understand that other names are certainly more deserving of preservation for posterity in this manner, you can understand that without any reservations the siemens gets my vote.

Harry A. Siemen, Sr.
RCA Service Co., Inc.
Patrick AFB, Fla.

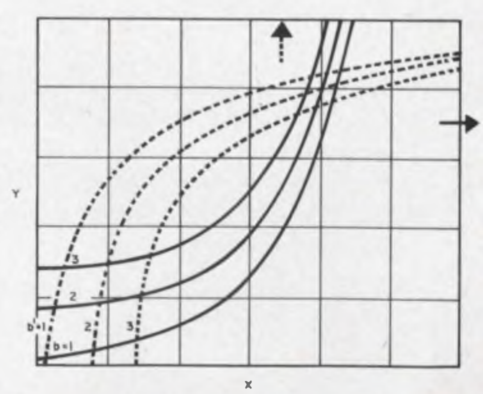
## Accuracy is our policy

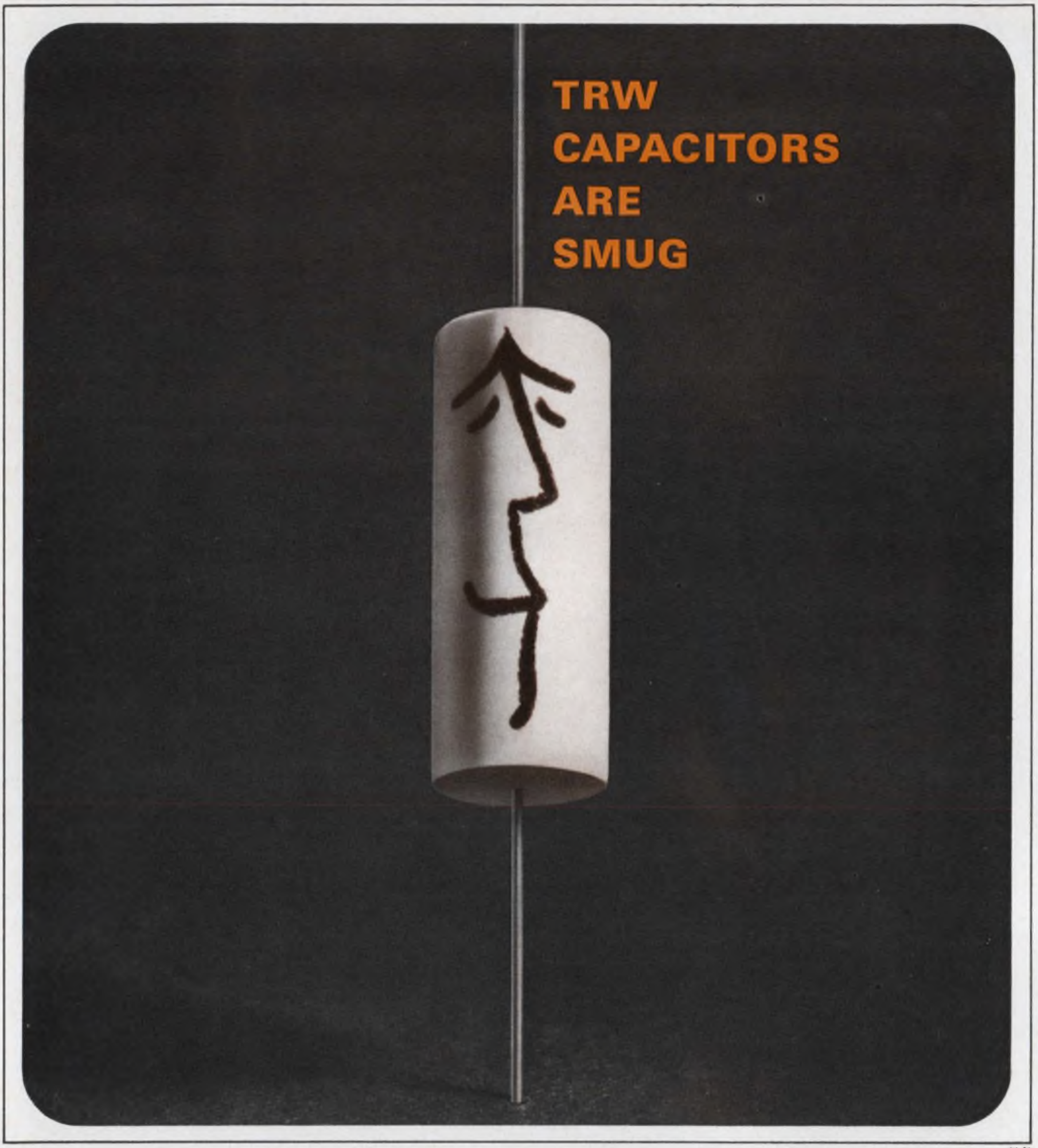
In ED 11, May 10, 1966, NASA Tech Briefs, pp. 73 & 74, the diagram with "70 watt-hours/lb from regenerative fuel cell" illustrates the following Brief, "Sleeve for RF cables bridges shielding gap," and vice versa.

In "Device-hunting for motor speed control," ED 11, May 10, 1966, p. 40, Fig. 4b, the inscription above the circuit should read: "C30B for $I_A \geqq 2$ A," not "C30B for $I_A \leqq 2$ A."

In "New FETs replace tubes," ED 6, Mar. 15, 1966, p. 199, the schematic of Fig. 5 belongs above the caption of Fig. 4, and vice versa.

In "Carpet plotting is easy," ED 6, Mar. 15, 1966, all the dotted lines shown in the graph below were omitted from Fig. 8, p. 228.






14-61

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ON READER-SERVICE CARD CIRCLE 16

EDITORIAL

# An ill wind blows for the baccalaureate

When is an electronics engineer a "professional"? Today it is when he receives a sheepskin signifying he has met the requirements for a B.E.E. or a B.S.E.E. But is this a satisfactory system? The timeliness of such questions is underlined by a recent report* of the American Society for Engineering Education, "Goals of Engineering Education." Briefly, the report recommends acceptance of the master's degree as the first recognized professional engineering degree; it would be awarded after five years' study. At the end of four, students would qualify for a bachelor's degree, which would be regarded as an introductory engineering degree.

The proposal is based on the premise that a longer period of study would necessarily improve the level of competence, and hence raise the professional status of engineering.

The main issue is the effectiveness of the proposal. Professional status is a vague, ill-defined term. Does it mean wider recognition from the general public? Is it a measure of individuals' responsibilities within their companies? Or is it their standing among their peers? Until a consensus is reached on the exact meaning of this goal, discussion of means to achieve it will amount to little more than academic argument. The report's recommendation would answer the first definition, but the second and third would require much more thoroughgoing changes.

Even today many engineers are not used to the full extent of their capabilities. Many are obliged to perform routine testing, administrative duties and other essentially noncreative but necessary engineering tasks. It goes without saying that not every engineer can attain the same position—there must be some Indians among the chiefs. But would an engineer with an advanced degree deign to do down-to-earth hardware-oriented work?

At present, advanced degrees still command higher pay and more responsibility. But, if most engineers had master's degrees, would the advanced degree preserve its standing, or would it become roughly equivalent to today's bachelor's degree from one of the better colleges or universities?

Another fundamental issue is whether there should be any formalized revision of the educational standard at all? Perhaps it should be shaped according to the demands of industry and the enterprise of individuals. Already many students recognize the need for continued education. The demands of industry are obvious from the "Help Wanted" columns: The master's degree is becoming a basic requirement of many companies. Is there, then, any need to establish a formal, binding requirement for it when the technical society is already demanding it?

A multitude of questions must be raised and answered before any change is made. The engineering community must be heard before steps of such impact and far-reaching effect are taken. Let us know your opinion and we'll forward it to the "Goals" committee.

MARIA DEKANY

*A copy of the "Goals of Engineering Education" may be obtained from ASEE, Dupont Circle Building, 1346 Connecticut Ave., N.W., Washington, D. C. 20036, for $1.

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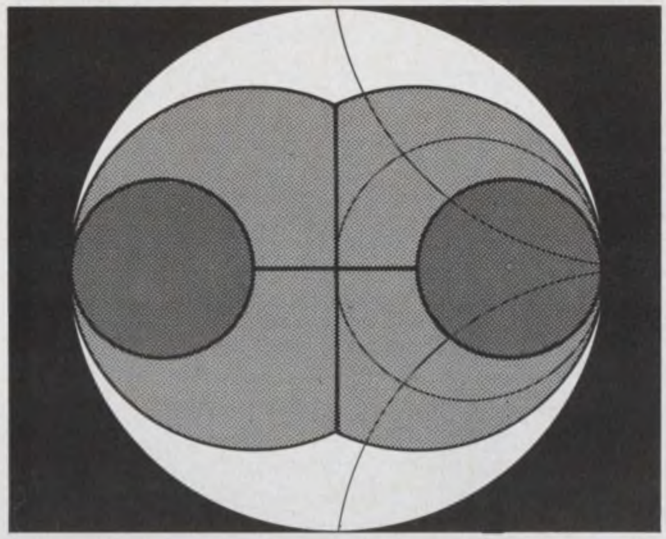
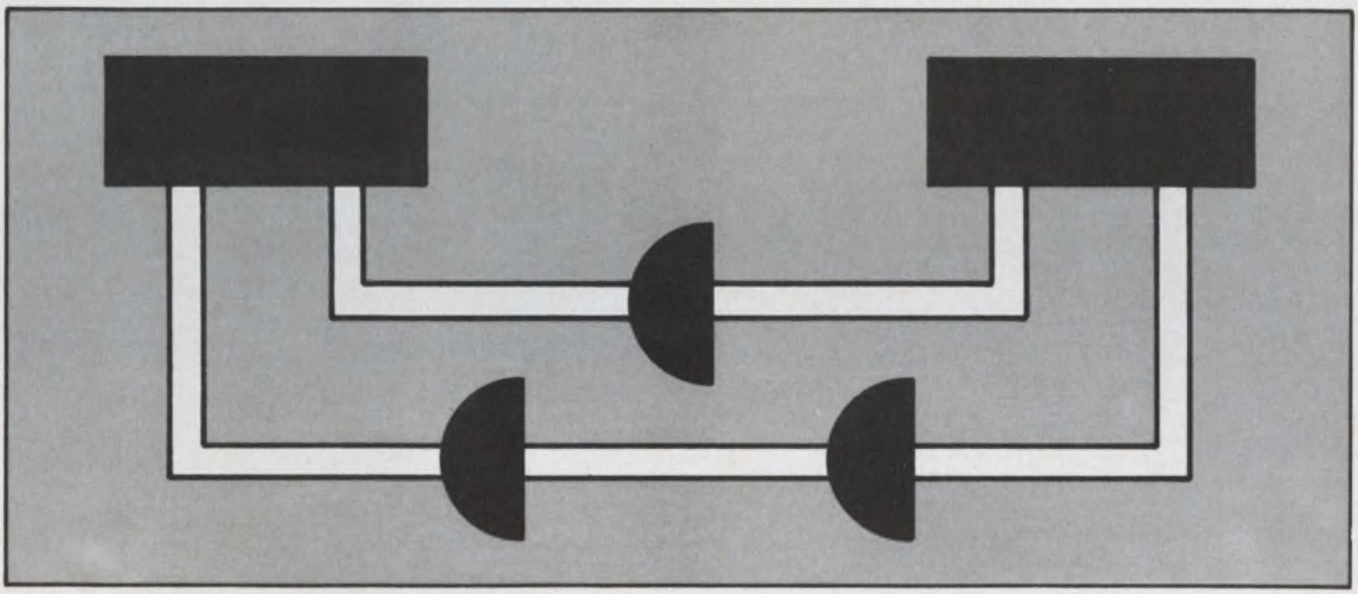
Milwaukee, Wisconsin 53201

# Technology

**Measuring and testing** the performance of IF amplifier that has simplified design. Page 38



**Division of Smith Chart** into regions facilitates choice of devices to match circuits. Page 46



**High-speed binary circuits** using microelectronics usher in faster digital computers. Page 52

## Also in this section:

**Nomograph gives amplifier noise data.** Page 60

**Three things must be done** before seeking a U.S. patent on your invention. Page 64

**Ideas for Design.** Pages 70 to 74

# Simplify IF amplifier design by letting gain and bandwidth guide the stage development. Here is the procedure for a double-tuned, wide-band 45-MHz strip.

Why make the design of transistorized wideband, double-tuned amplifiers any more complicated than need be? Use a practical approach based on the only primary criteria that really guide the over-all design—gain and bandwidth.

Consider the transistor as the primary determinant of gain and the double-tuned network as that of bandwidth. We need thus be concerned only with the functioning of each unit independently and with their influence upon each other.

Such important considerations as noise figure, dynamic range, biasing, gain controls, selectivity and mode of operation will not be covered in detail here. Our aim is to develop a systematic approach to double-tuned amplifier design. Therefore, all parameters other than gain and bandwidth will be deemed beyond the scope of our effort, as their inclusion would only serve to obscure the over-all design theme.

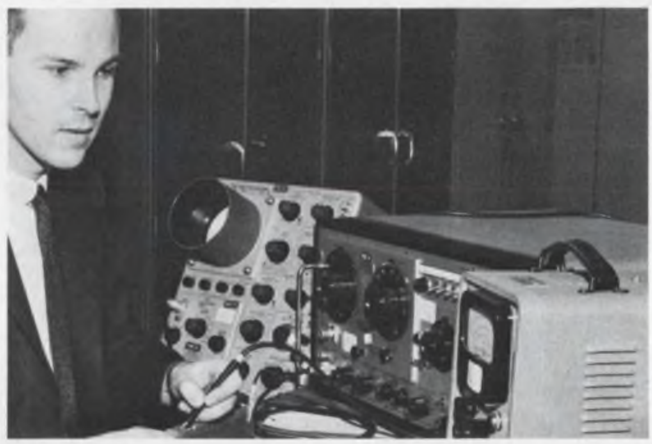
### Speed design by using curves

In designing double-tuned amplifiers, many engineers consult the IF-stage design curves in the MIT Radiation Laboratory Series.* The data in the curves are used in reference to the design of 30 and 45 MHz IF strips. Few engineers realize, however, that the curves may be extended to the design of double-tuned circuits with center frequencies considerably above or below these levels.

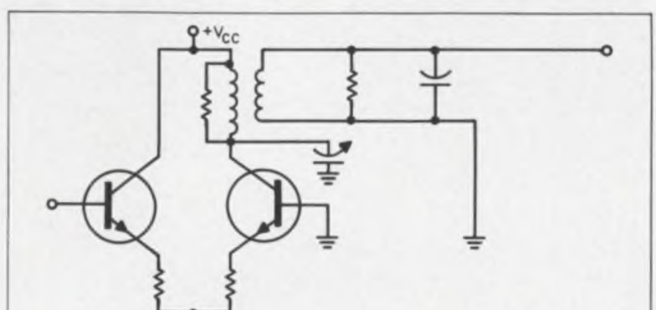
A step-by-step design for a wideband, double-tuned amplifier will demonstrate the usefulness of the technique. Frequent use will be made of the master design curves, to show how they apply to transistorized IF strips. The design will cover the following aspects of IF circuitry:

- Which configuration (common-emitter, common-base or common-collector) to use, and why.
- Determination of the number of stages to use.
- Bandwidth considerations (in each stage, over-all and shrinkage factors).
- Coupling factors (bandwidth and frequency aspects).
- Admittance effects (trade-offs, which parameters to use and the influence of strays).
- Frequency considerations (resonance, Q figures and compensation).
- Transformer design (coil, coupling and frequency behavior).

The design itself entails the use of an equal-Q transformer. These transformers require a great deal of RC shunting across both primary and secondary windings. This tends to mismatch and swamp out the parameter variations that are so characteristic of transistors. Equal-Q transformers typically have a low gain-bandwidth product, but this sacrifice in gain is well worth the improvement in stability and ease of design.



**Not a trace of instability** is found by Author Snow as he checks the performance of his wide-band, double-tuned 45-MHz IF amplifier.




1. **Simplified wideband, double-tuned amplifier** uses a common-collector, common-base combination. This mode yields a resistive-capacitive input and a flat gain response.

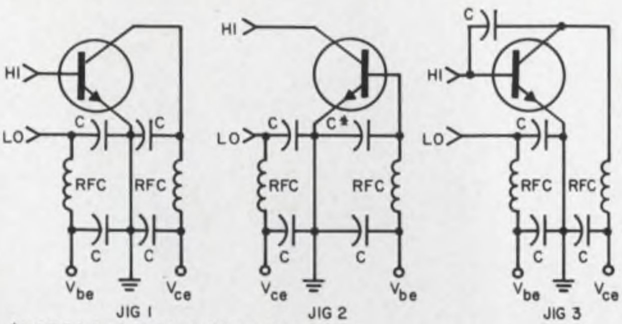
*Volume 18, Chapter 5 of "Vacuum Tube Amplifiers," by Valley and Waldman. Courtesy McGraw-Hill Book Co., New York.

**Philip Snow,** Design Engineer, ITT Gilfillan Inc., Los Angeles, Calif.

## Measuring Y parameters

$Y_i$ = short-circuit input admittance
$Y_f$ = short-circuit forward transfer admittance
$Y_r$ = short-circuit reverse transfer admittance
$Y_o$ = short-circuit output admittance
Second subscript: $e$ = common-emitter
$b$ = common-base
$c$ = common-collector

$Y_{ie}$ is determined from measurements with jig 1. $Y_{oe}$ is determined from measurements with jig 2. $Y_{oeo}$ is determined from measurements with jig 2, but with the asterisked capacitor removed. $Y_{ebscb}$ is determined from measurements with jig 3.




*NOTE: C IS BYPASS CAPACITOR

For each of the above measurements the Boonton $R_x$ meter, Model 250-A, is first nulled at the desired frequency, and the appropriate jig is then placed across its terminals. $V_{ce}$ is adjusted to the desired collector voltage, and $V_{be}$ is adjusted for the desired collector current, $I_c$. The $R_p$ and $C_p$ dials are then adjusted for a null on the meter and the respective values noted and recorded.

The admittance is calculated from:

$$Y_{ie} = (1/R_p) + j\omega_o C_p. \tag{1}$$

The rest of the common-emitter short-circuit admittances are calculated from

$$Y_{fe}' \approx Y_{ebscb} - (Y_{ie} + Y_{oe}) \tag{2}$$

$$Y_{re} = -Y_{ie}(Y_{oeo} - Y_{oe})/Y_{fe}' \tag{3}$$

$$Y_{fe} = Y_{fe}' - Y_{re}. \tag{4}$$

If the common-base or common-collector parameters are required, they may be calculated with

$$Y_{ib} = Y_{ie} + Y_{re} + Y_{fe} + Y_{oe} \tag{5}$$

$$Y_{rb} = -(Y_{re} + Y_{oe}) \tag{6}$$

$$Y_{fb} = -(Y_{fe} + Y_{oe}) \tag{7}$$

$$Y_{ob} = Y_{oe} \tag{8}$$

$$Y_{ic} = Y_{ie} \tag{9}$$

$$Y_{rc} = -(Y_{ie} + Y_{re}) \tag{10}$$

$$Y_{fc} = -(Y_{ie} + Y_{oe}) \tag{11}$$

$$Y_{oc} = Y_{ie} + Y_{re} + Y_{fe} + Y_{oe} \tag{12}$$

### Y parameters indicate compatibility

To select a proper transistor, it is important to determine first its short-circuit $Y$ parameters at the frequency and bias conditions used. Many transistor manufacturers specify these parameters, but if they are not available, they can be determined by following the procedure outlined (see box). The $Y$ parameters help to give an insight into the transistor's effect on the double-tuned network and to determine whether its input and output admittance will be compatible with the design values (see Reference).

Transistors operated in the common-emitter (CE) configuration generally exhibit a resistive-capacitive input admittance that is desirable in designing the tuned circuit. However, the shortcoming of this configuration is that the gain of the transistor is not flat over a wide band of frequencies. This CE property is due to the high intrinsic feedback between the base and collector of the transistor.

It is easily avoided through the use of a common-base configuration. The input admittance of the common-base mode, however, is generally a resistive-inductive combination, which is undesirable in double-tuned networks.

By combining a common-collector and common-base configuration (Fig. 1), the designer can achieve both a resistive-capacitance input admittance and a flat transistor gain response. Moreover this network offers the added feature of dc stability with temperature changes.

This is not to say that a single transistor in each stage in a common-emitter or common-base configuration should not be used. But it does imply that the calculated values associated with the tuned network will have to be altered to offset the shortcomings of these particular transistor modes. This complicates the tuned network design and is sometimes difficult to achieve physically. A transistor like the 2N918 has small feedback problems at frequencies below 50 MHz and can usually be used directly in the common-emitter configuration without much compensation. However, this transistor is relatively expensive. Let us therefore use the inexpensive two-stage approach (Fig. 1) and develop our design around it.

The first element to consider is the total number of stages needed for a particular IF application. We therefore turn to the gain-bandwidth-cutoff frequency curve (Fig. 2).

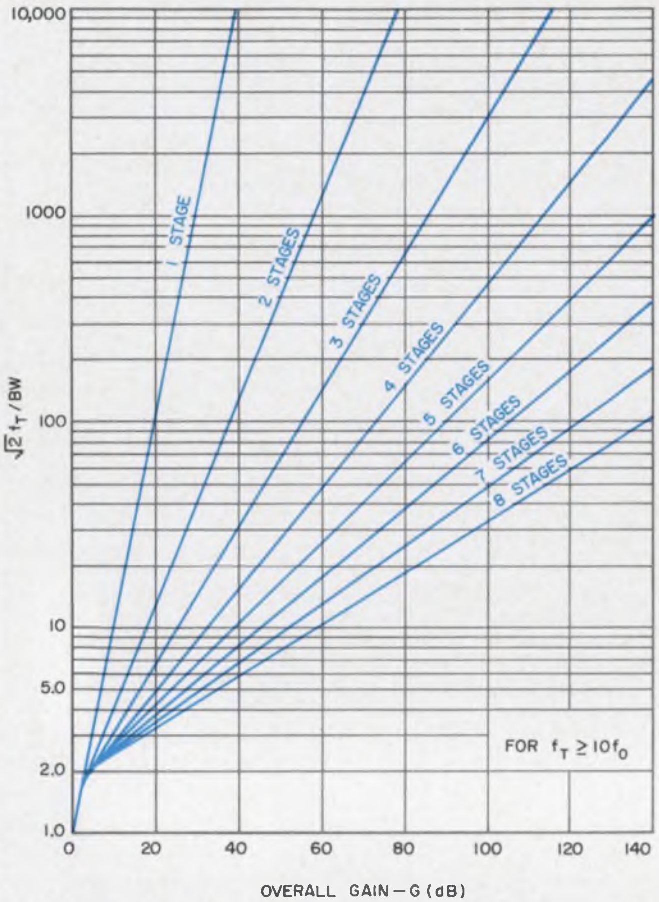
### Spotlight on stage needs

To demonstrate the application of this curve, Fig. 1 will be used as a basic stage configuration in the following example:

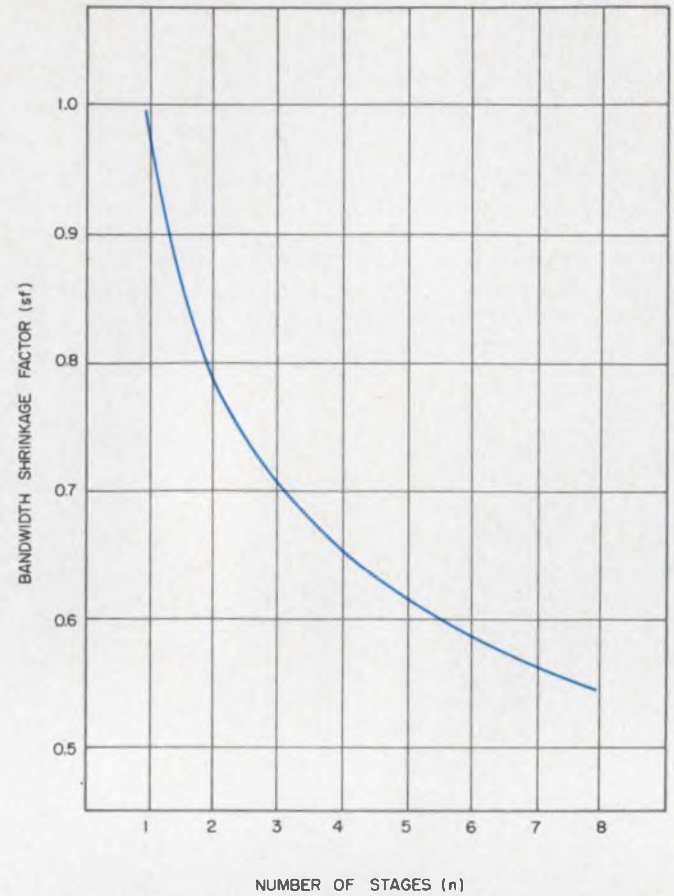
Design an IF strip with these parameters:

- Over-all nominal gain ($G$) = 30 dB
- Over-all bandwidth ($BW$) = 30 MHz
- Center frequency ($f_o$) = 145 MHz.
- Use 2N706 transistors—$f_T$=400 MHz.

The optimum number of stages ($n$) to be used is based on the over-all gain ($G$) and bandwidth ($BW$) requirements. To use Fig. 2, the designer must first relate the gain-bandwidth of the tran-




2. **To determine the number of stages** needed in an IF amplifier strip, the gain-bandwidth relationship must be considered. The ordinate here uses the ratio of gain-bandwidth cut-off to over-all bandwidth, and the abscissa is over-all gain.




3. **Bandwidth shrinkage factor is determined** by using this plot of shrinkage vs number of stages.

**Table-Short-circuit Y parameters***

| | Common-emitter | Common-base | Common-collector |
|---|---|---|---|
| $Y_i$ | 6.7 + j6.7 | 26 − j10.7 | 6.7 + j6.7 |
| $Y_r$ | −(0.14-j1.51) | −(0.5 − j.3) | −(6.6 + j5.2) |
| $Y_f$ | 18.8-j17.1 | —(19.4-j15.9) | −(25.5−j10.4) |
| $Y_o$ | 0.64 + j1.2 | 0.64 + j1.2 | 26-j10.7 |

*For 2N706 at 30 MHz

sistor to the over-all bandwidth. Thus,

$$f_T\sqrt{2}/BW = 1.415(400)/30 = 18.9 \qquad (1)$$

Note that the over-all gain required is 30 dB. To guarantee this, a factor of at least 20 per cent should be added to compensate for losses due to mismatch, transformer losses, etc. The new gain figure is thus 36 dB. The number of stages can now be determined by intersecting 36 dB on the abscissa with 18.9 on the ordinate. This produces a stage requirement of $n=4$.

Having established the number of stages, we turn to the calculation of the bandwidth shrinkage factor ($sf$). Using Fig. 3, we see that for $n=4$, $sf = 0.66$. To achieve an over-all bandwidth of 30 MHz, each stage must have an individual bandwidth ($B$) of BW/sf. Therefore

$$B = 30 \text{ MHz}/0.66 = 45.4 \text{ MHz}. \qquad (2)$$

The next design step involves the coefficient of coupling ($k$). To use the master curve (Fig. 4), we must first compute the ratio of individual bandwidth ($B$) to center frequency ($f_o$). Thus

$$B/f_o = 45.4 \text{ MHz}/45.0 \text{ MHz} = 1.01 \qquad (3)$$

Consulting Fig. 4, we see that $k=0.615$.

Knowledge of the value of $k$ permits us to calculate the RC component values. Referring to the plot of loaded-Q vs k (Fig. 5), we read off a value of $Q_L/2\pi = 0.23$. Thus

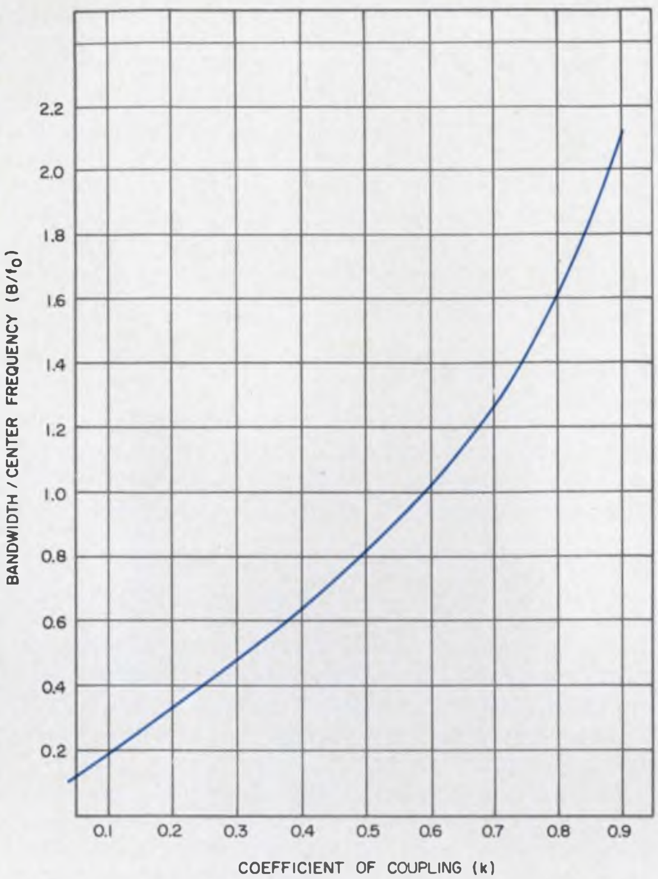
$$Q_L/2\pi = 0.23 = f_o R_1 C_1 = f_o R_2 C_2, \qquad (4a)$$

$$R_1 C_1 = R_2 C_2 = 0.23/45\times10^6 = 5.1\times10^{-9}. \qquad (4b)$$

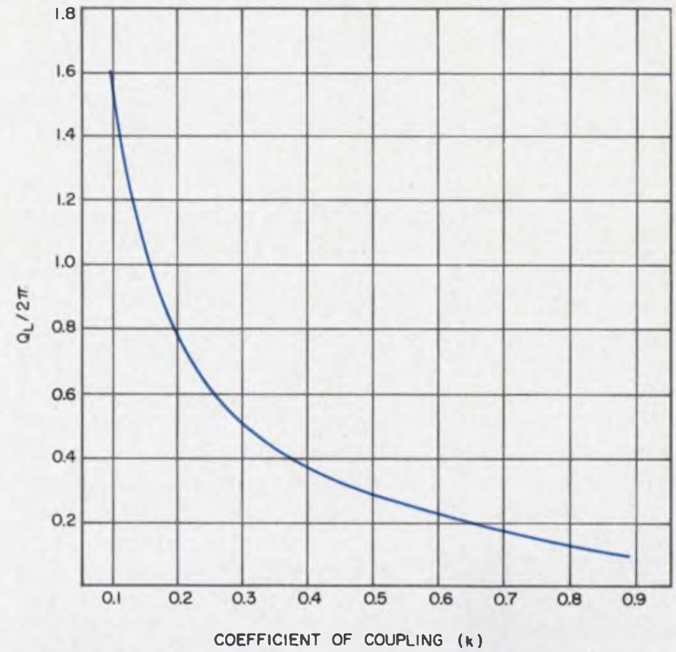
### RC product mates transistor and transformer

We must now determine how much effect the input and output admittance of the transistor has on the double-tuned transformer. The criterion for this compatibility is set up by the RC product that has just been calculated (Eq. 4b).

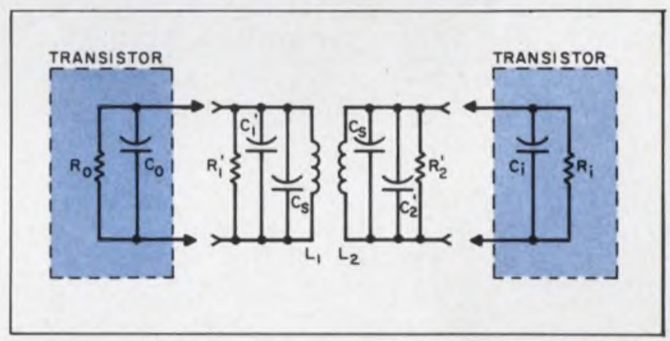
Naturally the best source of information here is experience in designing similar amplifiers with the same transistors, within the frequency range under consideration. Otherwise, the short-circuit input ($Y_i$) and output ($Y_o$) admittances should be determined. Parameters $Y_{oe}$ (common-emitter) and $Y_{ob}$ (common-base) give excellent results, as they do not change appreciably from the actual




4. **The coefficient of coupling (interstage)** is affixed by the bandwidth to center frequency ratio.




5. **The RC component values** are established by the loaded-Q figure. The relationship between the coefficient of coupling and $Q_L$ sets the RC product of each stage.




6. **Interstage connections** must account for all stray and shunt values of resistance and capacitance. Their influence must be accommodated by the RC products fixed by resonance.

output admittance in the final amplifier circuit. $Y_{ie}$ also is a very good index, but $Y_{ib}$ is not, for it will indicate a capacitive input that in reality becomes inductive in the final design.

The short-circuit $Y$ parameters of the 2N706 at 30 MHz have been measured and calculated for the three basic transistor configurations (see table). Since 45 MHz is within the same frequency range, the appropriate values for this design will be used.

Using the data in the table, we see that the input admittance is $Y_{ic} = (6.7 + j6.7)$ mmhos (common-collector). Thus, $R_i = 1/6.7 \times 10^{-3} = 150$ ohms, and $C_i = 6.7 \times 10^{-3}/(2\pi 30)\ 10^6 = 35.5$ pF. Similarly the output admittance $Y_{ob} = (0.64 + j1.2)$ mmhos (common-base); Thus $R_o = 1/0.64 \times 10^{-3} = 1560$ ohms, and $C_o = 1.2 \times 10^{-3}/2\pi 30 \times 10^6 = 6.4$ pF.

Experience tells us that $C_1$ is not 35.5 pF but more likely 9 pF, mainly due to the inductive load presented to the common-collector by the input admittance of the common-base amplifier (in Fig. 1). Having obtained the values for the input and output admittances, we now proceed to the design of the interstage connections.

**Interstage connections must match RC**

The interstage connections between the two transistors (Fig. 6) should meet the RC product established in Eq. 4. Referring to Fig. 6, we see a typical interstage connection for which the following equations apply:

$$R_1 = R_o R_1'/(R_o + R_1') \quad (5)$$

$$C_1 = C_o + C_1' + C_s \quad (6)$$

$$R_2 = R_i R_2'/(R_i + R_2') \quad (7)$$

$$C_2 = C_i + C_2' + C_s. \quad (8)$$

In these equations $C_s$ is the stray capacity (approximately 2 pF), $R_1$ is the physical primary shunting resistance, $C_1$ is the physical primary shunting capacity, $R_2$ is the physical secondary shunting resistance, and $C_2$ is the physical secondary shunting capacity.

Note that any design procedure for determining the values of $R_1'$, $C_1'$, $R_2'$ and $C_2'$ may be altered, if desired, provided the RC product of the primary and secondary circuit are adjusted to equal the value previously calculated (Eq. 4). In accordance with Eqs. 6 and 8, $C_1'$ will be a variable type with a mid-capacity of half $C_o + C_s$. Therefore

$$C_1' = 0.5(C_o + C_s) = 0.5(6.4 + 2) = 4.2\text{ pF}. \quad (9)$$

Thus $C_1 = 1.5(C_o + C_s) = 1.5(6.4 + 2) = 12.6$ pF, and since $R_1 C_1 = 5.1 \times 10^{-9}$ (Eq. 4b), we see that $R_1 =$

$5.1 \times 10^{-9}/12.6 \times 10^{-12} = 406$ ohms, and $R_1' = R_1 R_o/(R_o - R_1) = 406 \times 1560/1154 = 550$ ohms. Choosing a value of 100 ohms for $R_2$ and using Eqs. 7, 4b and 8 (in that order), we learn that $R_2' = (100)(150)/50 = 300$ ohms, $C_2 = (5.1)(10^{-9})/100 = 51$ pF, and $C_2' = C_2 - C_i - C_s = 51 - 9 - 2 = 40$ pF.

Having calculated the resistor and capacitor values, we proceed to the design of the transformer inductances. Once again we make use of a master curve plot of coupling coefficient vs frequency ratios (Fig. 7). In this curve $f_1$ and $f_2$ are the respective open-circuit primary and secondary resonant frequencies. For an equal-Q circuit, $f_1$ and $f_2$ are equal, and they determine the inductances of the primary and secondary of the transformer.

It can be seen (Fig. 7) that as the coupling increases, the open circuit resonant frequency must decrease from $f_o$. This is to compensate for the impedance that is reflected from the secondary to the primary and vice-versa. These impedances reduce the respective inductances and cause the equivalent circuits to resonate at higher frequencies. Using $k = 0.615$, we read $f_1/f_o = f_2/f_o = 0.876$. Thus, $f_1 = f_2 = (0.876) 45$ MHz $= 39.4$ MHz.

The primary and secondary inductances are computed from the relationship $L = 1/4\pi^2 f^2 C$. Thus

$$L_1 = \frac{1}{4\pi^2 f_1^2 C_1} = \frac{16.3 \times 10^{-18}}{12.6 \times 10^{-12}} = 1.3\ \mu\text{H} \quad (9a)$$

$$L_2 = \frac{1}{4\pi^2 f_2^2 C_2} = \frac{16.3 \times 10^{-18}}{51 \times 10^{-12}} = 0.31\ \mu\text{H}. \quad (9b)$$

**Transformer design follows form**

Once the size and type of coil form have been chosen, the design of the transformer is relatively simple. Since the loaded Q of a wideband transformer is generally small, the unloaded Q of the primary ($L_1$) and secondary ($L_2$) windings need not cause particular concern; the form can be selected almost entirely on the basis of packaging.

The transformer for this example will be designed for a standard Cambion coil form No. 1532 (PLST). To allow for sufficient adjustment of the coupling (the moving of one coil with respect to the other), the length ($l$) of each coil will be made half the length of the coil form, or 0.140 inch.

**Wrapping up coil design**

Also, for ease and consistency of fabrication, the coils will be closely wound. The following equations are used to determine both the total number of turns required and the diameter of the wire used:

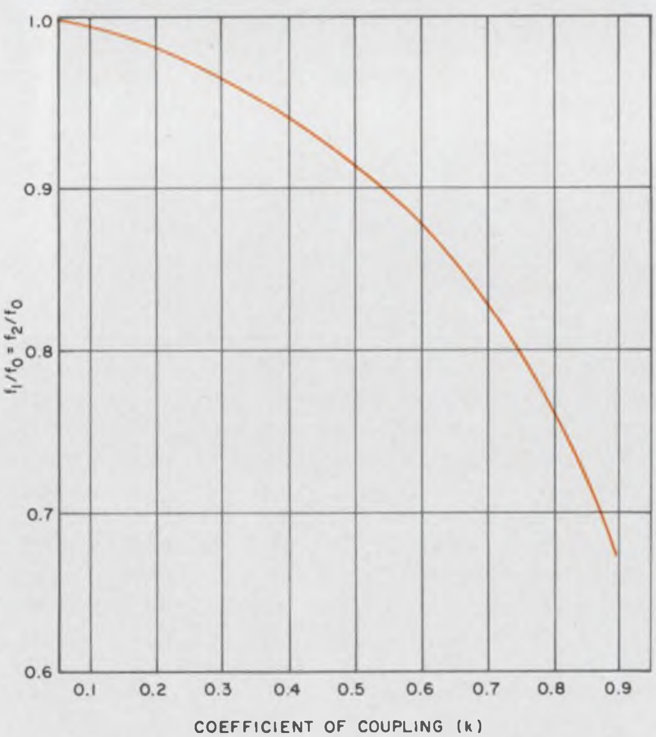
$$l = Nd \text{ (close windings)} \quad (10)$$

$$N^2 = L_o(9l + 3D)/0.2D^2 \text{ (single-layer coil).} \quad (11)$$

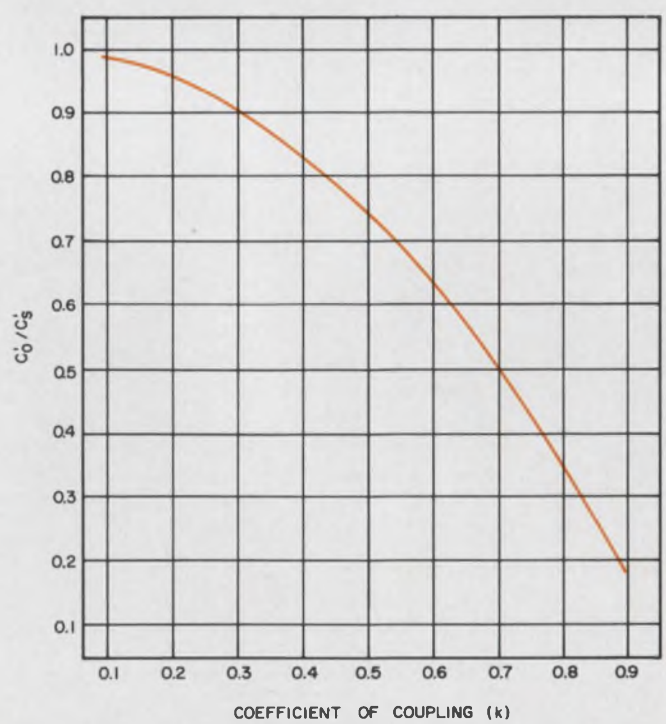
In Eqs. 10 and 11, $L_o$ is the air core inductance in microhenries, $D$ is the mean diameter of coil in inches, $l$ is the length of windings in inches, $N$ is the total number of turns, and $d$ is the diameter of wire in inches.

When the appropriate dimensions for the No. 1532 coil form are substituted into the equations, the latter reduce to $D = 0.205$ (if the diameter of the coil form is much greater than $d$) and $l = 0.140$ (half the length of the coil form).

We may now write $d = 0.140/N$ and $N = 14.9 (L_o)^{1/2}$ as simplified expressions. Since $L_1$ of the primary winding is $1.3\mu$H, $N = 14.9\ (1.3)^{1/2} = 17.0$ turns and $d = 0.140/17.0 = 0.0082$ inch (for No. 32




7. **A plot of the ratio** of primary and secondary resonant frequencies to center frequency, as a function of coupling coefficient, is used to compute transformer inductances.




8. **Proper coupling between stages** must account for the ratio of the open-circuit capacitance to the short-circuit capacitance.

gauge wire). Using a secondary winding inductance of $L_2 = 0.31\ \mu H$, we see that $N = 14.9\ (0.31)^{1/2} = 8.3$ turns and $d = 0.140/8.3 = 0.0169$ inch (for No. 26 gauge wire).

### Winding up transformer needs

To ease the winding of the secondary on top of the primary, a single-layer piece of Scotch or Teflon tape should be put between the windings. After the transformer is wound, the following procedure is used to check the windings for accuracy and adjustment for the proper coupling:

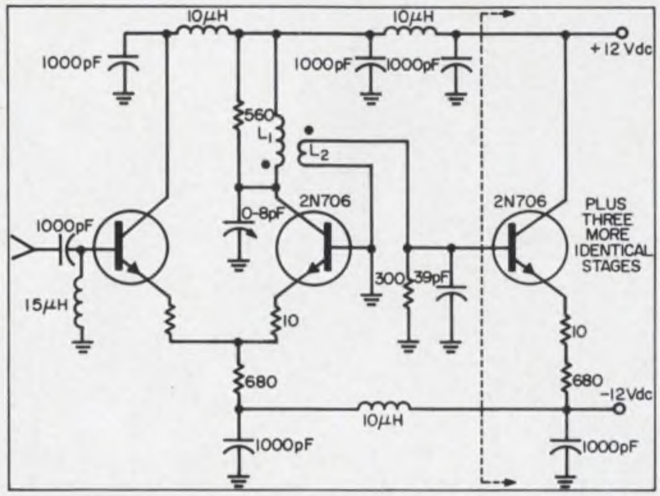
With a meter such as the Boonton $R_x$, model 250-A, measure the resonant capacity of the primary coil at $f_1$ and check to see if it agrees with $C_1$. If it doesn't, add or remove turns, as required, until $C_1$ is reached. Repeat the same procedure for the secondary coil, using $f_2$ and $C_2$ values (see box).

Measure the resonant capacity $C_o'$ of the primary at the center frequency ($f_o$) with the secondary open-circuited. Once again we must use a master design curve—namely, the plot of coupling coefficient as a function of the ratio of open-circuit capacitance to short-circuit capacitance (Fig. 8). Using $k = 0.615$, we pick off a $C_o'/C_s'$ ratio of 0.625. Using the measured value of $C_o' = 9.6$ pF, we calculate $C_s' = 15.3$ pF.

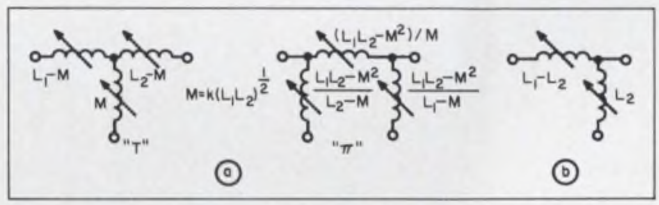
Now short-circuit the secondary and adjust it with respect to the primary, until the primary resonates with the capacity value (used) equal to $C_s'$.

### Complete IF strip uses 4 stages

Establishment of the transformer elements completes the design of the IF strip. Each of the four stages makes use of two 2N706 transistors (Fig. 9) and standard value components for the resistive and capacitive units.




9. **Complete IF strip consists of** four stages, has over-all gain of 30 dB over a bandwidth of 30 MHz and a center frequency of 45 MHz.




10. **For better parameter control,** either of the transformer circuits shown in "a" may be used (in place of the unit in Fig. 9). The "degenerate T" (b), which uses only two inductors, is still another alternative.

Alternate designs may be turned to for the double-tuned transformer portion of the circuit. If packaging allows, either of the equivalent circuits shown in Fig. 10a could be used to give better control of the parameters, especially for production units.

A special form of the equivalent "T," called a degenerate "T," could also be used. Note that with the degenerate "T" the condition $L_2 = M = k(L_1 L_2)^{1/2}$ must be satisfied (Fig. 10b).

If there is a need for variable coils, powdered-iron cores can be used. Eqs. 10 and 11 are still used to determine the coil construction parameters, with the inductance $L_o$ modified by

$$L_o = \frac{L}{\left[1 + a\left(\frac{r_1}{r_2}\right)^2\left(\frac{l_1}{l_2}\right)(u-1)\right]}, \quad (12)$$

where $L_o$ is the air-core inductance, $L$ the powdered-iron core inductance, $r_1$ the radius of iron core and $r_2$ the mean radius of the coil.

Also, $l_1$ is the length of core and $l_2$ the length of coil; $a = 0.8$, when $l_1$ is less than $l_2$, and 1.0 when $l_2$ is less than $l_1$, and $u$ is a factor equal to 1.5 to 3.0, depending on the density of the coil form used. With the No. 1532 form, $L_o = 0.8L$ with a centered iron core. ■ ■

### Measured data from Rx meter

| Parameter | $C_p$ | $R_p$ |
|---|---|---|
| $Y_{ie}$ | 35.5 pF | 150 Ω |
| $Y_{oe}$ | 6.4 pF | 1560 Ω |
| $Y_{oeo}$ | 6.4 pF | 220 Ω |
| $Y_{ebscb}$ | −25 pF | 38 Ω |

Note that this data was taken with the 2N706 transistor. The device was biased with a $V_{ce}$ of 12 volts dc at a collector current of 8.0 mA. The measurement frequency was 30.0 MHz. Jig decoupling-capacitor used was 1500 pF and the RFC coil was 18.0 $\mu$H.

This data was used in calculating the values of the short-circuit Y-parameters ($Y_i$, $Y_r$, $Y_f$ and $Y_o$) for the three basic configurations (see Table on p. 40).


**Reference:**

TECHNEWS, Amperex Electronic Corp., Jan.-Feb. 1961, Vol. II, No. 1.

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COMPARISON OF ELECTRICAL PARAMETERS

| Parameters | Amperex 2N2857 | Amperex A485 |
|---|---|---|
| $f_T$ (min) $V_{CE}$ = 5V | 1000 Mc at $V_{CE}$ = 6V, $I_C$ = 5 ma | 1000 Mc at $I_C$ = 2 ma<br>1300 Mc at $I_C$ = 20 ma |
| $h_{FE}$ (min) $V_{CE}$ = 1V | 30-150 at $I_C$ = 3 ma | 25-200 at $I_C$ = 2 ma<br>20-200 at $I_C$ = 20 ma |
| NF (max) 200 Mc | – | 3.5 db |
| 450 Mc | 4.5 | 4.5 db |
| $C_{obo}$ (max) | 1.8 pf | 1.5 pf |
| $C_{re}$ (max) | – | 0.8 pf |
| $V_{CE}$ sat (max) | – | 0.25 V |
| $V_{BE}$ sat | – | 0.75-0.95 V |
| $d_{im}$ (Intermodulation distortion) | – | -53 db typ. |

$I_C$ = 14 ma, $V_{CE}$ = 6V

f = 217 mc

$V_o$ = 10 mv, $R_2$ = 37.5Ω

$f_1$ = 183 Mc, $f_2$ = 200 Mc

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# **Make impedance matching easier** by dividing the Smith chart into regions that provide a quick insight into the effects of alternate matching circuits.

The engineer needs no special expertise to use the Smith chart to solve impedance-matching problems. By dividing it into eight regions, he can quickly pick out the best matching circuit with the minimum number of components.

Every engineer who spends any part of his time with microwave problems eventually encounters impedance-matching networks. In a typical situation, an antenna or a transistor must be matched to a system. Since the impedance of the element to be matched is known, the designer usually turns to the Smith chart to find the simplest and best impedance-matching network.

The regions of the Smith chart, shown in Fig. 1, are bounded by circles of constant resistances and conductances. The circled numbers inside each of the eight areas correspond to the recommended matching circuits.

If the impedance of the element to be matched falls in regions I, II, III or IV, a single reactance will do the job. In regions I and II series or shunt capacitances, respectively, are needed. In regions III and IV series or shunt inductances are needed, respectively.

If there is a bandwidth to be matched, the situation becomes more complex. A single reactance for impedance matching will do the following:

- Shunt C: Moves the high frequency more than the low frequency.
- Shunt L: Moves the low frequency more than the high frequency.
- Series C: Moves the low frequency more than the high frequeny.
- Series L: Moves the high frequency more than the low frequency.

### Two reactances needed at pheriphery of circle

An impedance in regions V, VI, VII or VIII can be matched with a better than 2:1 vswr only through the use of two or more reactances. Again, the circuits in Fig. 1 show the different alternatives for achieving the best vswr. The choice depends on the availability of dc bias, the need for dc grounding and so on.

Note that a series reactance moves an impedance along a line of constant resistance, and a shunt reactance moves an impedance along lines of constant conductance. (The constant conductance lines can be visualized by overlaying a reversed transparent Smith chart on top of another Smith chart so that zero impedance on one chart is over infinite impedance on the other.

A parallel resonant circuit that shunts the load can wrap an impedance plot of the type shown in Fig. 2 into a smaller circle. A series resonant circuit in series with the load improves impedances of the type shown in Fig. 3.

The amount of improvement can be controlled by varying the LC ratio of the resonant circuit, or, if transmission lines are used at matching elements, by varying the characteristic impedance of the stub.

An impedance that plots in either region V or VII may also be improved through an in-line transformer.

In region V the characteristic impedance of the in-line transformer must be lower than that of the chart's center. In region VII, the transformer's impedance must be higher.

The in-line transformer may be larger than several lumped Ls and Cs, but it provides a match over a greater bandwidth. The in-line transformer is a distributed equivalent of cascaded Ls and Cs, with a certain characteristic impedance and an electrical length. Its design combines the Smith chart and the $Z\Theta$ chart.

### In-line transformer from $Z\Theta$ chart

The characteristic impedance of an in-line transformer is given by the equation:[1]

$$Z_{trans} = \sqrt{\frac{R_L |Z_G|^2 - R_G |Z_L|^2}{R_G - R_L}}, \qquad (1)$$

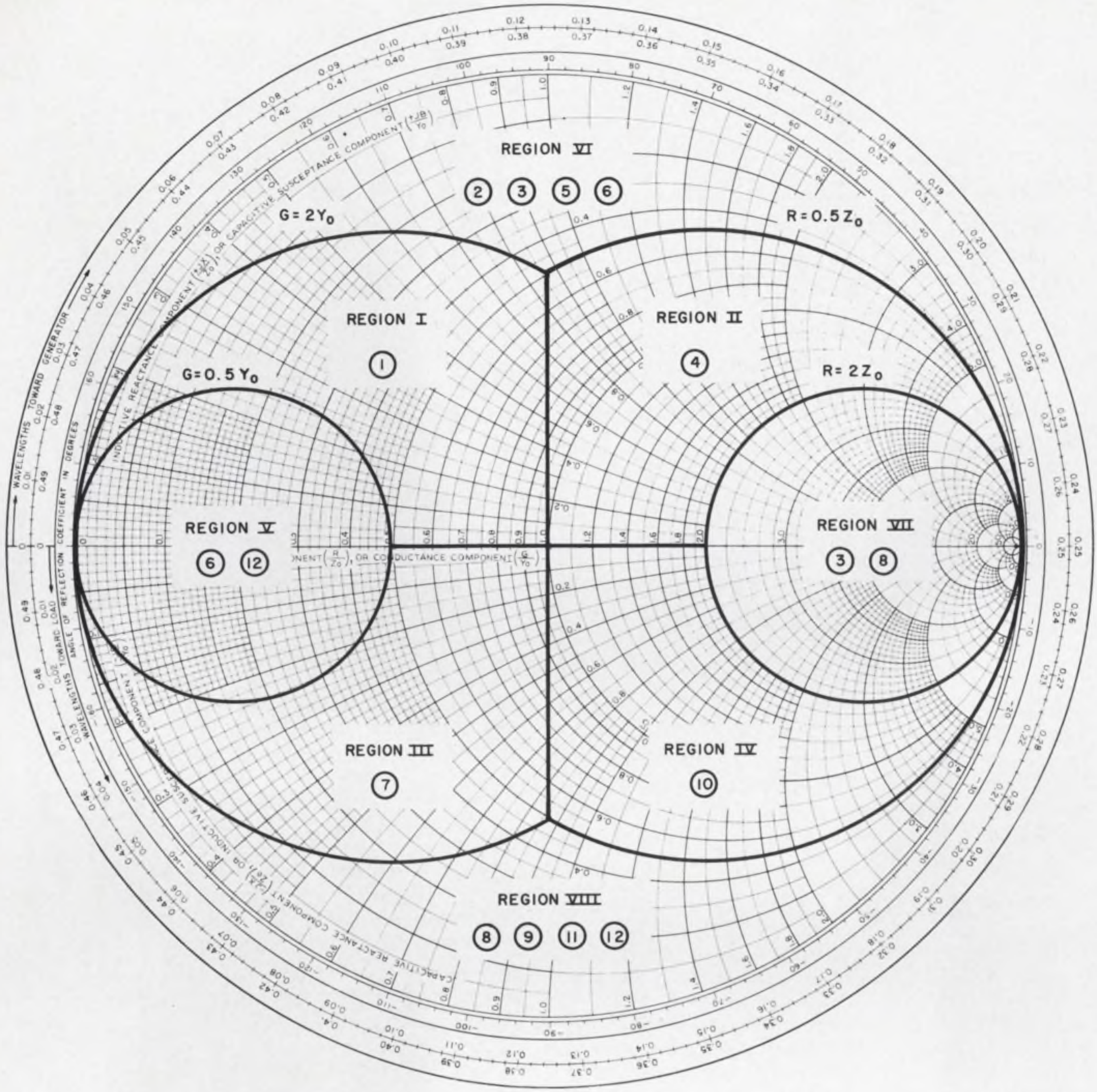
and its length is determined by:

$$\tan(\beta l)_{trans} = \frac{Z_o(R_L - R_G)}{R_L X_G - R_G X_L}, \qquad (2)$$

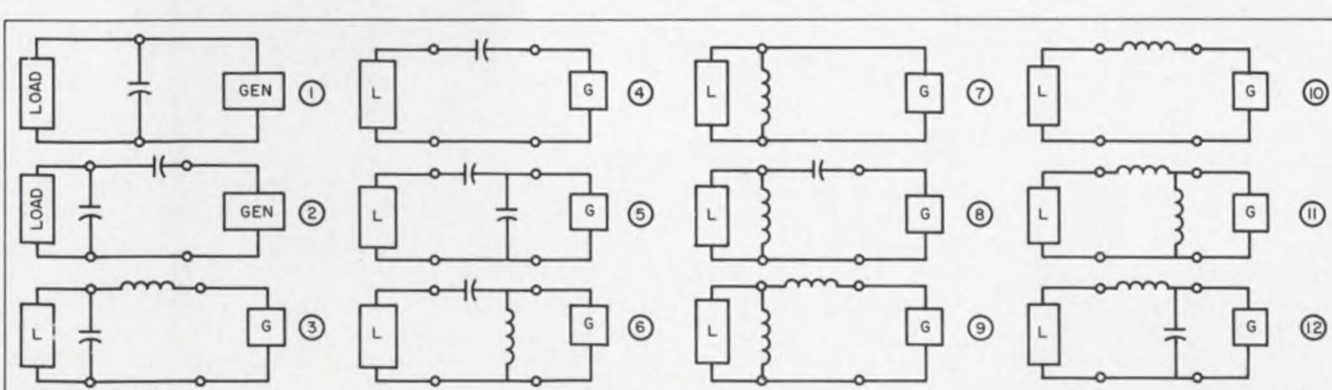
where

$Z_G$ = generator impedance = $R_G \pm jX_G$, and

**Gerald E. Martes,** Section Head, Antennas, Electronic Specialty Co., Los Angeles.

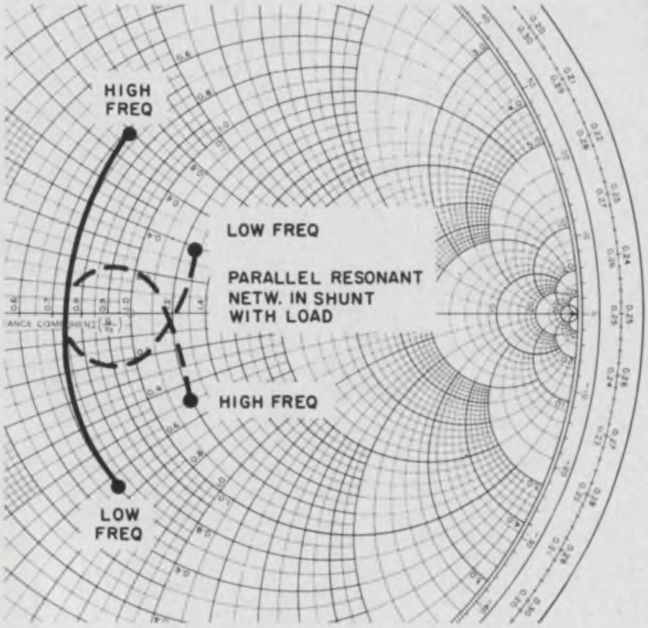



(a)

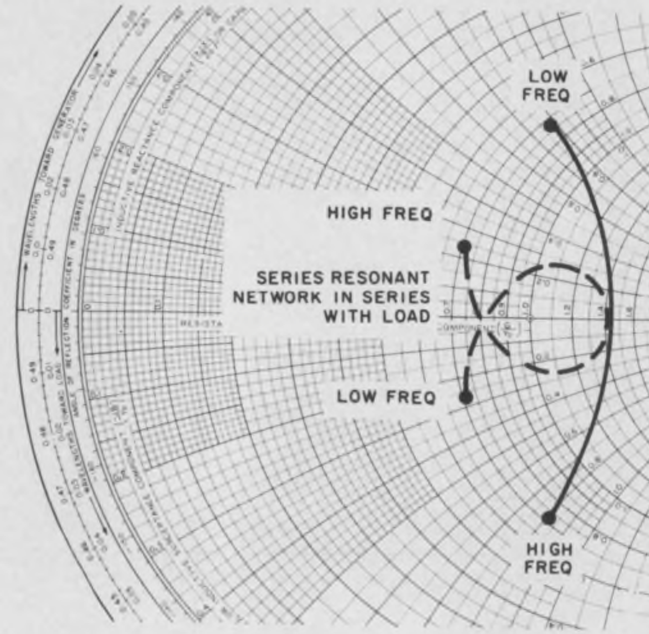



(b)

1. **Divide the Smith chart into eight regions** for a quick look at the effects of matching circuits (a). The circles inside the areas correspond to the recommended matching circuits (b) that use the least number of components.




2. **Parallel resonant circuit,** in shunt with the load, wraps certain impedances into a smaller circle, and thus improves the match.




3. **Series resonant circuit,** in series with the load, improves the match for impedances represented by the solid line.

$Z_L$ = load impedance = $R_L \pm jX_L$.

Obviously it is easier to use the Smith chart than the equation. The exception is if the load impedance falls on the resistive axis. In this case the in-line transformer must be a quarter-wave long, and its impedance is easy to compute without the chart:

$$Z_T = \sqrt{Z_{gen} Z_{load}} \quad . \tag{3}$$

However, if the load is complex, the so-called $Z\Theta$ chart is helpful in determining the characteristic impedance and the length of an in-line transformer. A load impedance, plotted on a Smith chart with 50 ohms as its center, can be replotted on to a $Z\Theta$ chart of the same size by overlaying the Smith chart on a $Z\Theta$ chart and piercing through the impedance point on to the $Z\Theta$ chart. The resulting point on the $Z\Theta$ chart identifies the $Z\Theta$ of the load. The overlaying and piercing operation simply converts the rectangular coordinates of an impedance to its polar coordinates.

The $Z\Theta$ chart is a valuable tool when a load impedance must be converted from one characteristic impedance reference to another. For instance, consider the in-line junction of two transmission lines with different $Z_o$'s. The load impedance, plotted with reference to one $Z_o$, can be quickly replotted with reference to the other $Z_o$ by moving the load point along a line of constant angle. The amount of shift depends on the ratio of the two $Z_o$'s.

### How the charts are used

Consider the following problem: At a frequency of 1080 MHz, match an impedance of 250 $-j150$ Ω with an in-line transformer.

Plot the impedance on a $Z\Theta$ chart. This may be done by converting $R\text{-}jX$ to $Z/\Theta$, using the fundamental mathematical method, or by overlaying the Smith chart plot (Fig. 1) on a $Z\Theta$ chart (Fig. 4). (The charts must be of the same size and have the same center $Z_o$.) Pinpoint through the plot on to the $Z\Theta$ chart. The load impedance is 290 ohms, at 31°.

With a compass, draw an arc that passes through the load impedance and the $\Theta = 0$ line. This is approximately $7Z_o$ in this example.

Compute the line tranformer's $Z_o$ with $Z_{load} = 7Z_{gen}$:

$$Z_T = \sqrt{(Z_{gen})\ (Z_{load})} = \sqrt{(Z_{gen})\ (7Z_{gen})} = \sqrt{7\ Z_{gen}^2} = 2.65\ Z_{gen}.$$

$Z_T = 2.65 \times 50\Omega = 132.5\Omega$.

Replot the load on a $Z\Theta$ chart with 132.5Ω as its center:

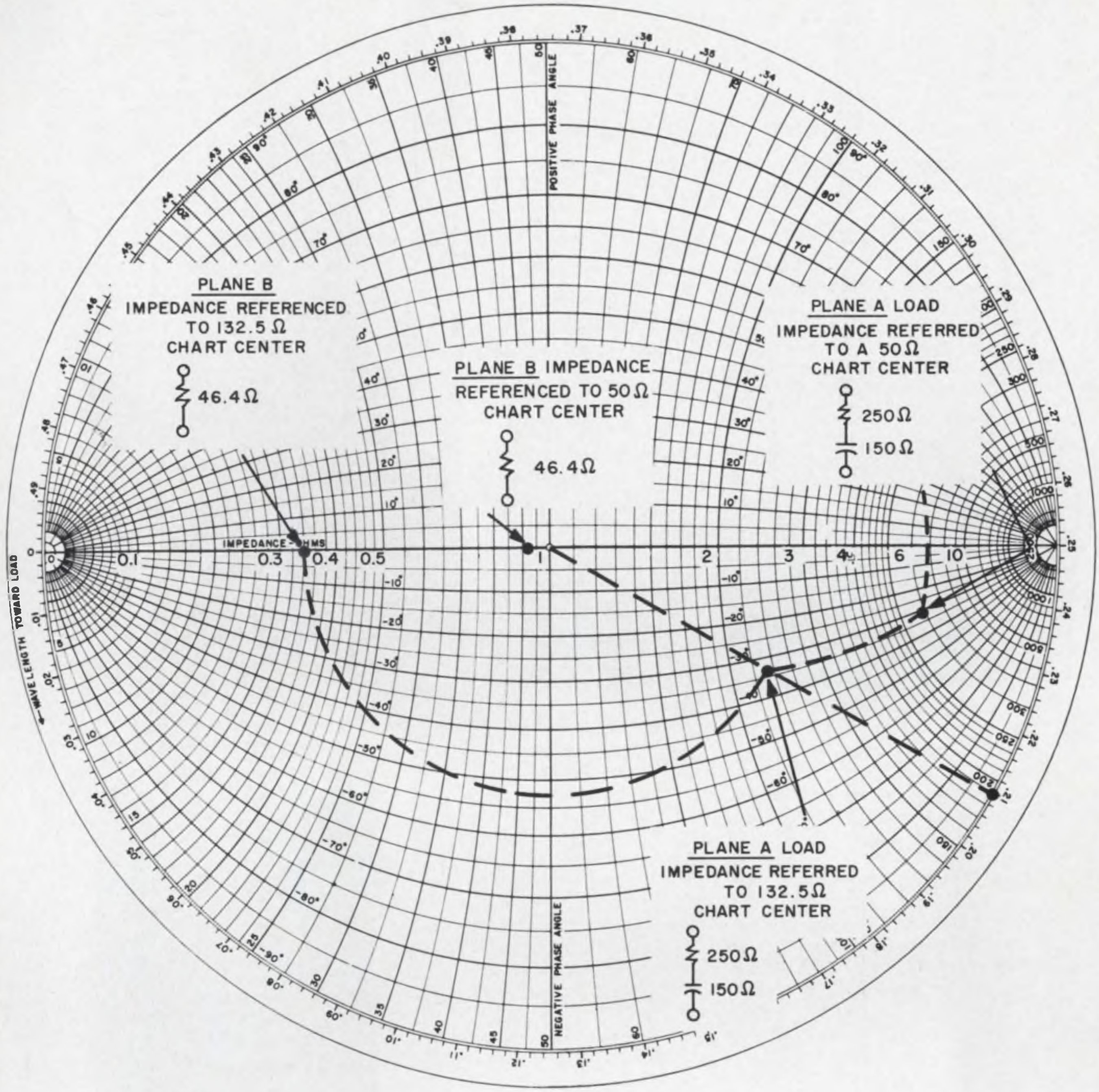
$$\frac{Z_{load}}{Z_o} = \frac{290/\underline{-31^\circ}}{132.50} = 2.19/\underline{-31^\circ}\ .$$

Draw a straight line from the chart's center through the load $Z_o$ (referenced to the in-line transformer $Z_o$) out to the edge of the $Z\Theta$ chart. From the intersection of this line with the edge of the chart, determine the length of the in-line transformer. In this example the transformer must be 0.21λ to move the plot toward the generator to the purely resistive line.

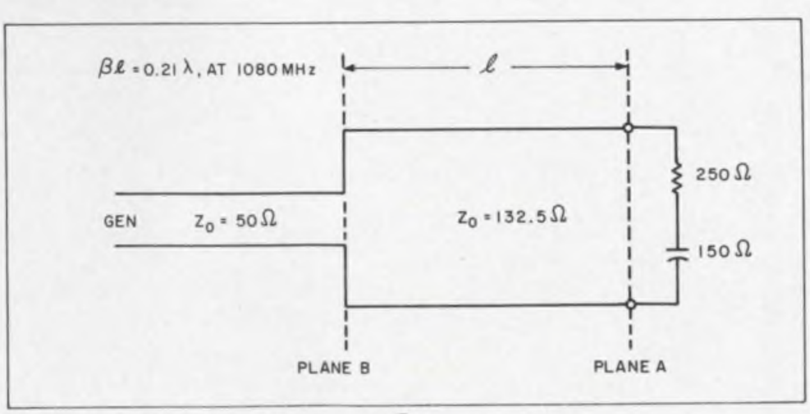
The impedance, at this plane, can be transferred back to a 50-Ω $Z_o$ line, to provide an excellent match. ■ ■

**Reference:**

1. Henry Jasik, Antenna Engineering Handbook, McGraw Hill Co., 1961 p 31-9.




(a)




(b)

4. **Z$\Theta$ chart, combined with the Smith Chart,** is helpful in the design of in-line transformers to match impedances that fall into regions V and VII. The reference $Z_0$ may be changed by a shift along lines of constant angles.

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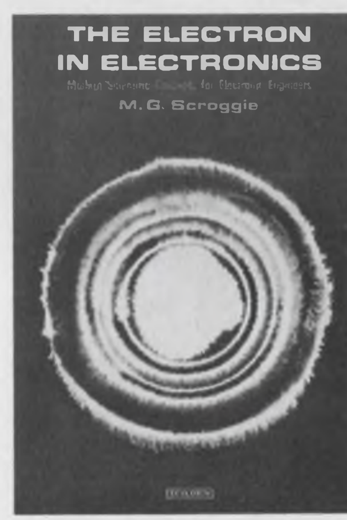


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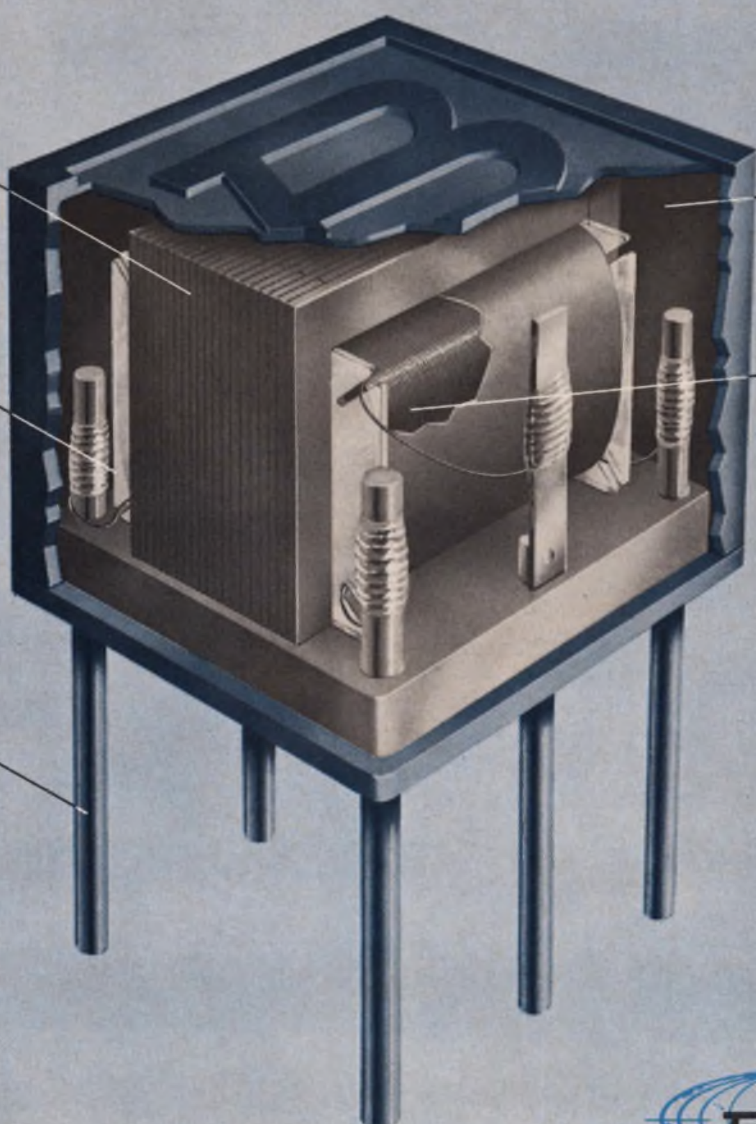


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# **Microelectronics opens the gate** to faster digital computers. Faster algorithms take advantage of reductions in hardware size and cost.

*Part 1 of a two-part article.*

Faster algorithms that take advantage of inexpensive, high-density microcircuits can improve the speed of digital computers' arithmetic units at reasonable cost.

In general, any increase in computer speed requires additional hardware. Up to a point the increase in speed is proportionally greater than the required increase in hardware. Advances in integrated-circuit technology, however, have given the designer greater freedom in dealing with this speed-to-hardware trade-off. Greater circuit density in less space and at lower cost now permits the use of algorithms that simply weren't feasible a few years ago.

The phase of computer design to be dealt with here is the procedure by which the computer executes arithmetic functions. Methods for both high-speed addition and multiplication will be discussed.

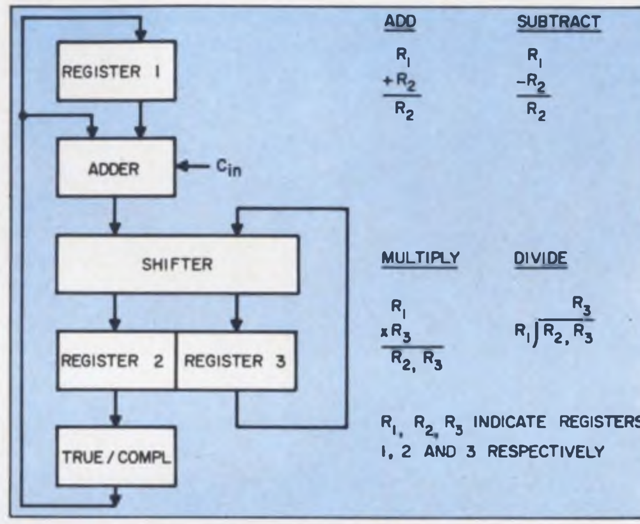
First will be the slowest form of parallel adder, the *ripple-carry adder*, which allows a carry to ripple through each adder position from the lowest-order bit to the highest, one position at a time. The ripple-carry adder will then be used as a basis for comparison for a second method, which allows the carry to skip across adder positions rather than ripple through them. This is called, predictably enough, the *carry skip* technique. Boolean expressions will be used to describe the operation of both the ripple carry and carry skip techniques.

Finally, improved methods of binary multiplication will be described and compared with the basic method of multiplication by repeated addition.

The basic arithmetic unit in a digital computer consists of the registers, adders, controls and other elements used to perform fundamental arithmetic operations. Fig. 1 shows a minimum configuration for a parallel arithmetic unit.

Registers 1 and 2 hold arguments for addition and subtraction. The result from the adder replaces the contents of register 2. Multiplication begins with the multiplicand in register 1 and the multiplier in register 3. The high-order bits of the product are obtained in register 2, while the low-order bits are obtained in register 3.

Division starts with registers 2 and 3 holding the dividend, and register 1 holding the divisor. When the operation is complete the quotient is in register 3, with the remainder in register 2.




1. **Here is a basic parallel arithmetic unit** as used in a digital computer. How the circuits process data to produce the desired result is explained in the text.

Subtraction is performed by 2's complement addition. The contents of register 2 are inverted before entering the adder by passing through the complement gates, and an additional *1* is effectively added by inserting a carry into the low order position of the adder.

The shifter is used for shifting intermediate results during multiplication and division. It may also be used for aligning operands before addition, or for shifting the final result.

Modern arithmetic units are considerably more complex than this basic parallel arithmetic unit. They include additional adders and registers; in some systems, addition, multiplication, and division are performed in separate, special purpose units to permit optimization in the design, and concurrent operation.

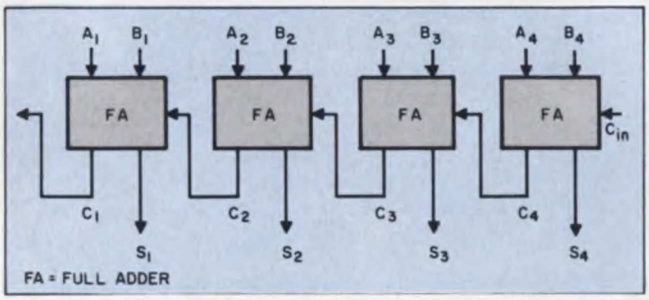
## Fast parallel adders

The ripple-carry adder is a simple parallel adder consisting of identical stages, one corresponding to each bit position of the incoming operands. Each stage produces a sum output and a carry output based on the corresponding bits of the two input operands and the carry from the previous stage. These stages are called full adders and are interconnected as shown in Fig. 2 to form

**Martin S. Schmookler,** Project Engineer, IBM, Poughkeepsie, N. Y.

**Handling multiplier bit-pairs**

| Multiplier Bits | Old Borrow | Multiple Required | New Borrow |
|---|---|---|---|
| 00 | 0 | 0 | 0 |
| 01 | 0 | 1 | 0 |
| 10 | 0 | 2 | 0 |
| 11 | 0 | —1 | 1 |
| 00 | 1 | 1 | 0 |
| 01 | 1 | 2 | 0 |
| 10 | 1 | —1 | 1 |
| 11 | 1 | 0 | 1 |




2. **Carries ripple through** the full-adder stages of this 4-bit ripple-carry adder. Eliminating the stage-by-stage ripple increases the adder's speed of operation. Ripple time limits the speed of this adder.

the parallel adder. Carries ripple through each succeeding stage starting from the lowest-order bits.

The speed of the ripple-carry adder is limited by the time required for the carry to ripple through each stage. The methods used for accelerating addition aim at speeding up stage-to-stage transmission of these carries.

The logic functions describing the sum and carry in each stage are:

$$S_n = (A_n \oplus B_n) \oplus C_n^{+1},$$

where $\oplus$ indicates the EXCLUSIVE OR, and

$$C_n = A_n B_n + (A_n + B_n) C_n^{+1},$$

In the expression for the carry, the $AB$ term signals when a carry is generated at that stage, while the $(A+B)$ term signals when a carry can propagate through the stage. We can therefore define two auxiliary functions, carry *generate*, $G_n$, and carry *propagate*, $P_n$:

$$G_n = A_n B_n$$

$$P_n = A_n + B_n$$

We can rewrite the carry expression as:

$$C_n = G_n + P_n C_n^{+1} \tag{1}$$

For a four-bit adder, (see Fig. 3) the carries can be generated directly from the inputs, elim-

## The speed/cost trade-off

To illustrate the relationship between speed and cost, consider two algorithms for decimal multiplication. Algorithm A is illustrated below.

```
     76   Storage Registers:      multiplicand   1
  ×  43                           multiplier     1
  -----                           product        1
     76
  +  76   Total hardware:         3 registers and
  -----                           1 adder
    152
  +  76
  -----
    228   For many-digit numbers, time required
  +  76   is:  worst-case           9 additions/digit
  -----        average            4.5 additions/digit
    988
  +  76
  -----
   1748
  +  76
  -----
   2508
  +  76
  -----
   3268
```

In this algorithm, multiplication is done by adding the multiplicand a number of times equal to the multiplier digit. A worst case of 9 additions could be required, but the average should be only 4.5 per digit. Besides the adder, 3 registers are required. The result of each addition is stored in the third register, which, at completion, contains the product.

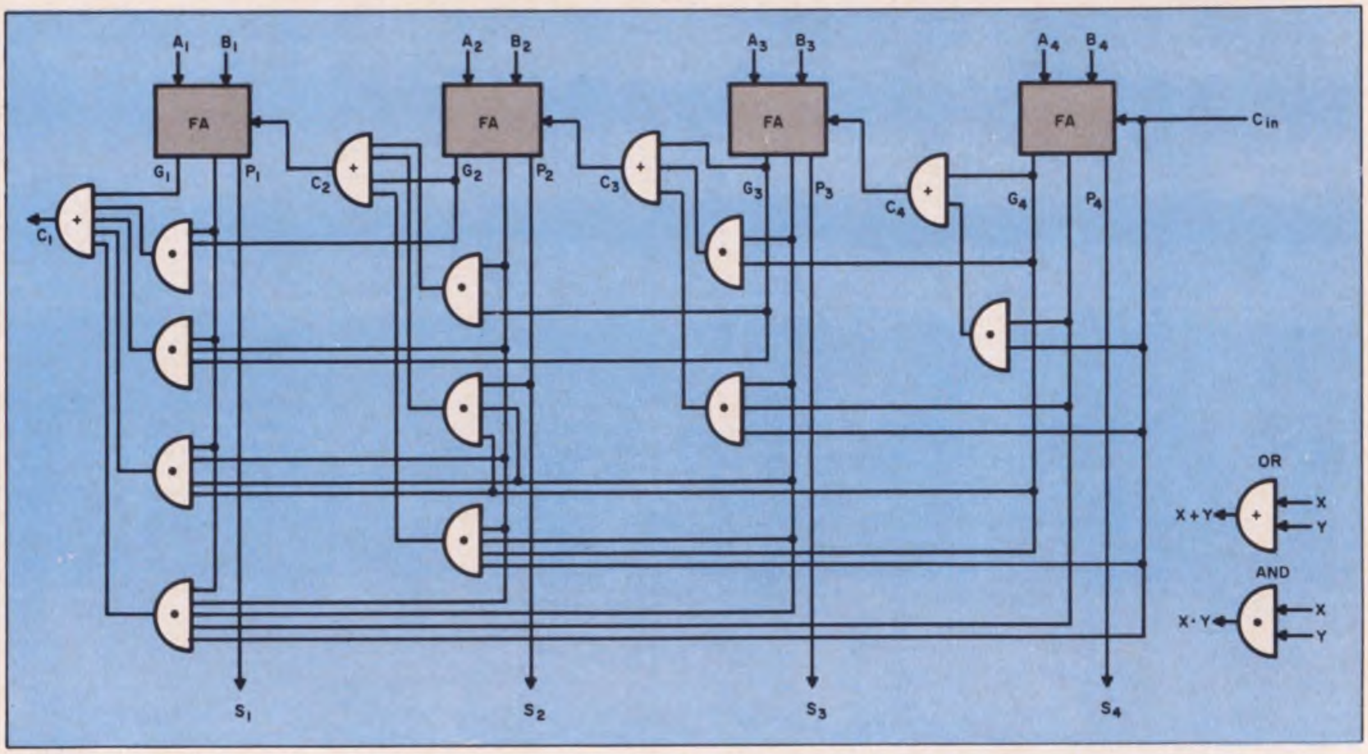
Algorithm B, which accomplishes the same result, is shown below.

```
     76   228 (3× multiplicand)
  ×  43
  -----
    228   Storage Registers:      multiplicand     1
   228                            multiplier       1
  -----                           3× multiplicand  1
   2508                           product          1
     76
  -----
   3268   Total hardware:         4 registers and
                                  1 adder

      For many-digit numbers, time required is:
          worst-case              4 additions/digit
          average               2.1 additions/digit
```

In this algorithm, three times the multiplicand is first obtained and stored in a register for future use. A worst case of 4 additions could be required (if digit is 8), with an average of 2.1 per digit. Two additions are also needed initially to obtain the 3-times multiplicand. For many-digit numbers, this method requires less than half as many additions as algorithm A, but an extra register is needed. Assuming that the adder requires about twice as many circuits as a register, an increase in cost of about 20% gives a better than 2:1 speed improvement, for this particular example. If more registers were used, further improvement would be obtained, but it would be proportionately much less.

In the above example, only the relative cost and speed for the multiplication function were considered. In practice, one should compare the relative costs and over-all speed of the entire system. Functions which are used frequently might be designed for speed, while other functions which are seldom used might be designed for minimum cost.




3. **This 4-bit adder** uses the auxiliary functions generate (G) and propagate (P) to speed up the transmission of carries between full-adder stages. An adder using these functions is called a carry-look-ahead adder.

inating the delays through each stage. The functions for each carry are found by substitution in equation (1):

$$C_4 = G_4 + P_4 C_{in} \qquad (2)$$

$$C_3 = G_3 + P_3 C_4$$
$$= G_3 + P_3 G_4 + P_3 P_4 C_{in} \qquad (3)$$

$$C_2 = G_2 + P_2 C_3$$
$$= G_2 + P_2 G_3 + P_2 P_3 G_4 + P_2 P_3 P_4 C_{in} \qquad (4)$$

$$C_1 = G_1 + P_1 C_2$$
$$= G_1 + P_1 G_2 + P_1 P_2 G_3 + P_1 P_2 P_3 G_4$$
$$+ P_1 P_2 P_3 P_4 C_{in}, \qquad (5)$$

where $C_1$ is the carry-out of the adder.

Examining the terms in the expression for $C_1$, we see that the first stage (i.e. the $A_1 B_1$ adder) has a carry if it generates it ($G_1$); OR if it can propagate it and the second stage generates it (e.g. $P_1 G_2$); OR if the first two stages can propagate it and the third stage generates it (e.g. $P_1 P_2$-$G_3$); and so forth. The last term says that there is a carry from the first stage if there is a carry into the fourth stage, and all the intervening stages propagate it.

As the adder gets much larger, three effects prohibit us from implementing the carry functions in this direct matter:

- Fan-in (number of inputs) to the circuit soon exceeds allowable limitations.
- The driving capability of the circuits forming the propagate and generate functions is soon exceeded.
- The number of components increases nearly by the square of the number of bits, and eventually becomes a limiting factor.

It therefore becomes necessary for the adder to be broken into small groups. The carries within a group are only functions of the adder inputs corresponding to the group, and a carry into the low-order bit of the group. For a four-bit group, the expressions for the carries would be the same as shown for the four-bit adder.

The carry, $C_{in}$, into the group would be the carry-out of the next-lower-order group. For a small number of groups, the carries might be permitted to ripple between groups. For a larger number of groups, however, carry speed-up circuits can be used between them.

Looking at equation (5) note that the first four terms are the conditions which generate a carry from the group, while the fifth term is the condition for propagating a carry from the lower groups. Auxiliary functions, similar to those defined for the internal carries of a group, may be defined for the carries between groups.

$G_{Gi}$ = group carry generate

$P_{Gi}$ = group carry propagate

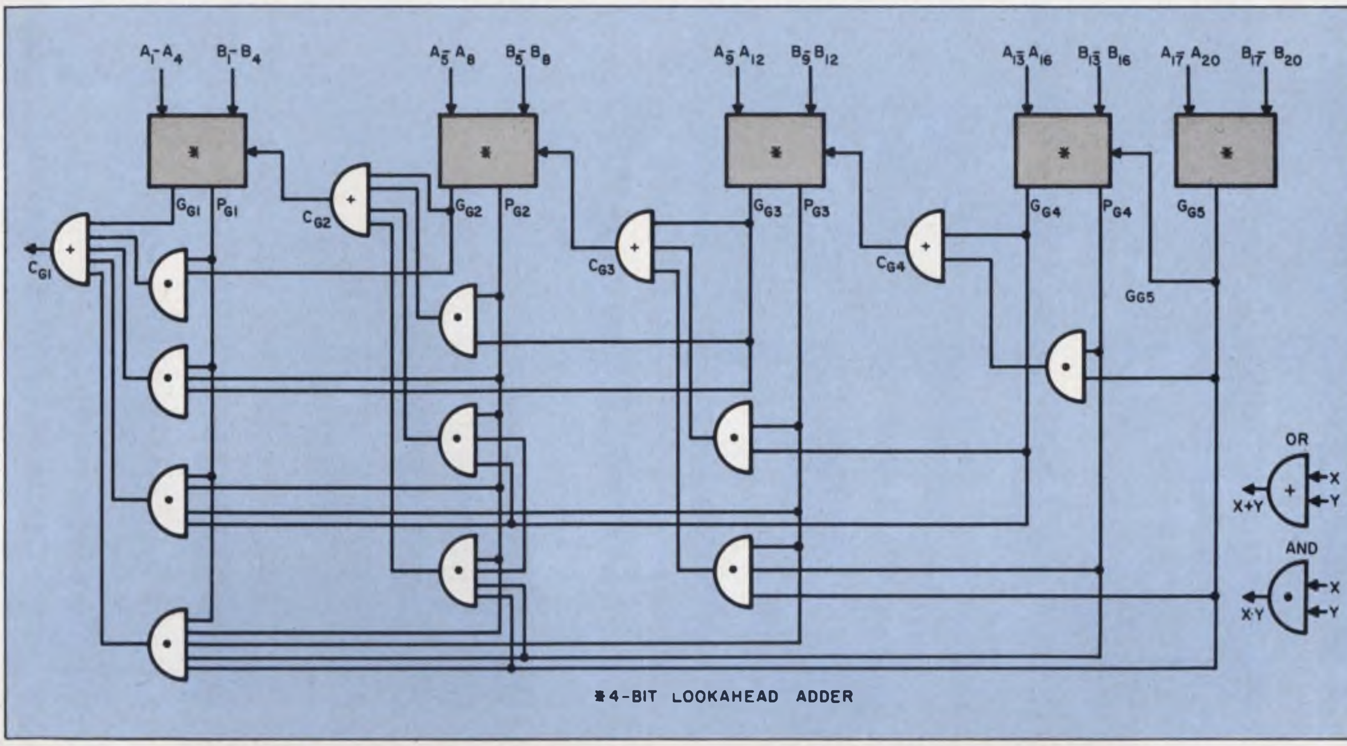
Rewriting the expression for the group carry gives:

$$C_1 = G_{G1} + P_{G1} C_{in}.$$

Suppose an adder has five groups, numbered from left to right. The group carries above the lowest-order group are found by the method used for equations (2) through (5):

$$C_{G4} = G_{G4} + P_{G4} C_{G5}$$

$$C_{G3} = G_{G3} + P_{G} C_{G4}$$
$$= G_{G3} + P_{G3} G_{G4} +$$




4. **Carry-look ahead techniques** are especially useful in large capacity adders. The circuit shown here illustrates the generation of a carry from a group of 4-bit look-ahead adders. Generate and propagate functions are used.

$$P_{G3}P_{G4}C_{G5}$$

and similarly for $C_{G2}$ and $C_{G1}$.

### Look-ahead adder speeds carries

An adder which uses the auxiliary functions *generate* and *propagate* as described above in carry speed-up circuits is called a *carry look-ahead* adder (Fig. 4). The levels which a signal must go through in the longest path of a carry look-ahead adder are as follows.

At the first level, the auxiliary function $P_n$ and $G_n$ are generated simultaneously. Next, the group auxiliary functions are formed. From these, the group carries are developed. The group carries are combined with the auxiliary functions $P_n$ and $G_n$ to obtain the carries to each bit. Thus, only four levels are needed to obtain all the carries. A final level is needed for the sums. Each of the levels cited might require more than one circuit level to implement, depending on the logical power of the circuit family used.

For very large adders, the groups may be organized to form several sections, each section containing many groups. Further auxiliary functions may easily be defined to provide look-ahead between sections. As many as six levels might be needed to obtain all carries. The list of levels for the longest path would be:

1st level: $P_n$, $G_n$, auxiliary function for internal carries
2nd level: $P_G$, $G_G$, group auxiliary functions
3rd level: $P_s$, $G_s$, section auxiliary functions
4th level: $C_s$, section carry
5th level: $C_G$, group carry
6th level: $C_n$, internal carry
7th level: $S_n$, sum

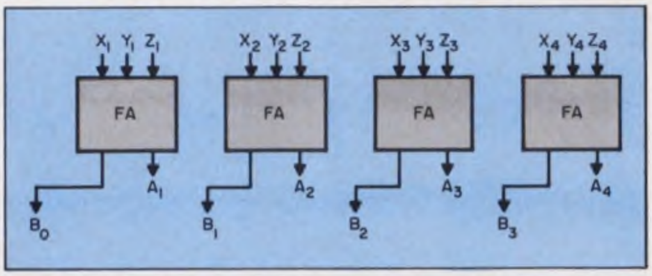
### How a computer multiplies

Multiplication in a binary machine is usually performed by repeated addition. The multiplier is examined one bit at a time from the right hand side to determine when the multiplicand should be added to the partial product, as in the following example:

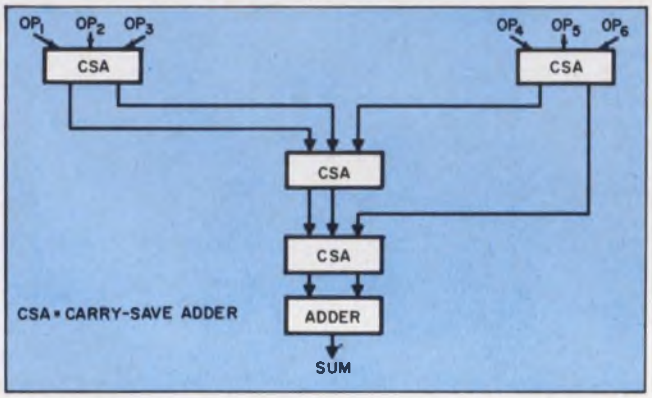
| LONGHAND METHOD | COMPUTER METHOD |
|---|---|
| *1101* | *1101* |
| × *1011* | × *1011* |
| *1101* | *1101* 1st partial product |
| *1101* | *1101* |
| *1101* | *100111* 2nd p.p. |
| *10001111* | *0000* |
| | *100111* 3rd p.p. |
| | *1101* |
| | *10001111* product |

While it appears that the multiplicand is shifted left for each iteration, the proper relative positions between the multiplicand and the partial product can be maintained also by shifting the partial product to the right.

If the multiplier bit under examination is *1*, the multiplicand is added to the partial product. The output of the adder then shifts the result to the right before replacing it in the partial product register. This lines it up in the proper position with respect to the multiplicand when the next bit of the multiplier is examined. If the multiplier bit is *0*, the partial product is shifted without addi-




5. **Carry-save adders** reduce three input quantities to two outputs which can then easily be processed by a parallel adder. This technique can be used to obtain higher multiplication speeds.




6. **Six operands are reduced to two** by use of carry-save adders. The resulting two operands can then be summed in the parallel adder.

tion. A variable shifter can be provided which would permit *0*'s in the multiplier to be skipped over without additional delay. The time required to perform multiplication then is proportional to the number of additions required. On the average, an addition would have to be performed for every two bits in the multiplier. The worst case, however, would require an addition for each multiplier bit, as in the case where they are all *1*'s. Some methods of reducing the number of additions required will now be discussed.

Consider a string of *n1*'s in the multiplier. With respect to the low-order bit in the string, the value of the string would be $2^{n-1} + 2^{n-2} + 2^{n-3} + \dots + 2^1 + 2^0$. It is easily verified that it is equivalent to $2^n - 1$. For example, using a signed digit representation, the string *1111* could be written as *1000-1*. Thus, for any string of ones in the multiplier, one subtraction and one addition of the multiplicand would be sufficient. In practice, subtraction is usually performed by adding the *2*'s complement of the multiplicand. The resulting partial product is always negative after a subtraction, and is usually left in complement form. It should be noted here that when a complement partial product is shifted to right, *1*'s must be inserted at the high-order end.

It should now be apparent that multiplication can be considerably improved by permitting additions and subtractions. The time required to do subtraction is the same as the time required to do addition. Speed of multiplication can therefore be measured by the number of additions and subtractions that must be performed.

Multiplication speed can also be increased by a method which only requires one addition or subtraction for every two multiplier bits. This method permits a uniform shift of two after each iteration. It also provides a basis for understanding how further improvement can be achieved with *carry-save* adders, which will be described later.

In this method, the multiplier bits are considered in pairs. Clearly, if the first pair is *00*, no addition is required. If it is *01* or *10*, only one addition is needed. The pair *10* calls for the two-times multiple of the multiplicand, which is obtained by shifting it one position to the left as it is entered into the adder. The pair *11* calls for the addition of three times the multiplicand. This can be accomplished by subtracting one times the multiplicand from the partial product and later adding the four-times multiple. Since the addition of the four-times multiple is postponed, a "borrow trigger" may be turned on to remember that it must be performed. We must now consider how to treat the pair of multiplier bits when the "borrow trigger" is on. Since the partial product is shifted two places to the right after each iteration, a request for four times the multiplicand may be satisfied with one times the multiplicand after the shift. We therefore take the numerical equivalent of the new pair under consideration and add *1* to it. Thus, the pair *00* is now interpreted to mean a request of one times the multiplicand. Similarly, the pair *01* would now be treated as *10*. The pair *10* would be treated as *11*, which again calls for subtraction of one times the multiplicand, and leaves the "borrow trigger" on. The pair *11* now calls for the four times multiple, which leaves the borrow trigger on, but requires no addition or subtraction during the present iteration. The actions which may be taken for each pair of multiplier bits are summarized in Table 1.

The method of multiplication just described requires one iteration for every two bits of the multiplier. One additional iteration is required if the "borrow trigger" is on after processing the high-order bits. One multiple of the multiplicand is added to the partial product during each iteration. The number of iterations required would be reduced if several multiples could be added to the partial product simultaneously. Naturally, several pairs of multiplier bits would have to be examined at the same time, but this poses no serious problem. The use of *carry-save* adders provides a means of adding more than two operands in a single operation.

### The carry-save adder (CSA) at work

The addition of three quantities is performed as shown below:

*11001110*
*10001100*
*01101101*
*00101111* sums
*11001100* carries
*111000111* final sum

The sums and carries in each column are formed separately. The carries are moved one position to the left so they can be added to the sums to form the final sum. The element which forms the sum and carry in each column is the full adder, which we previously encountered in the discussion of the ripple-carry adder.

The versatility of this element is further exploited in performing the addition of the three quantities shown in the example. The carries are not immediately passed on to succeeding stages but are saved for later use. There is no interconnection between each of the full adders. Figure 5 shows a group of full adders arranged to form the sums and carries of three quantities, $X$, $Y$, and $Z$.

Notice that with full adders, the three quantities are reduced to only two. They can now be added in a parallel adder. A group of full adders used in this manner is called a carry-save adder (CSA).

It may be argued that the same reduction could be achieved by putting two of the quantities through a parallel adder. In fact, a ripple-carry adder would require the same number of circuits. However, the delay through the ripple-carry adder to the carry outputs would be $n$ times the delay through the carry-save adder. If a parallel adder with look-ahead circuits for the carries were used, it would still have considerably more delay than the carry-save adder. It would also require one-and-one-half times or twice the number of circuits.

### Multiplication using CSAs

As we've seen, the CSA reduces three operands to two operands, which can then be added in a parallel adder. Several CSA's may be used if more than three operands must be added. Each CSA reduces the number of operands by one, so that if six operands are to be added, four CSA's would reduce this number to two, which would then be added. A system for adding six quantities is shown in Fig. 6.

With four CSA's, six multiples of the multiplicand can be entered at the start of multiplication, permitting twelve bits of the multiplier to be decoded at once. The resulting sum is the first partial product which must be used as one of the operands on the following iteration. This allows five multiples of the multiplicand to be entered on each iteration after the first, corresponding to ten multiplier bits.

Techniques for increasing the division speed of a computer will appear in Part 2 of this article, in the next issue. ■ ■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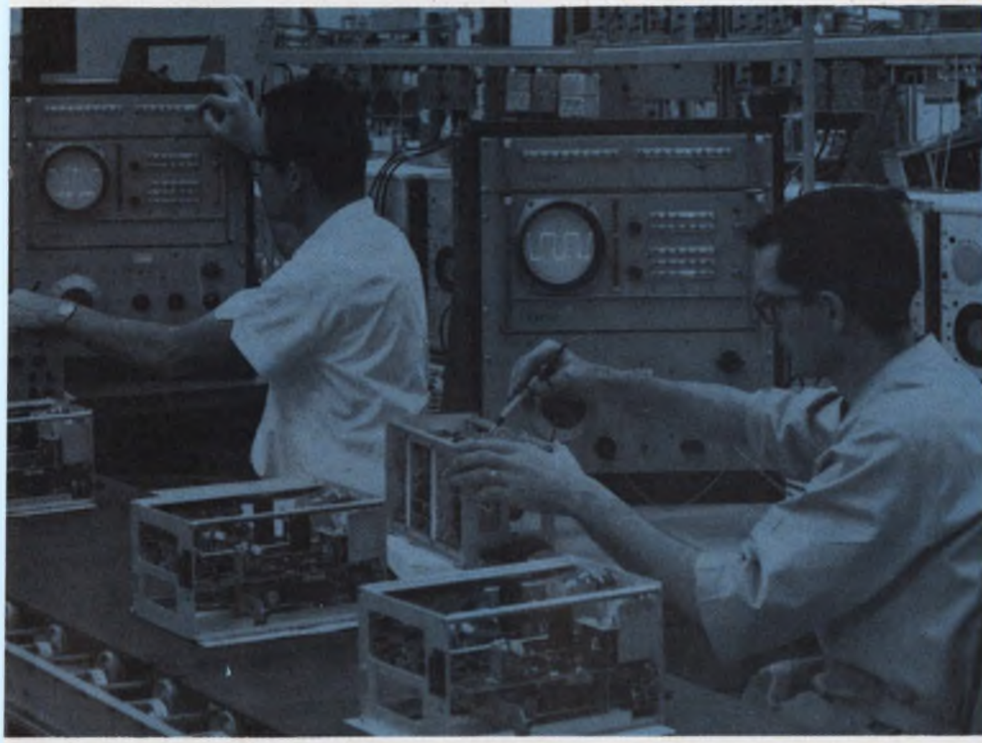

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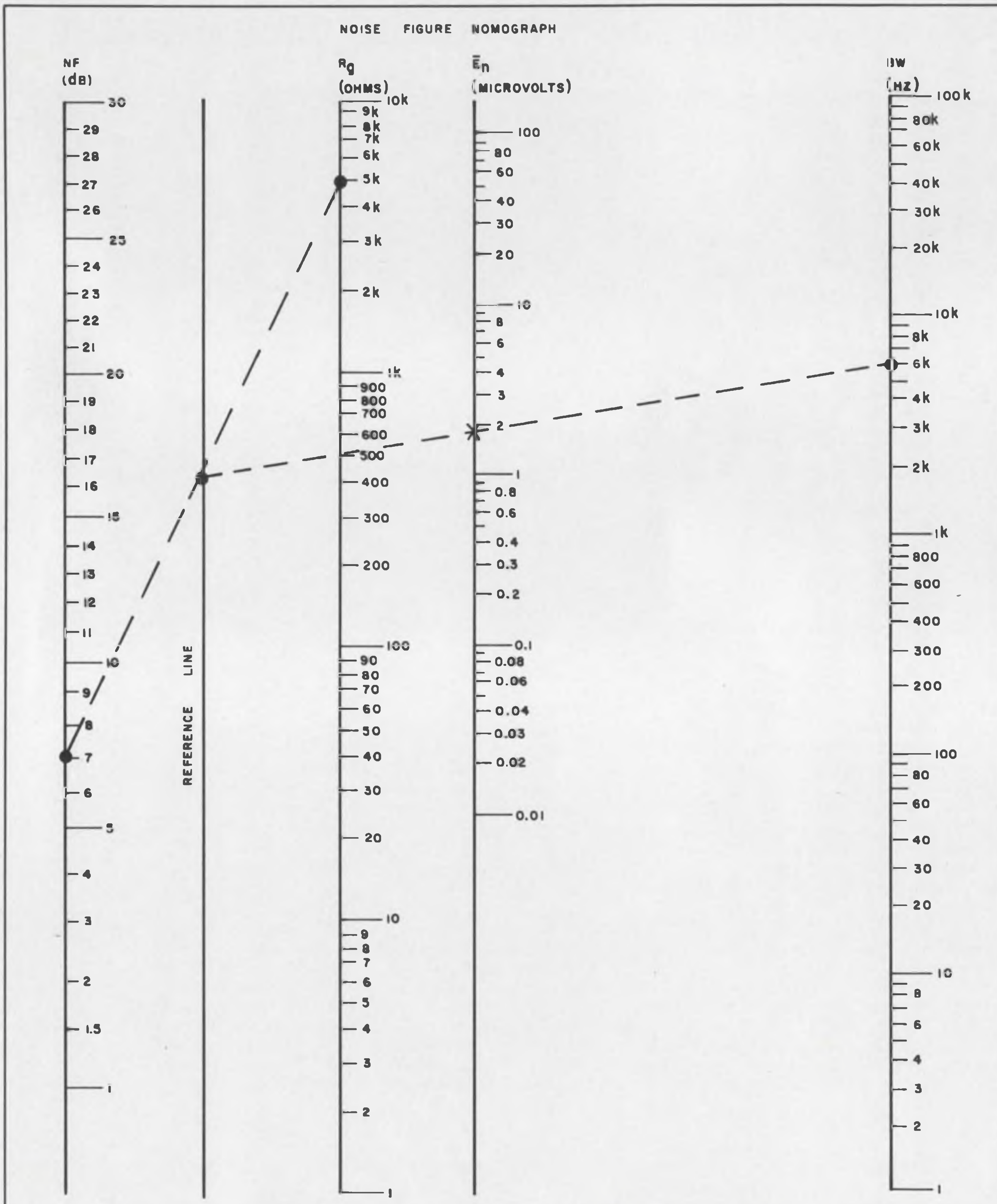
ON READER-SERVICE CARD CIRCLE 19

# Nomograph gives amplifier noise data

rapidly and accurately once a transistor noise figure is known. It also helps to select the correct device.



Here is a nomograph that permits designers to find out quickly the equivalent noise voltage at the input to an amplifier.

To use it, merely take the noise figure of the input transistor stage from the specification sheet. A nomogram scale indicates the amplifier input noise. It also tells if a given transistor is suitable for use in an amplifier stage.

The nomograph is a solution to the well-known equation describing the equivalent-noise input voltage of an amplifier (at room temperature), $E_n$:

$$E_n = 1.58 \times 10^{-10} \sqrt{BW\, R_g (f^2 - 1)} \qquad (1)$$

where $BW$ is the 3-dB bandwidth and $R_g$ is the source resistance (in ohms). In addition the amplifier is assumed to have a high-frequency roll-off of 6 dB per octave, this giving it a noise bandwidth of 1.57 $BW$.

Note that the noise figure, $NF$, rather than the noise-voltage factor $f$ (of Eq. 1), is used in the chart. These two parameters are related by:

$$f = \text{antilog}\, NF/20 \qquad (2)$$

An example will illustrate the use of the nomograph:

An amplifier with a voltage gain of 1000 and a bandwidth of 6 kHz has a maximum output noise specification of 0.002 volt. Will a 2N780 transistor be suitable for the first stage?

### Solution

1. The 2N780 has a noise figure of 7 dB (maximum) for a source resistance of 5 kΩ. Draw a straight line between 7 on the $NF$ scale and 5k on the $R_g$ scale.
2. Connect the point of the intersection of this line and the reference line with the 6-KHz point on the $BW$ scale.
3. This last line crosses the $\overline{E_n}$ scale at 1.75 microvolts. Since the amplifier gain is 1000, the noise output is 0.00175 volt, which is below the allowable maximum. Therefore the 2N780 will be satisfactory. ■ ■

**George Feinman,** Design Engineer, Andrea Radio Corp., New York, N. Y.

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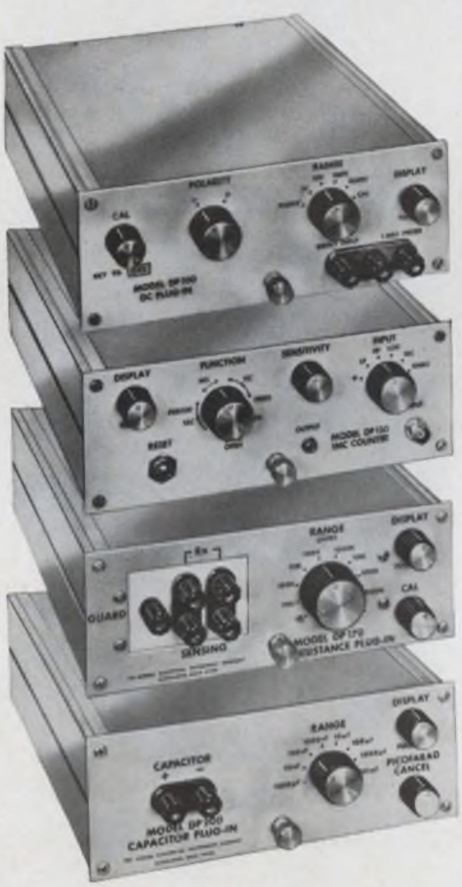

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ON READER-SERVICE CARD CIRCLE 23

# So you want to be an inventor.

## There are three things you had better do before applying for a U.S. patent. Do them before you start to invent.

Many an engineer fancies himself a would-be inventor merely because he has devised something novel. But before he approaches the United States Patent Office with his brainchild, he is well-advised to take three basic steps. Otherwise he is probably wasting his own and everyone else's time.

The three steps are these:

1. He must be sure he has an invention. Odd as it may sound, not all things that the public loosely calls "inventions" qualify as such legally.

2. He must find out if he has something that can be patented. Mere newness is not the final test here; sufficient advantage and ingenuity in comparison with previous inventions in the same field are at stake. A patent search must be made.

3. He must *prove* he is entitled to a patent. Exhibits, drawings, witnesses—all are important in the presentation of the inventor's case. Ideally, the work of getting a patent starts long before the inventor comes up with the finished, patentable product.

### An invention is something tangible

What then is an invention—legally? An invention is a device or process that is useful and has not existed before. Two words in that definition are worth repeating: an invention is a *device* or *process*. A mere idea will not do; neither will a simple discovery nor some profound theoretical research, by itself. Not even an Einstein could patent the Theory of Relativity. The facts obtained through research or discovery must be built into a useful device or method before you have a patentable invention. The inventor must tell the public how to construct the machine or perform the process to derive new and useful results. This is an essential part of invention as defined by the United States Patent Office.

### Check the patents already issued

What is an invention by definition is not necessarily an invention that can be patented. There is the question of whether it is sufficiently new and better than previously known similar devices to merit the grant of a patent. If the invention is a natural result of everyday activities, in all probability it will not satisfy the criteria of the Patent Office. To find out whether he has a patentable invention, the engineer must know what preceded him in the field.

If he works for a good-sized company, he should turn to its patent department. Most patent departments keep files on disclosures submitted to them and will allow the engineer to search them. Larger companies have a scientific library, and the librarian should be consulted for a literature search. The company patent department may run a patent search to determine the state of the art in Washington, D. C., besides checking its own patent files.

Reference librarians in better libraries can do much for the individual inventor by recommending the proper references. If possible, he should also conduct his own search in Washington. This type of search is known as a "pre-x" search and can be undertaken at a minimal cost by the inventor or by his attorney.

Besides becoming more familiar with the problem, the inventor may be able to improve his concept after such research. In any event, he is in a much better position to ascertain whether or not he has a patentable invention.

### How to prove you're "first"

All fair-minded persons agree that, if a patent is to be granted, it should go to the first, the true, inventor. This requires proof—written proof that fixes the time of the invention and shows that the person who signs the patent application is the true inventor.

In organizations where several persons are working or thinking about the same general problem, considerable care must be taken to decide which person is entitled to sign the patent application. If there is any doubt, the patent department should be consulted. If more than one person is to share the credit, then they are joint inventors, and they must be so designated.

The inventor's dated laboratory notebook entries are accepted proofs that he is the first. Therefore, these entries must be made regularly and as completely as possible. Indeed, the inventor should get into the habit of writing down his achievements at the end of each day.

The entries should be made in bound notebooks

**Robert Levine,** assistant resident patents counsel, P. R. Mallory & Co., Inc., Indianapolis, Ind.

that are assigned to the engineer. Records are more easily preserved in a bound notebook, and, more importantly, if they are entered properly, it is virtually impossible to make a change or substitution without detection. Thus, this type of notebook possesses greater credibility than loose-leaf notes. The following rules should be observed when making entries:

- Use ink whenever possible.
- Write the date and a short title for the material at the beginning of each invention.
- Sign and date the entry at the end.
- Have at least one witness, preferably two, read, sign and date the entry at the end.
- Make all entries on a page in handwriting on the same date. Witnesses may sign the page at a later date.
- Don't leave blank space at the bottom of the page.
- Put changes and corrections on a new page, dated at the day these changes are made. The new page, together with the original entry, forms a complete record.

In addition, any sketches, drawings or written descriptions outside the notebook should likewise be dated, signed and witnessed. All of these records should be preserved in the engineering department's files.

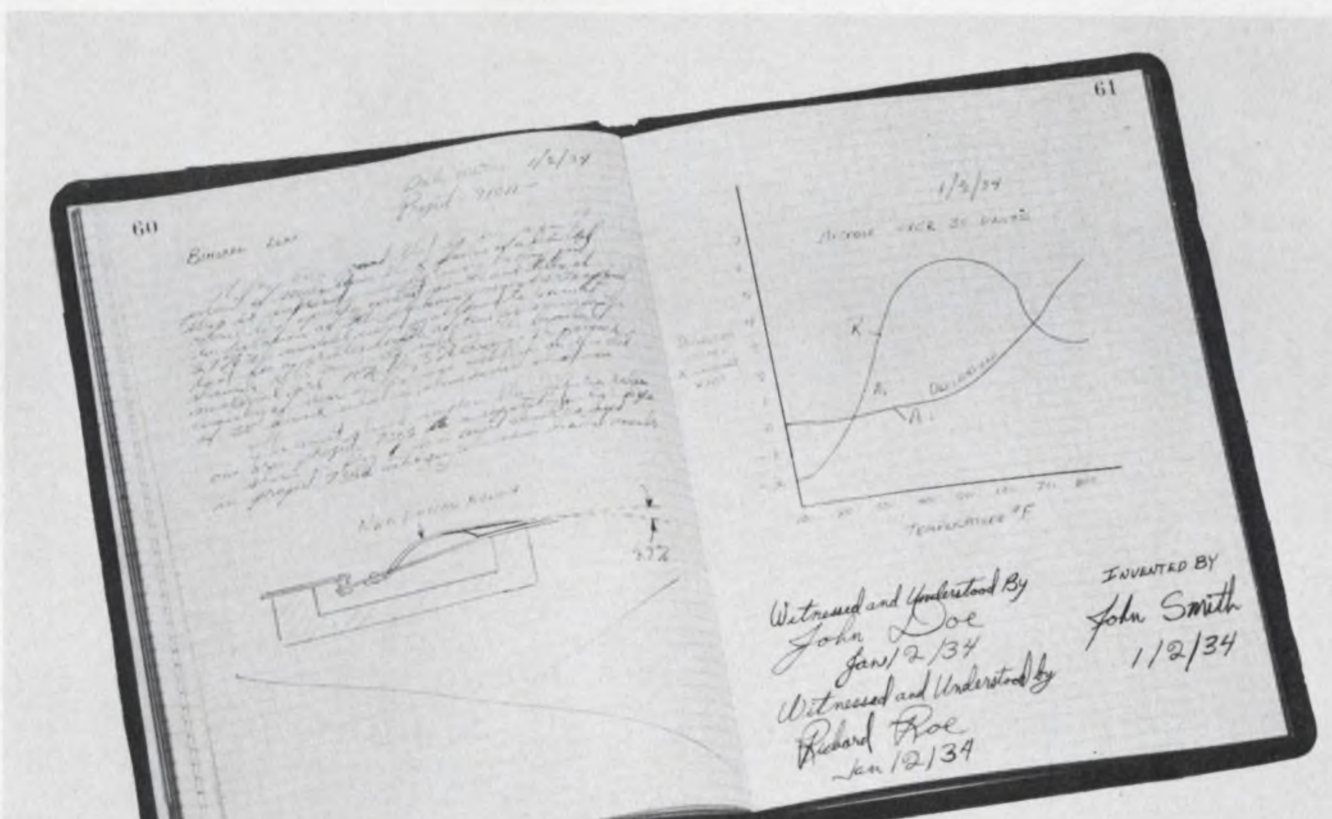
Models of the invention should be clearly identified. Photographs should be taken, if possible. The models and photographs should also be filed in the engineering department, and a fully witnessed record should be kept of the date of completion. Tests of a model or process should be conducted in the presence of at least one witness, preferably two or more. Witnesses' signatures should take the following form:

"'On (date), I personally witnessed the tests referred to herein and certify that the results are accurately set forth in this record. Signed:
Date: ."

These witnessed data, too, should be preserved by the engineering department. A copy of the test results should be sent to the company patent department, if an application has not been filed before the tests are completed.

### Select your witnesses carefully

In all cases the witnesses must have sufficient technical knowledge to understand the nature of the invention when it has been explained to them or after reading the notebook entries. This is very important. A person who merely signs his name to a notebook entry, without understanding the nature of the invention, is not a very good corroborative witness. There have been instances where such witnesses have been the stenographer or the




**Laboratory notebooks,** if prepared the right way, protect the inventor, by proving the progress and the date of the invention. Signing witnesses must be capable of grasping the significance of the material.

wife of the engineer. These persons have very little idea of what the invention is about and are unable to relate the circumstances of the invention to prove the contents of the entries.

Another important point is that all correlated data—drawings and information that substantiate the notebook entries—should be mentioned in these entries and kept for reference.

If these entries are made properly and promptly and all correlated information and data are collected, there should be very little doubt of proving the actual chronology and facts of inventorship.

### Notes help tell the story

Laboratory notes are the basis from which a patent disclosure is prepared by the company patent department. It is a part of the patent law that an inventor must disclose his invention in the best and most complete manner. Therefore, it is necessary to scan the data in the notebook entries and to fashion such information into a logical, clear description of the invention.

To do this, companies usually provide a disclosure form that helps engineers organize the data. A disclosure sheet includes basic data—like the date of the invention, the name of the inventor, a drawing of the device, its advantages and objectives—and a brief description of the device and its operation. Two competent witnesses have to sign the document.

The components of the drawing should be numbered to agree with the description. The drawing should show structures of all necessary parts. In the case of a process, all apparatus required to carry out the steps of the process must be included. Although the drawing need not show the design in a form suitable for commercial use, it is essential to provide an operable circuit, structure or a completed series of process steps.

To obtain complete patent protection for the invention, the description must encompass even the smallest details. Since most inventors are extremely familiar with the problem concerned, they are prone to describe the components of the structure, circuit or process very sketchily. They forget that a disclosure may be relatively new to the attorney who is to prepare the patent application.

The inventor should proceed in his description as though he were demonstrating his device or progress to someone unskilled in the field. Technical jargon should be carefully defined.

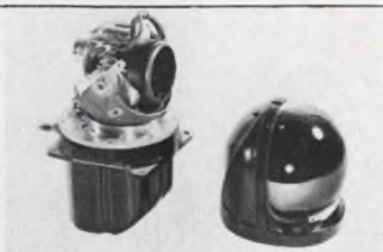
In describing the structure in the drawing, remember the following:

- All elements should be numbered.
- The important element should be isolated from the description and specially emphasized.
- The operation of the device should be described.
- The principle of operation should be explained, if possible.
- The novel features of the invention should be pointed out, together with the advantages over other patents. ■ ■

# INFRARED ENGINEERS AND SCIENTISTS:

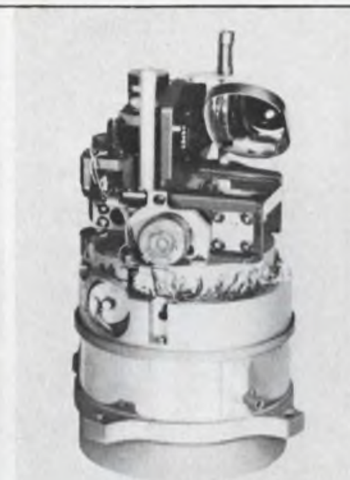
## Can you contribute to the development of products like these?

Homing guided missile seeker head.

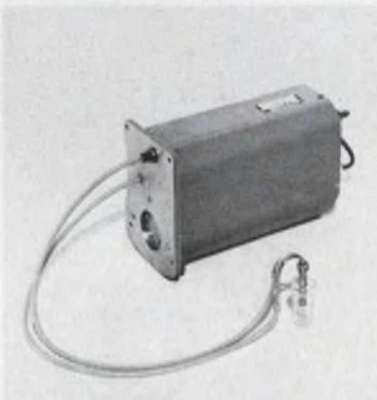


Interceptor IR search/track set.

Anti-tank missile controller.

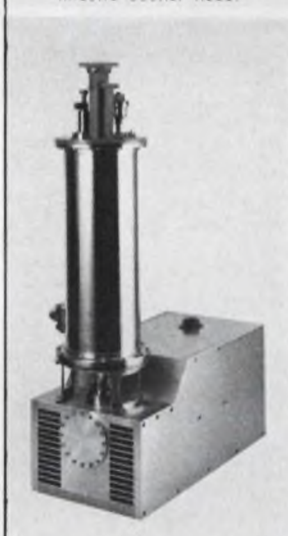


Star tracker for SURVEYOR spacecraft.

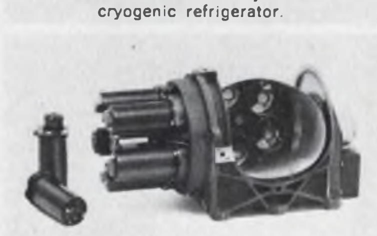


Miniature closed-cycle cryogenic refrigerator.

20-element Ge:Hg detector array.



Cryogenically cooled parametric amplifier.



Radiometer for NIMBUS weather satellite.

Multi-element cooled IR detector.

Cast silicon IR optical components.

Rapid growth of Hughes infrared activities in the Aerospace Divisions and the Santa Barbara Research Center has created many responsible positions for qualified engineers and scientists in all phases of IR systems development from conception through production engineering.

Immediately available assignments include openings in such diverse technologies as optical design, semiconductor physics, cryogenics, mechanical engineering, precision electro-mechanisms, electronic circuit design, servo systems . . . and many other areas.

Current Hughes IR contracts include advanced systems for: space exploration, weather satellites, anti-ballistic missile defense, night reconnaissance, aircraft and space vehicle defense, and tactical weapon guidance and fire control.

Professional experience, an accredited degree and U.S. citizenship required.

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**Head of Employment**
**Hughes Aerospace Divisions**
**11940 W. Jefferson Blvd.**
**Culver City 42 , California**

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## A new feather in our old hat

### ACE Digital Test Command System

Motorola's leadership in Integrated Circuits has been extended by another state-of-the-art achievement — the design and production of the First Integrated Circuit Automatic Checkout Equipment, used at Cape Kennedy for compatibility testing of Apollo systems prior to launch. This DTCS, (shown above) processes command messages to produce and channel test stimuli to various spacecraft systems under test. Each DTCS contains some 8,000 Motorola MECL Integrated Circuits.

This is but one example of Integrated Circuit Applications. New technology is being applied daily to advanced analog, RF, and digital circuitry in sophisticated system configurations. We have projects ready and waiting for qualified circuit design engineers and system analysts.

Check the specific job openings listed below and contact Phil Nienstedt, Manager of Recruitment. Department 627.

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**Tracking & Telemetry**
**Fuzing**
**Digital Data Transmission**
**Guidance & Navigation**
**ECM & Elint**
**Checkout Systems**
**Coherent Transponders**
**Radar Transponders**
**Integrated Electronics**
**Antennas & Propagation**
**Reliability & Components**
**Advanced RF & Microwave Techniques**

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- All forms are delivered unopened to one reliable specialist at ELECTRONIC DESIGN.
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- All original applications are placed in confidential files at ELECTRONIC DESIGN and after a reasonable lapse of time they are destroyed.

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*Position Desired* ________________________________

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| *College* | *Dates* | *Degree* | *Major* | *Honors* |
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*Recent Special Training* ________________________________

*Employment History*

| *Company* | *City and State* | *Dates* | *Title* | *Engineering Specialty* |
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*Professional Societies* ________________________________

*Published Articles* ________________________________

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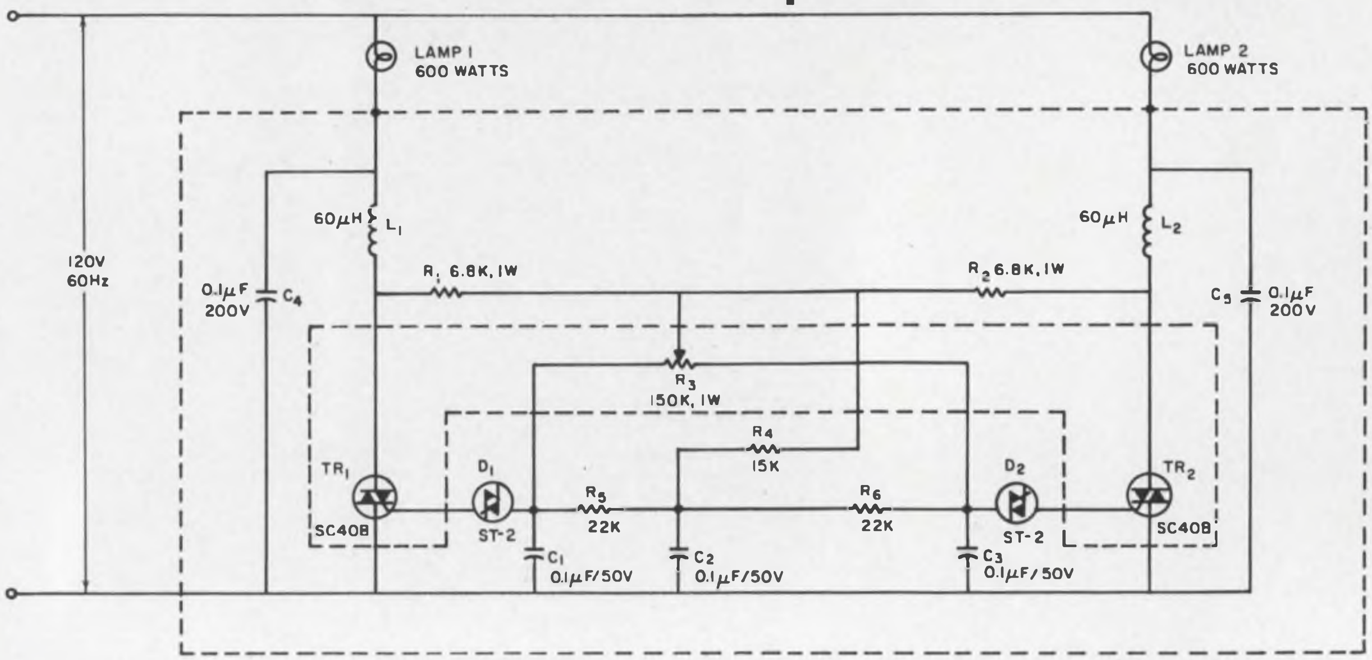
925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949

# Tandem dimmer uses Triac power controllers




**Triac power-controller** establishes a tandem dimmer. Potentiometer $R_3$ determines relative lamp brightness.

The tandem dimmer is an electronic, solid-state control that simultaneously increases the brightness of one lamp while decreasing the brightness of another. This system can be easily and inexpensively realized with two Triac power-controllers.

This type of light action is often employed in the theater for fading out one scene while bringing up another or for dimming out the stage as the auditorium lights go up. It can also be used in the home for transferring from room lighting to the light of a slide or movie projector. This cross-fading action can lend a professional touch to slide projection by transferring back and forth between two slide projectors to bring in one picture while the previous picture fades out.

The tandem dimmer (see schematic) uses the Triacs to control power to the two lamps. The Triacs are triggered by Diac trigger diodes from an RC phase-shift network that is cross-coupled between the Triacs. A single potentiometer, $R_3$, controls both lamps.

When the potentiometer is set at the extreme end closest to $D_1$, lamp #1 is operating at full brightness and lamp #2 is completely OFF. As the potentiometer is moved across to the other extreme, lamp #2 will increase in brightness and lamp #1 will decrease in brightness. The circuit components have been chosen so that during the transition from one lamp to the other the total light emitted by both lamps together is virtually constant, changing by no more than 15% through the entire transition range. This particularly suits the system to the slide projector application.

If a wider variation in total light level is desired, the control circuit can be further simplified by eliminating resistors $R_4$, $R_5$, and $R_6$, and capacitor $C_2$, and by changing the value of potentiometer $R_3$ from 150 KΩ to 75 KΩ. Radio frequency interference is suppressed through use of inductors $L_1$ and $L_2$ and capacitors $C_4$ and $C_5$.

If the lamp load on either Triac is less than 100 W, the LC filter circuit may tend to oscillate and prevent proper operation of the Triac. Should this occur, the LC circuit must be damped by the addition of resistance (approximately 33 Ω) in series with capacitors $C_4$ and $C_5$. The damping resistors should be bypassed by small capacitors (approximately 0.02 μF) to preserve RF interference suppression at higher RF frequencies.

*E. K. Howell, Applications Engineer, General Electric Co., Auburn, N. Y.*

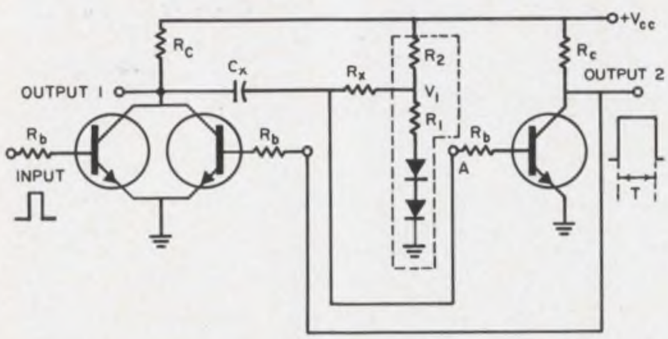
VOTE FOR 110

**SEND US YOUR IDEAS FOR DESIGN.** Submit your IFD describing a new or important circuit or design technique, the clever use of a new component, or a cost-saving design tip to our Ideas-for-Design editor. If your idea is published, you will receive $20 and become eligible for an additional $30 (awarded for the best-of-issue Idea) and the grand prize of $1000 for the Idea of the Year.

# IC double-gate stabilizes monostable multivibrator

Temperature stability of a conventional two-transistor IC monostable multivibrator can be improved by use of IC double-gates. A stability of better than ±0.5% accrues simply with the addition of a pair of diodes and resistors.

Two-transistor multivibrators are commonly sensitive to temperature as well as to supply-voltage variations. This is particularly true when the supply voltage is low, as is typical in integrated circuit versions. With reference to the figure, a




**Temperature stability better than ±0.5%**, from −10 to +70°C, is achieved in this standard IC multivibrator by addition of resistors $R_1$, $R_2$ and the two diodes shown.

multivibrator period is given by:

$$T = R_x C_x \log \left\{ \frac{\frac{R_x}{R_x + R_b}(V_1 - V_{BE\,SAT}) + V_{CC} - V_{CE\,SAT}}{V_1 - V_{A\,(THRESHOLD)}} \right\}$$

Most of temperature drift comes from $V_{BE\ SAT}$ and $V_{Ath}$ variations. These variations, similar to those of the forward voltage drop, $V_D$, of a diode, can be canceled by making $dV_1 = K\,dV_{BE} = KdV_D$. This is realized with a two-resistor-two-diode network where:

$$1 < K = \frac{2R2}{R_1 + R_2} < 2.$$

This compensation network has been proved successful with a monostable using a Fairchild double gate μL914. When $R_x = 10$ kΩ, $R_1 = 200$ Ω and $R_2 = 470$ Ω ($K = 1.4$), the temperature drift was reduced from ±6% to less than ±0.5% in the −10° to +70°C temperature range. Variations of $T$ have been reduced to less than 3% for a ±30% supply-voltage change.

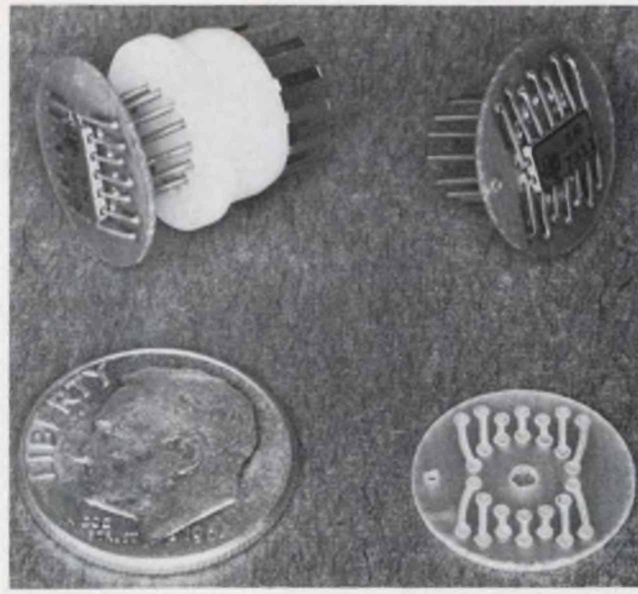
Monostable multivibrators built with other types of RTL ICs can be compensated in the same way. $K$ must be adjusted (in most cases between 1.3 and 1.6) to give optimum results.

*Jean C. Rivet, Applications Engineer, SGS Fairchild, Milan, Italy.*

VOTE FOR 111

## Adaptor provides plug-in convenience for IC flat-packs

Flat-packs, the most widely used integrated-circuit packages, give many assembly problems in breadboard and prototype design. In order to reduce these problems, an adaptor has been designed to which the flat-packs can be hand-soldered. A set of connector pins enables the user to plug any flat-pack into a mating receptacle located on an assembly board.



**Etched printed-circuit board and gold-flashed nickel pins** are major ingredients in this useful adaptor. Matching socket is a readily available off-the-shelf item.

The adaptor (see photograph) is made up of only three components: an etched 1/32-inch single-clad epoxy printed-circuit board; a set of pins (10 or 14 per adaptor) (Eltee Mfg. Co.); and a socket (10 or 14 pin) (Barnes Development Co.). The pins, 0.24-inch long and about 0.02-inch in diameter, are made of gold-flashed nickel wire. A shoulder on one end permits soldering to the pad.

After the leads are bent to mate with the holes in the PC board, the flat-pack is inserted on the board and both pins and flat-pack soldered in place. The mating socket may then be mounted on an assembly board or in a test circuit. Recently, a total of 350 such adaptor-modules were used in assembly board or in a test circuit.

*Frederick A. Buuck, Engineering Specialist, ITT Federal Laboratories, Fort Wayne, Ind.*

VOTE FOR 112

## Diodes and capacitor make astable self-starting

Astable multivibrators can easily be made self-starting by the addition of two diodes and a capacitor to the multi circuitry. This modification is far simpler and less expensive than the complex feedback techniques usually employed.

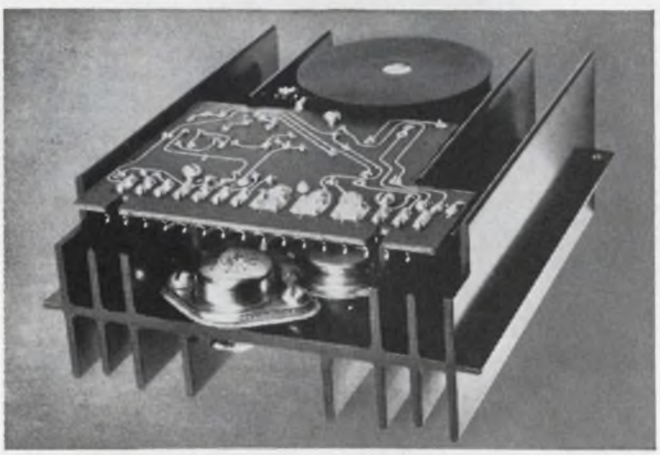
When power is applied to a conventional astable multivibrator, it is possible for both its transistors to become saturated and lock up. This condition may cause persistent starting problems.

In the modified astable circuit (see schematic) $CR_1$ and $CR_2$ cause capacitor $C_3$ to be charged to the positive supply and thus provide charge current through resistors $R_5$ and $R_6$ to $C_1$ and $C_2$. Should both $Q_1$ and $Q_2$ become saturated, $C_3$ will automatically be discharged and $Q_1$ or $Q_2$ will be turned OFF. This shut-down will set off regeneration in the multivibrator. In the circuit, $R_1 = R_4 < R_5 = R_6$; $C_3 >> C_1$ and $R_2 = R_3$. $R_2$ is chosen

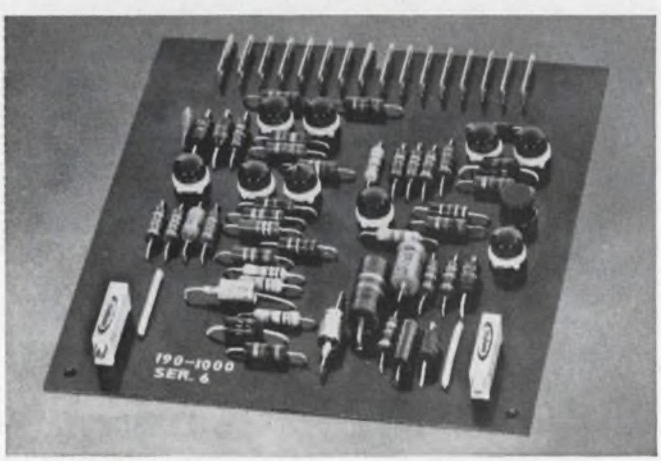
# Does your present custom power supply give you...

| | | | |
|---|---|---|---|
| 70% to 90% efficiency? ? | Instant fault repair by plug-in module replacement? ? | Add-on power capability by using more modules? ? | Ability to handle full load steps while maintaining out put in regulation band? ? |

# New Omnimod does!



Omnimod power control module.




Omnimod control amplifier.

**OMNIMOD gives you all these features—*and* more—*and* at a lower price! Want to know more?**

**OMNIMOD is a dc to dc converter using transistors in a CONSTANT PULSE WIDTH, variable repetition rate switching mode to regulate output voltage or current. Two small plug-in units make-up the OMNIMOD concept—a power control module and a control amplifier.**

Output can be regulated between ± 2 and ± 60 dc at up to 20 amperes using the OMNIMOD family of modules WITHOUT MODIFICATION OR ADJUSTMENT. Higher current ratings are obtained by paralleling power control modules.

Any number of power controller modules can be controlled by one amplifier. OMNIMOD has a current limiting parameter, over voltage protection, voltage sequencing, and remote sensing.

To design a custom power supply, one must simply

**1.** design one input power converter to change unregulated line ac power to unregulated dc power

**2.** select the number of plug-in OMNIMOD power control modules to supply the power needed for each output

**3.** package these elements with filter capacitors and a plug-in amplifier module for each output

All the power used by every element in a typical data processing system could be supplied by custom power supplies constructed with interchangeable OMNIMOD modules.

Isn't this enough to consider OMNIMOD for your custom requirement? We will design an OMNIMOD custom power supply to your specs, or will help you design your own system using our plug-in OMNIMOD modules.

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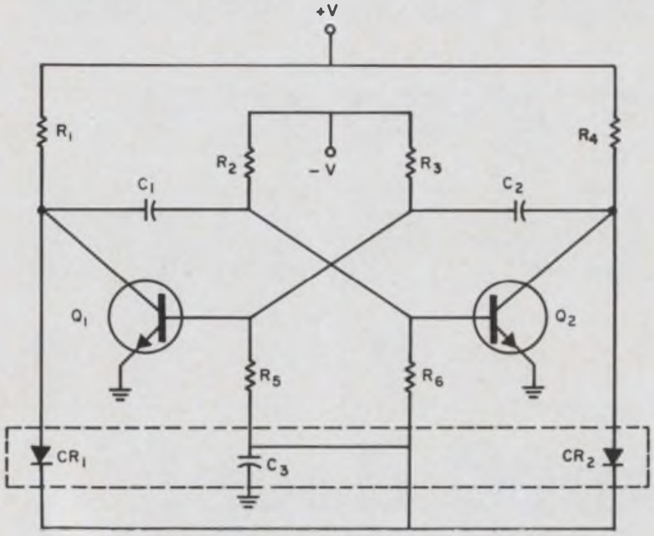



**Diodes and capacitor** provide astable multivibrator with a guaranteed self-starting capability.

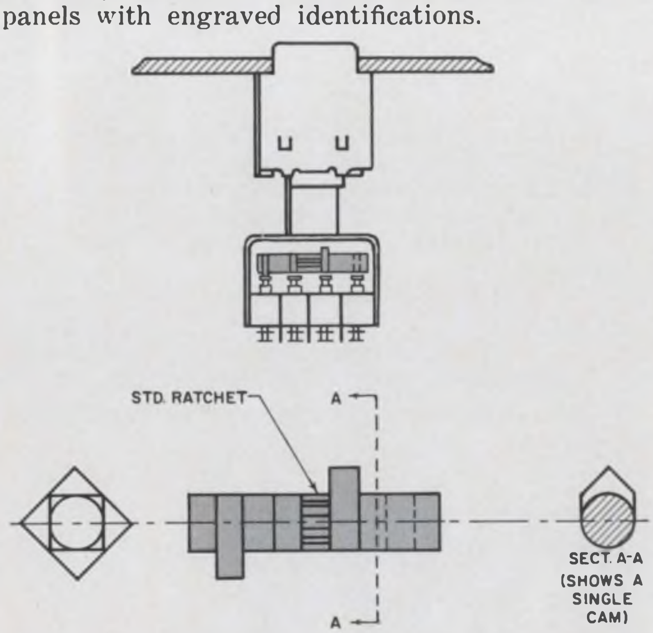
to negate the $I_{CBO}$ effects at high temperatures.

*A. Mall and J. F. Shagena, Jr., Design Engineers, Bendix Radio Div., Baltimore, Md.*

VOTE FOR 113

## Cam-shaft adds contacts to push-button switches

A simple ratchet-operated cam-shaft can be used to facilitate the construction of illuminated push-button switches when more than the standard two contacts are required. Normally, when more than two positions are needed a wafer switch is used. But if the switch location is poorly illuminated, this poses the additional problem of either providing auxiliary lighting or using edge-lighted plastic panels with engraved identifications.




ENLARGED VIEW OF SHAFT

**Ratchet-operated cam-shaft offers** a simple way to increase the number of contacts that an illuminated push-button switch can handle.

The figure shows an illuminated push-button switch with an energizing ratchet that has four cams, each offset by 90°. This arrangement enables a single switch to yield four useful positions. This approach can also be used for to up to eight positions. There the ratchet would have to have eight cams, each offset by 45°.

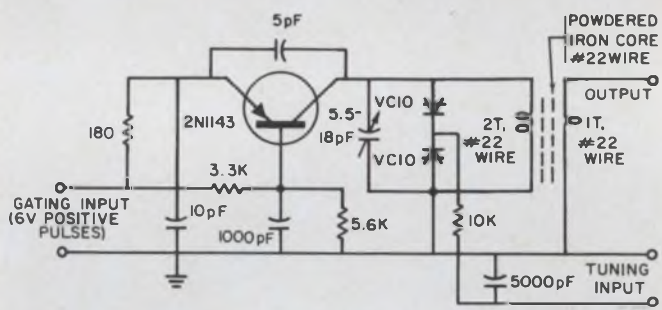
*Louis J. Brocato, P. E., Box 1897, Baltimore, Md.*

VOTE FOR 114

## Phase-controlled oscillator has electronic frequency-tuning

Phase-controlled oscillators are extremely useful in frequency-synthesis and harmonic-generation applications. With such an oscillator a crystal-controlled high-frequency signal may be used to control a frequency up in the UHF range. Such a circuit (see schematic) offers extreme simplicity and economy and high output levels.

Additional benefits include the ability to produce a selected signal that is 40 dB above adjacent




**Oscillator uses back-to-back Varicaps** to provide electronic tuning capability. This circuit produces a selected signal that is 40 dB above adjacent harmonics.

harmonics and the possibility of frequency-programing the oscillator by using Varicap tuning.

The gating input is a 10-MHz crystal-controlled positive-going pulse, which accurately controls the output of a uhf oscillator. The frequency of operation of the oscillator is selected by tuning the LC circuit at the output; in this particular circuit, a positive signal between 4 and 10 volts adjusts the oscillator frequency, centered at 200 MHz, over a ±15-MHz tuning range. The output frequency varies directly with increasing positive voltage.

The phase-controlled oscillator's frequency can be changed to any harmonic of the input signal that falls within the tuning range of the Varicap tuned circuit. Frequency-shifting may be accomplished by applying predetermined dc control levels, or positive time-variable alternating signals, to the Varicap tuned circuit.

*Frank A. Memmo, Sr. Project Engineer, EIMAC, Div. of Varian Assoc., San Carlos, Calif.*

VOTE FOR 115

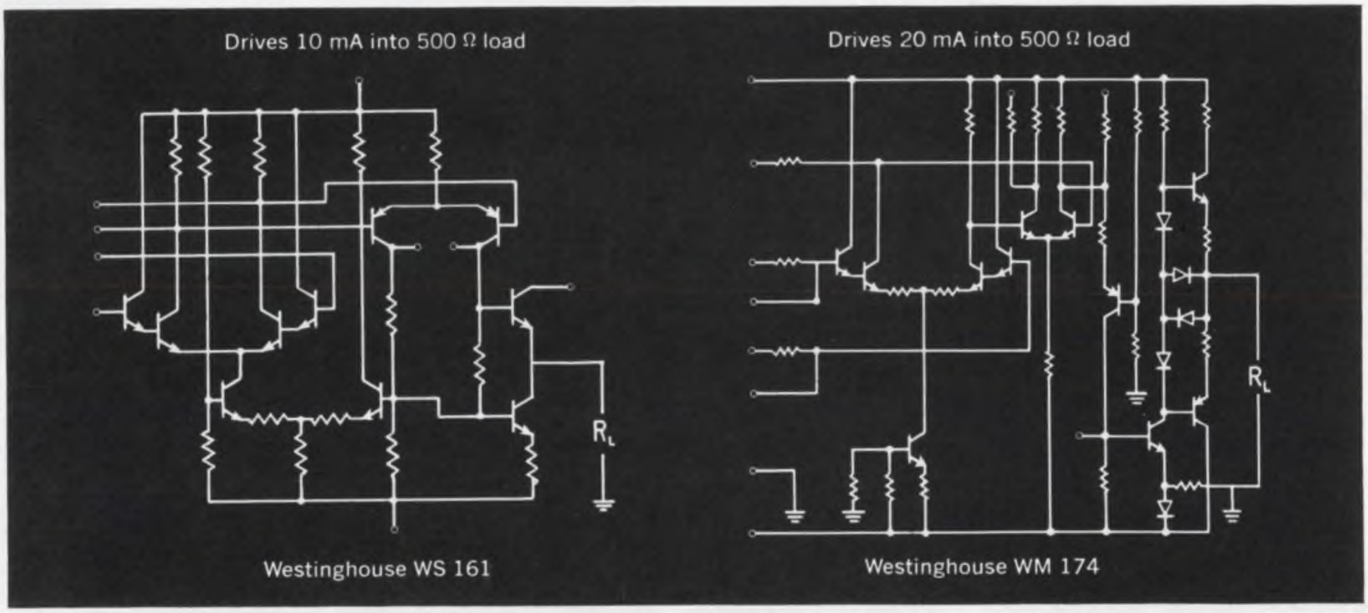
**IFD Winner for March 29, 1966**

**Murray F. Feller**, Design Engineer, Santa Maria, Calif.

His idea, "Two-stage network provides 60-dB agc," has been voted the $50 Most Valuable of Issue Award.

**Cast Your Vote for the Best Idea in this Issue.**

# Westinghouse offers the two IC op amps for low impedance drive applications




You can drive sizable inductive, capacitive, or resistive loads directly with either of these two IC op amps. They're unmatched for "muscle". Using them, you can omit an intermediate driver stage or power amplifier in many applications.

The driving power of the WS 161 and WM 174 can make equipment smaller, simpler, and lower in cost. With this pair, you can fill virtually all integrated op amp requirements. They come in 14-lead, ¼" x ¼" Q-style packages.

If you want maximum unity gain bandwidth, moderate open loop gain, and very high current output with low voltage drift, no other IC op amp comes near the WS 161.

If you want maximum open loop gain, maximum output current, and very high unity gain bandwidth, the WM 174 is far and away your first choice.

Get the full data on these outstanding IC's now. They'll do difficult jobs for you. Call your Westinghouse distributor. Or write Westinghouse Molecular Electronics Division, Box 7377, Elkridge, Maryland 21227.

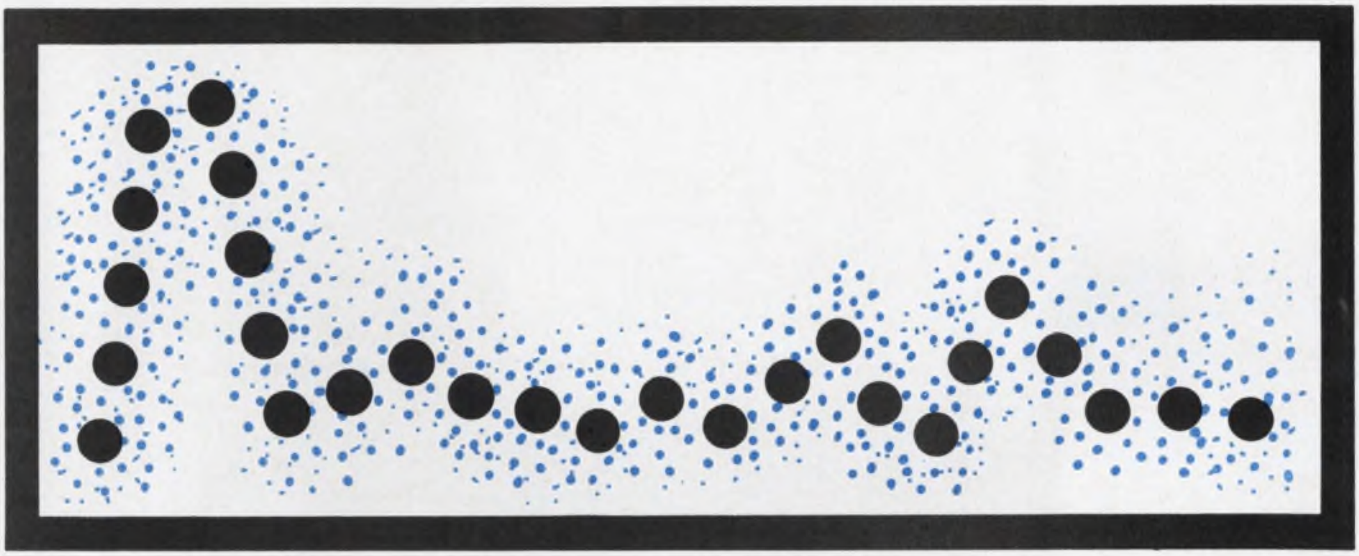
J-09126

| | WS 161 | WM 174 |
|---|---|---|
| Open Loop Gain | 2,000 | 50,000 |
| Unity Gain BW | 20 MHz | 10 MHz |
| Output Current | 10 mA | 20 mA |
| Output Impedance | 40 Ω | 70 Ω |
| Input Current | 120 nA | 120 nA |

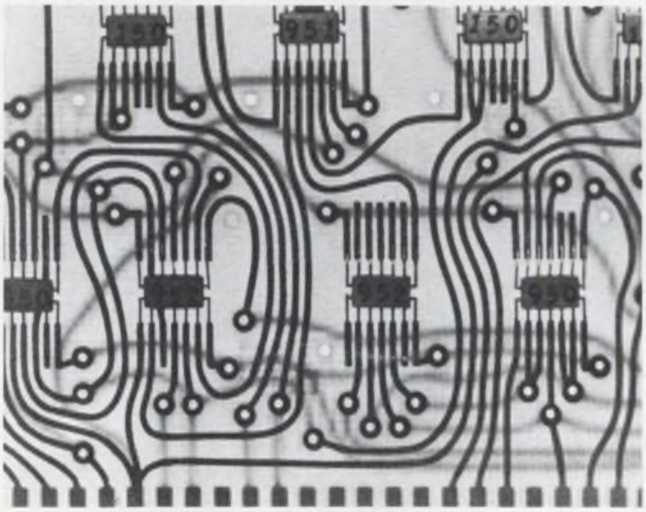
**You can be sure if it's Westinghouse**

ON READER-SERVICE CARD CIRCLE 25

# Products

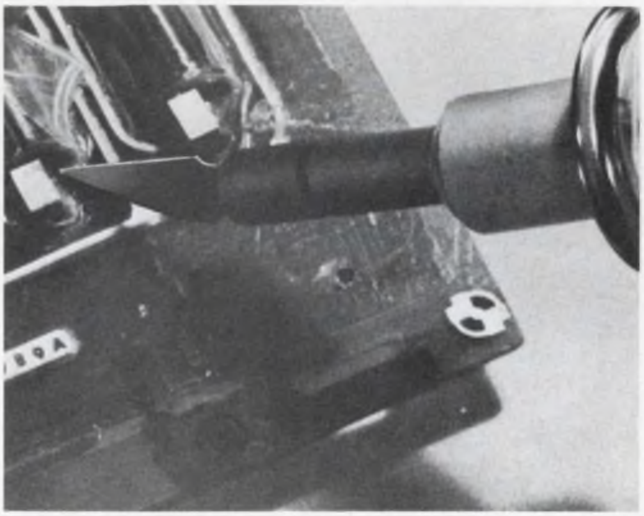


**Noisy signals** are quickly found with this digital memory oscilloscope. Serial digitizing gives it elephantine memory. Counting circuits automatically normalize data. Page 78.





**Up-down counter** includes four flip-flops, preset and reset inputs and all gating. Page 96.



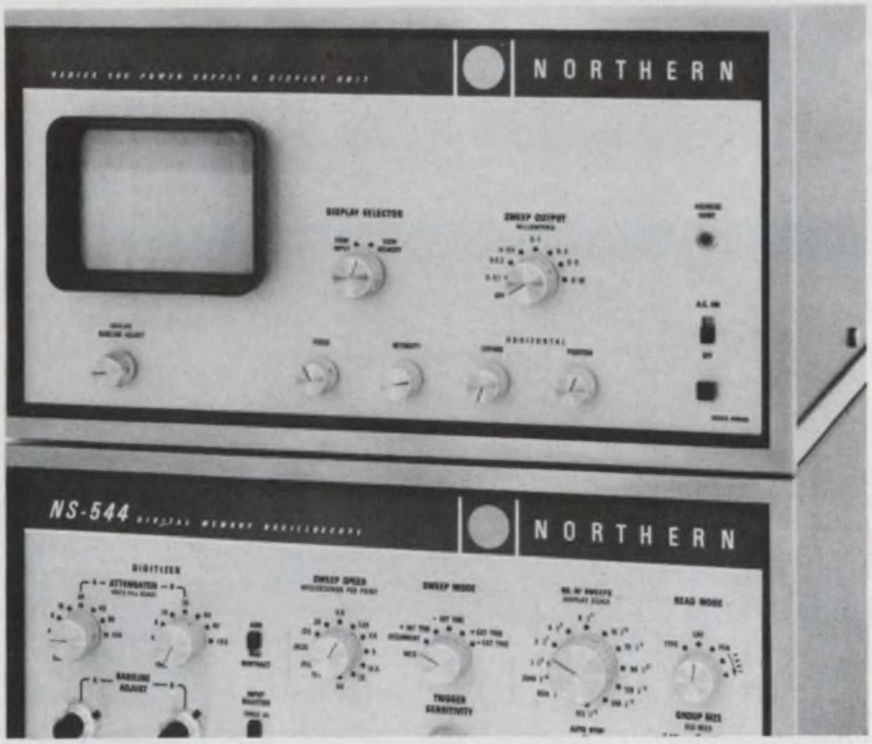
**Low-cost iron** simultaneously cuts and heat seals PC board epoxy encapsulants. Page 90.

## Also in this section:

**Digital driver** replaces ns relay for dc logic transmission. Page 86.

**Microminiature transformer** has hollow laminated core. Page 88.

**Postmortem failure analysis** of mounted semiconductors. Page 90.




# Digital memory scope plucks recurrent signals from noise

The problems of rising "baseline" and data normalization commonly associated with "totaling-type" signal averagers have been largely eliminated in the NS-544 digital memory oscilloscope. It has none of the ambiguities associated with memory overflows. Self-contained automatic timing circuits keep the growth of signals independent of sweep speed.

Basically, the scope has a serial digitizer and adder and a sequentially addressed 1024-word memory to produce totals of a recurrent signal waveform. It employs a time-averaging technique to eliminate noise present with the test signal. Originally tailored to the needs of biomedical and nuclear magnetic instrumentation, the scope should find applications in any low-level analysis.

The two-channel scope samples a signal in 512 or 1024 time intervals and measures digital magnitudes by means of an A/D converter. The magnetic core remembers the values, and, as later signals occur, their voltage magnitudes are measured across the same intervals and added to the information in the memory. Since the polarity of noise components is random, totals increase consistently due only to the true signal component. The scope accepts information at a rate of two readings per ordinate point per signal occurrence for all sweep speeds except 62.5 $\mu$s/point. Sweep speeds range from 62.5 $\mu$s/point to 250 ms/point in 12 switch-selected steps. The sweep consists of advancing the memory address scaler in sequence from one point to the next. This is accomplished with a quartz oscillator and a decimal-scaler frequency divider. External oscillators are not used.

With other scopes, displayed signals "grow and ride" on a rapidly rising baseline causing memory overflows and ambiguities. The NS-544 has a 10-turn pot baseline adjustment for each input which is digitally held at a fixed value for proper setting of dc level.

Normalization problems have previously arisen because of the dependence of signal growth rate upon sweep speed. In the NS-544, signals grow at a rate of 128 units per unit signal voltage per signal occurence for all sweep speeds. Automatic timing circuits stop the measurement after $2^n$ signal occurrences (n is switch-selectable from 0 to 11). This "autostop" may be switched off if no stop is wanted. The number of signals measured is automatically recorded in the memory and digitally recorded during read-out. This value is, in fact, the normalizing constant needed to convert the recorded coordinates to absolute values. The unit automatically normalizes data during the read-out mode for an experiment of $2^n$ sweeps. At the operator's option, read-out information in each ordinate is divided by the constant preset on the "autostop" switch. The digital display scale selector is a binary switch providing a scale change of factors of 2 per switch position. When "autostop" has been used, the waveform is exactly normalized when the signal count recorded is displayed at full scale.

The instrument may also be operated in a subtract mode. Noisy signals may be measured, a parameter in the test system changed and the same number of signals subtracted to show differences.

Memory groups are 0 to 1023, and 0 to 511 and 512 to 1023, with an included display overlap of these memory halves. Word lengths are 16 bits. Digitizer resolution is 0 to 128 pulses per ordinate per signal and linearity is $\pm 0.5\%$. Resolution of the display decoder is seven bits. Input signals may range from 0-2 V to 0-100 V depending on attenuator setting. Input impedance is 1 M$\Omega$ $\pm 5\%$. Trigger signal range is $\pm 4$ V with internal, external or automatically recurrent modes. Stability is $\pm 20$ mV/day. Sweep output is 0-0.1 mA to 0-10 mA in seven steps. Sweep current linearity is $\pm 0.01\%$ and stability is $\pm 0.1\%/10$ hours. Sweep speed accuracy is $\pm 0.02\%$ for sweep-flyback, multi-channel scaling, latency histogram or interval histogram mode. Readout is via a 5-in. CRT. Waveforms may be recorded with a pen recorder and final values may be recorded with a computer readout typewriter

P&A: $9400; 30 days. Northern Scientific Inc., 303 Price Pl., Madison, Wis. Phone: (608) 238-4741.

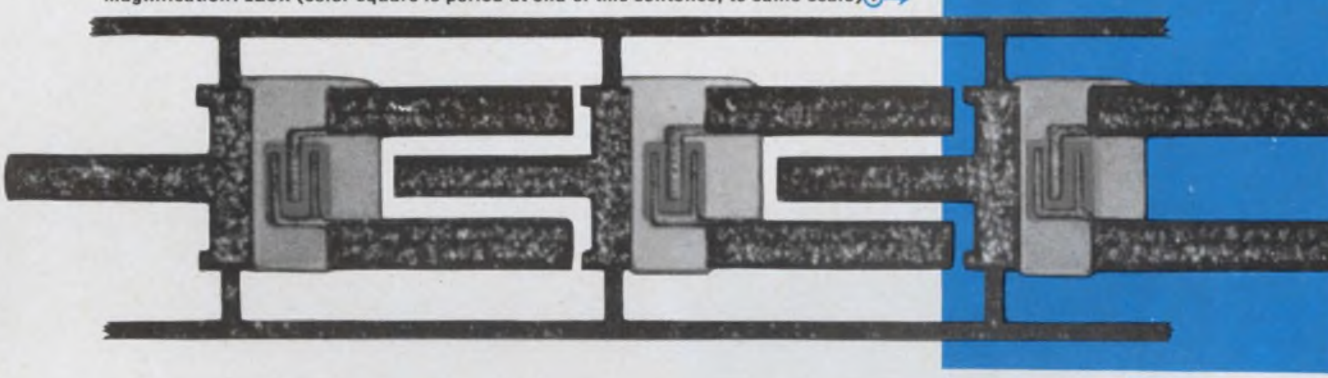
*Circle No. 300*

Report from

**BELL LABORATORIES**

# "Beam lead" technique for fabricating solid-state devices

**Magnification: 125X (color square is period at end of this sentence, to same scale)**



**Row or "ladder" of beam-lead transistors fabricated experimentally at Bell Laboratories has a transistor every 16 mils along its length. Each transistor (on light-gray areas) has three beam leads (dark-gray rectangular areas) for electrical and mechanical connection. The side rails at top and bottom of photo are used only for support and ease of handling.**

To make tiny solid-state devices and circuits, groups of elements are generally formed on a single semiconductor slice or substrate. Then the slice is "diced" (physically separated) into pieces as either individual units or groups of units for integrated circuits. If used individually, they are connected to terminals or to other devices with short segments of extremely fine wire—a difficult and time-consuming operation. If used as groups of devices, they often need special processing to electrically isolate those making up each circuit.

Bell Laboratories' M. P. Lepselter has developed a promising solution to both of these problems. After the device elements are formed, mechanically strong electrical leads are deposited onto them. These electrically and mechanically intraconnect the devices and circuits. Unwanted semiconductor material between the individual devices in a circuit is then removed . . . isolating them electrically, yet leaving them mechanically joined. This permits batch processing of electrical leads, eliminating many individual connections and requiring only connection to external terminals.

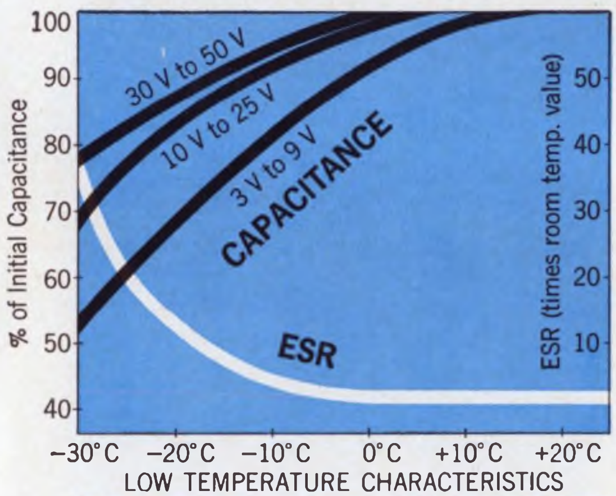
Thus, handling tiny devices and circuits is simplified. The leads, precisely positioned with respect to each other, are easily connected to a circuit board or other support, perhaps eventually by automated techniques. They are strong enough so that the semiconductor wafer or chip needs no further attachment to the substrate. Entire circuits joined by beam intraconnections can be handled as one unit.

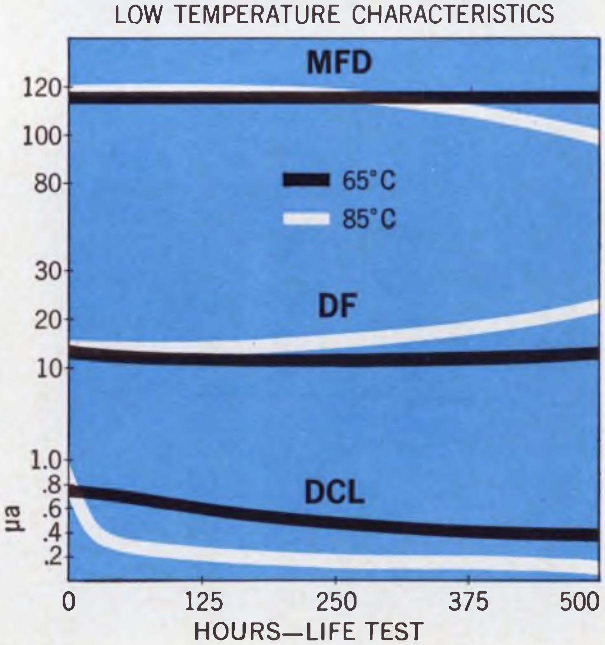
**M. P. Lepselter examines beam-lead model (enlarged about 300 times). Beams were thermally aged in 360° C steam for 1000 hours, centrifuged to 130,000 G, bent 90° twenty times without failure. Beams can be tapered for smooth impedance matching, widened to act as heat sinks.**

**Bell Telephone Laboratories**
Research and Development Unit of the Bell System

# If you can't believe an electrolytic can be this good unless it's in a metal can...

## Test the molded-case MTA yourself.

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**Life at High Temperature**—zero failures in one million piece-hours at 85°C. Only one failure in 2½ million piece-hours at 65°C.

**Stability at Low Temperature**—equal to or better than most metal-case miniatures down to —30°C.

**Maximum Values**—800 mfd, 3 VDC, to 85 mfd, 50 VDC.

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ON READER-SERVICE CARD CIRCLE 26

# HIGH Q encapsulated | HIGH Q wafer | HIGH K encapsulated

## Now, JFD Uniceram® Fixed Capacitors Come THREE ways

**High Q** Uniceram High Q ceramic fixed capacitors offer a unique combination of small size, exceptional stability and a guaranteed minimum Q of 5000 . . . with up to ten times more capacitance per unit volume than competitive units . . . up to .206 mfd/in$^3$.

**GLASS ENCAPSULATED**—105 models, with capacitance values from 0.5 to 3000 pf, provide the ultimate in High Q, reliability and stability. All models meet applicable requirements of MIL-C-11272B.

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**High K ENCAPSULATED**—A High K series of Uniceram ceramic fixed capacitors with up to 1 mfd capacitance is also available. These glass encapsulated units meet applicable requirements of MIL-C-11015C. Volumetric efficiency . . . up to 48 mfd/in$^3$.

**WAFERS**—Uniceram High K capacitors will soon be available as unencapsulated wafers, also.

**WRITE FOR CATALOG UNM 65-2**

**ON READER-SERVICE CARD CIRCLE 226**

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JFD NEW YORK-NORTHERN, Damiano Pl., P. O. Box 96, New Hartford, N. Y. 13503
JFD MID-ATLANTIC, P. O. Box 5055, Philadelphia, Pa. 19111
JFD MID-ATLANTIC-MARYLAND, P. O. Box 7676, Baltimore, Md. 21207
JFD MIDWESTERN, 6330 W. Hermione St., Chicago, Ill. 60646
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JFD WESTERN, 9 Morlan Place, Arcadia, California 91006
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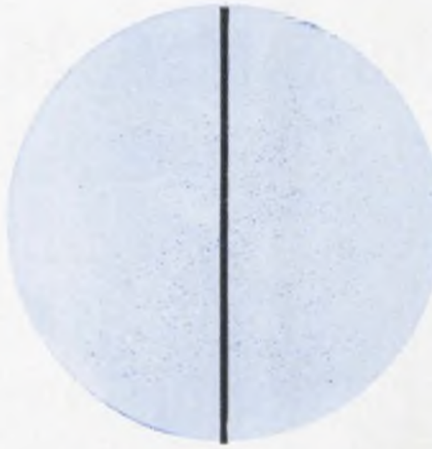
JFD ELECTRONICS, EUROPE S A, 7 Rue de Rocroy, Paris, 10, France

Precision Piston Trimmer Capacitors ■ Metalized Inductors ■ LC Tuners ■ Ceramic Fixed and Variable Capacitors ■ Fixed and Variable Distributed and Lumped Constant Delay Lines

Average human hair magnified 500 times.



0.000069" rolled metal magnified 500 times.

# 0.000069"

## IS A "THINNESS", NOT A THICKNESS

Sixty-nine millionths of an inch is the thinness to which The Arnold Engineering Company has precisely rolled metals and alloys as soft as copper. Alloys as hard as Type 302 stainless, Elgiloy, S-816, Nichrome V and other hard materials have been rolled to 0.0002" and less.

Orders to these specifications obviously aren't average. Then Arnold isn't average, either. The Arnold Engineering Company is fully equipped to roll ultra-thin gauges of ferrous and non-ferrous metals to extremely close tolerances. With dual source, non-contacting beta-ray gauges Arnold has held tolerances totalling 0.000017" on a week's run of .0011 gauge.

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The Arnold Engineering Company has the capability of precision rolling over 55 different metals within tolerances of millionths of an inch.

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◄ ON READER-SERVICE CARD CIRCLE 227

## Spectrum generator

Model BSSG-1 has an output amplitude of 1000/400/10/1$\mu$V for any spectral line into 50 $\Omega$ resistive. Spectral line spacing can be either 100 or 50 kHz from 100-kHz internal oscillator or 5 to 500 kHz from an external source. External drive is 100 kHz nominal input, 1 to 20 V p-p at 500 $\Omega$. The internal oscillator stability is $\pm$10 ppm at 0 to 50°C. Leakage is 10 dB below 1 $\mu$V.

Squires-Sanders Inc., Martinsville Rd./Liberty Corner, Millington, N. J. Phone: (201) 647-3200.

*Circle No. 252*

## Pulse modulator

A hard-tube pulse modulator finds applications in high resolution radar studies, microwave tube development and nondestructive testing. Pulse widths extend down to 25 ns at amplitudes of 10 kV at 30 A. Rep rate is single shot to 250 kHz continuously variable, and up to 500 kHz at 60% voltage. Floating deck design permits either polarity and 25-ns rise and fall times.

Cober Electronics Inc., 7 Gleason Ave., Stamford, Conn. Phone: (203) 327-0003.

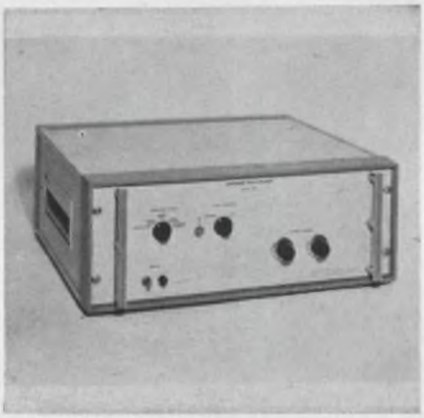
*Circle No. 253*

## Research photometer

A research photometer employs FET design and features plug-in printed circuitry. Model IL600 has 9 ranges of sensitivity for a total range of 300,000:1, 4 ranges of cancellation current and a recorder output with 5 drive positions. Accuracy is 1%. It operates from an integral regulated ac supply or from its 8-hour rechargeable battery. The instrument operates with photoresistive and photovoltaic cells, solid-state photo detectors and gas or vacuum phototubes.

P&A: $625; stock. International Light Inc., 12 Unicorn St., Newburyport, Mass. Phone: (617) 465-5923.

*Circle No. 254*

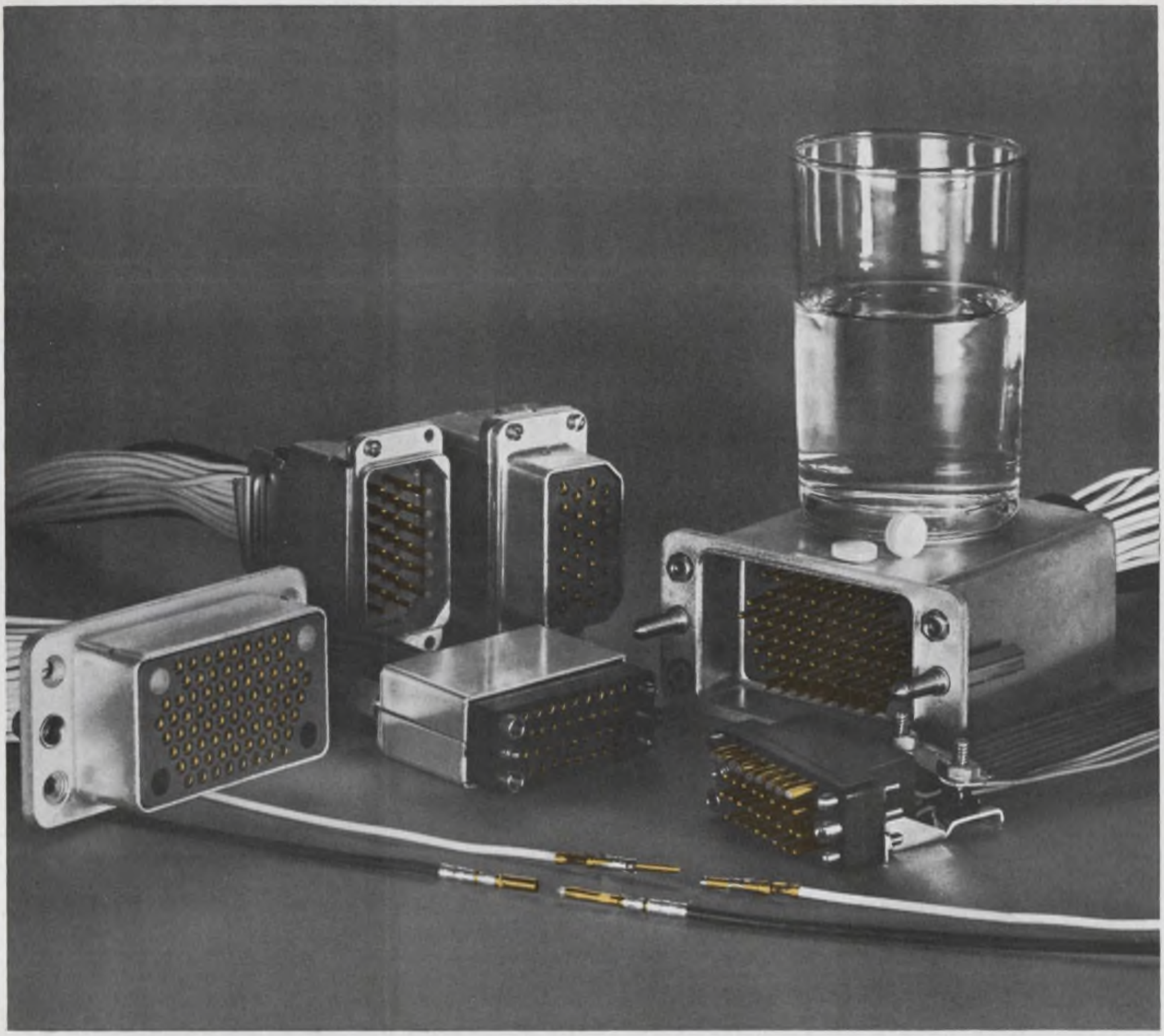


## Crossbar multiplexer

Crossbar multiplexers connect one analog input at a time to a single output in accordance with a fixed or controllable program. They are designed for time-sharing dc differential amplifiers between a large number of input channels. Series 3080 features 1-, 2- or 3-pole switching, 50-channel second scanning and 100 to 1000 channel inputs.

Price: $1700. Control Equipment Corp., 19 Kearney Rd., Needham, Mass. Phone: (617) 444-7550.

*Circle No. 255*



# Fast 4-way relief for inventory headaches...mix your own!

Ordering and stocking a different connector configuration for each new product design requirement can be a real headache. If this is your problem, aspirin won't help you. But, our pin and socket connector housings will—four ways!

These housings, available with or without die-cast aluminum shells, now accept four types of size 16 contacts—including coaxial. Which means you can bring both **power and shielded circuits** through the same connector **in any desired combination,** up to 160 positions.

All four contacts are crimp snap-in types for fast, dependable termination with AMP's matched application tools. Three types of pin and socket contacts are available; type II is a precision screw-machined contact meeting applicable requirements of MIL-C-8384, types III and III(+) are continuous strip formed contacts for high production at lowest installed cost.

For your low-level signal lines, our new subminiature COAXICON* contact is ideal. It's applied by AMP's exclusive **single-stroke crimping technique** which simultaneously crimps center conductor, braid and cable support. And, it snaps into any connector cavity just like the pin and socket contacts.

So take a tip, not a pill. Minimize your inventory problems by selecting A-MP* Series M, D, DD, W or WW connector housings in the materials and sizes you'll need. Then, mix your own contacts in whatever configuration the application calls for. Sound good? Write today and get the complete story.

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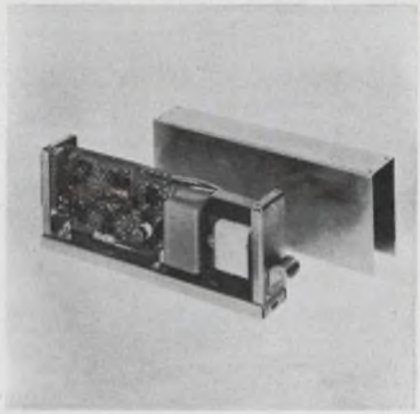
## Recording voltmeter

A memory voltmeter, combined with a strip chart recorder, measures and records the peak voltage of a single or repetitive pulse and displays this reading until reset. Reset interval is adjustable from 10 ms to 5 s, so that amplitude peaks as fast as 50 ns may be recorded. Automatic reset permits use as a peak-reading voltmeter to 50 MHz. Voltage range is 0 to 1000 V in 6 steps.

Price: $995. Micro Instrument Co., 13100 Crenshaw Blvd., Gardena, Calif. Phone: (213) 321-5704.

*Circle No. 256*

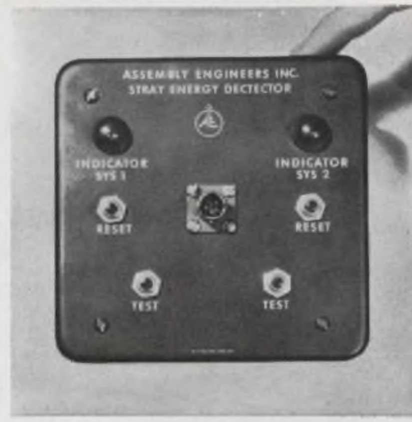


## FET audio amplifier

A FET and silicon-planar transistors are incorporated in this audio amplifier. Primarily a microphone preamplifier, the T-11-08 is also a booster or line amplifier. The unit has noise equivalent to an input of −124 dBm and low power drain. An external passive equalizer is enclosed in an active feedback loop of the amplifier allowing the operator to attenuate at high and low frequencies without loss or gain.

Universal Audio Products, 11922 Valerio St., North Hollywood, Calif. Phone: (213) 764-1500.

*Circle No. 257*




## Stray energy detector

The stray energy detector replaces a circuit squib element during a preliminary circuit check-out. Input impedance is matched to the squib bridge wire impedance. Level of sensitivity can be set at 5 mV min dependent upon input impedance. Detection of voltage is indicated by a warning-light which also opens the impedance circuit. Operating time (0.005 s min) is a function of required impedance.

Assembly Engineers Inc., 3650 Holdrege Ave., Los Angeles. Phone: (213) 870-9861.

*Circle No. 258*

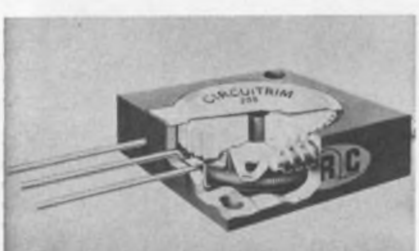
WESTON MODEL 80
ANALYZER
1KV DC
1KV AC
10 AMPS
OHMS
ADJ.
OUTPUT
VOLTS
OHMS
MA
COMMON
-DC
±AC
V AC
V DC
MA DC
OHMS


## Floating digital driver replaces ns relay

An isolating digital circuit for transmission of dc logic levels is the equivalent of a nanosecond relay requiring very small reactive coupling between the drive circuit and the switch closure. The floating digital driver provides combinations for inversion, translation and bipolar operations of digital dc transmissions requiring ns response. The 7-oz package mounts directly on PC cards. Fan-out capability is sufficient for driving numerous circuits or matching to transmission lines. Operating frequency is from dc to 500 kHz and typical propagation plus rise or fall time is 500 ns for "1" and 700 ns for "0". Leakage capacitance is 5 pF.

Dynamics Instrumentation Co.. 583 Monterey Pass Rd., Monterey Park, Calif. Phone: (213) 283-7773.

*Circle No. 259*



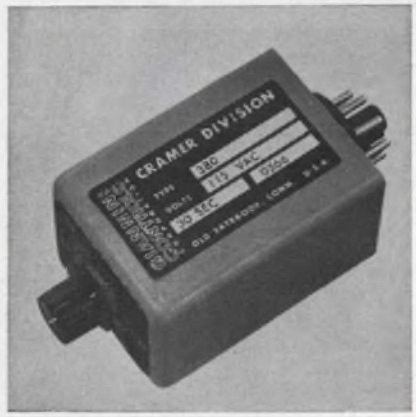

## Wirewound trimmer pots

Wirewound 1/2-in.$^2$ trimmer pots have molded-in PC board pins and epoxy seals. Rated 1 W at 70°C, the units are available with resistance values from 10 Ω to 50 kΩ. Resistance tolerance is ±5%. The trimmers meet MIL-R-27208.

P&A: $3.81 (100 lots); stock to 4 wks. IRC Inc., 401 N. Broad St., Philadelphia. Phone: (215) 922-8900.

*Circle No. 260*

## Time delay relay

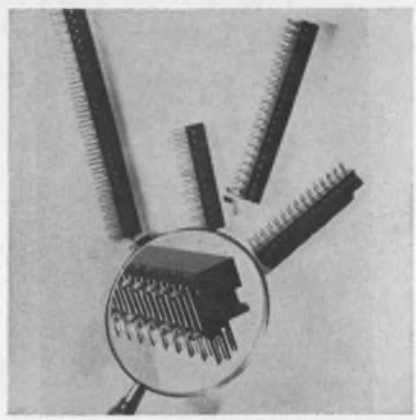



Four standard time ranges and 2 levels of accuracy are offered by this time delay relay. Available as a plug-in or a panel-mount, it has standard delays of 15, 30, 60, or 120 s. Standard accuracy is ±10% with repeat accuracy of ±5%. Reset time is 30 ms and lifetime is claimed to be $10^7$ operations.

Giannini Controls Corp., Cramer Div., Old Saybrook, Conn. Phone: (203) 388-3547.

*Circle No. 261*

## Strip mount connectors

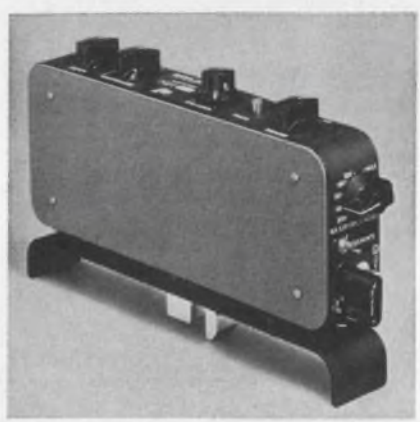


Strip mounted connectors with 3 to 51 contacts snap into PC boards without staking. The "split leg" design connectors feature one leg per contact. Contacts are retained in the strip by formed tabs extending through the upper surface. Contacts are gold plated phosphor bronze mounted on 0.1-in. staggered centers and are available with upper or lower rows only on 0.2-in. centers.

P&A: $.30 to $2.75; stock to 6 wks. Methode Electronics Inc., 7447 W. Wilson Ave., Chicago. Phone: (312) 867-9600.

*Circle No. 262*

## Electrometer amplifier



The NF1 amplifier is a wideband, direct coupled electrometer with neutralizable input capacity. It has $10^{11}$ Ω input resistance, input leakage current of $10^{-12}$ A and a gain of 3. Frequency response extends from dc to over 1 MHz. A six-position, low-pass filter selects cutoff frequencies of 300 Hz, 1, 3, 10, 30 kHz, and maximum bandwidth.

Price: $470. Bioelectric Instruments Inc., P.O. Box 204, Hastings-on-Hudson, N. Y. Phone: (914) 476-1234.

*Circle No. 263*

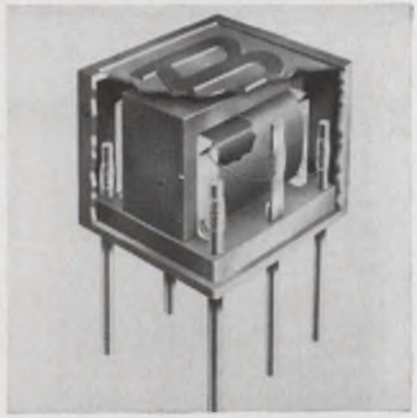
## Elapsed time programer


A solid-state, elapsed time digital programer programs contact closures. The unit can start or stop a test at selected times by thumbwheel coding switches mounted on the front panel. Minimum resolutions are 0.1 s with a 60 Hz time base. The unit is available in ranges of up to six decades of time information.

Parabam Inc., 12822 Yukon Ave., Hawthorne, Calif. Phone: (213) 679-3393.

*Circle No. 264*

## Hollow-core transformer



A 1/4-in.³ MIL-spec transformer features a laminated core. At 1 kHz, insertion loss is less than 3 dB. Frequency range is 400 Hz to 250 kHz and droop is 5%, overshoot is 10%, and rise time is 100 ns for square wave operation. Power rating is 1 W max. Turns ratios to 100:1 are available.

Price: \$10 (over 100). Bourns Inc., 1200 Columbia Ave., Riverside, Calif. Phone: (714) 684-1700.

*Circle No. 265*

## Time mark generator


A new pocket-sized self-contained time mark generator is for use as a calibrator or frequency standard. Three preselected frequencies (100 kHz, 1 MHz, and 10 MHz) having a tolerance of $\pm 0.005\%$, or an optional $\pm 0.0025\%$, are standard. A standard BNC interface for direct plug-in and internal battery power source are featured.

Price: \$79.95. Dayton Electronic Products Co., 117 E. Helena St., Dayton, Ohio. Phone: (513) 461-4951.

*Circle No. 266*

## Audio amplifier

Seven transistors and one thermistor give this audio amplifier frequency response of $\pm 1$ dB, 20 to 20,000 Hz, and a harmonic distortion less than 1%. Gain exceeds 80 dB. A shielded input transformer permits use with 50- to 150-Ω microphones. Transformer output has an 8-Ω and a 500-Ω winding capable of delivering 200 MW. The unit draws approximately 100 mA.

Price: \$34.50. Round Hill Associates, 434 Avenue of the Americas, New York. Phone: (212) 228-6600.

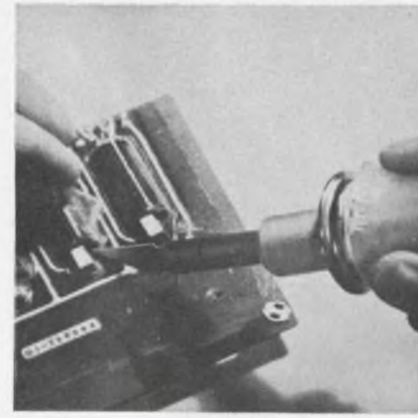
*Circle No. 267*

## Miniature 6 pdt relay

A 50% size reduction over conventional 6 pdt relays is represented by this 2.2-oz, 1-in. high, 1-in. diameter relay. It is designed for dry-circuit to 2-A applications. Coil resistance is 200 Ω at 25°C and initial contact resistance is 0.05 Ω max. Pull-in voltage is 14 Vdc max and drop-out voltage is 2 Vdc min. Operate and release times are 10 ms max at 26.5 Vdc. Insulation resistance is 1 GΩ min.

Electro-Tec Corp., P. O. Box 667, Ormond Beach, Fla. Phone: (305) 677-1771.

*Circle No. 268*

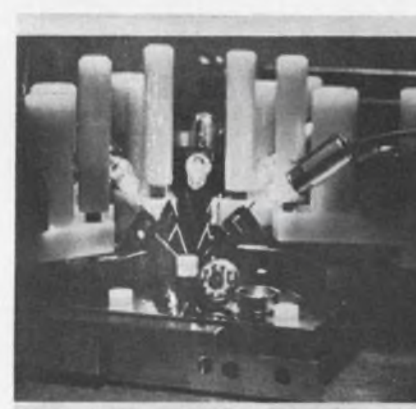


## Soldering knife

A 47-1/2-W heating unit with a collet closure, coupled with a razor-type blade, cuts low temperature epoxy coatings used to encapsulate components on PC boards. The cutting blade reaches 500° F. The "Hot-Knife" cuts and seals without pressure to prevent raveling and fraying.

Eldon Industries Inc., 2701 W. Elgundo, Hawthorne, Calif. Phone: (213) 757-2151.

*Circle No. 269*

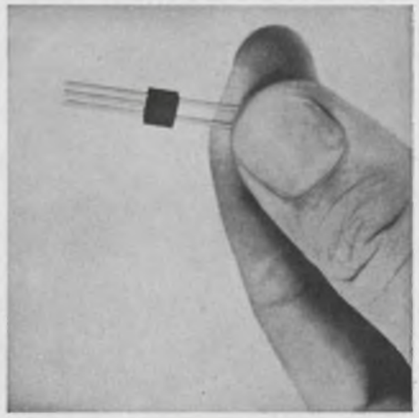


## Semiconductor probe

The "Autopsy Probe" enables testing of a mounted semiconductor device for failure analysis. The five probe points are manually controlled. An array of lens-shaped lamps provides illumination of devices under test. The probe consists of a base, an air-operated probe head and individually mounted probe point assemblies. The gold-plated vacuum chuck is manually rotational and mounts directly on an X-Y mechanical stage.

P&A: under $2000; 10 days. Unitek, 950 Royal Oaks Dr., Monrovia, Calif. Phone: (213) 359-8361.

*Circle No. 270*

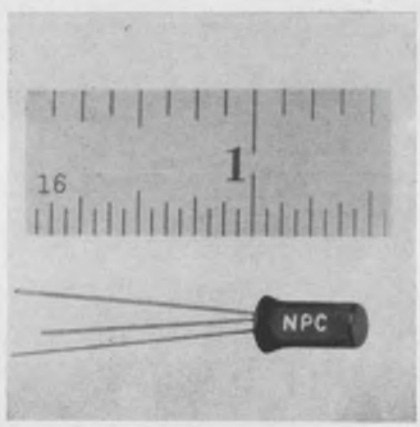


## Micromin chopper

Linear switching or chopping by this 0.5-gram "Microchopper" covers a dynamic range from $\pm 20$ $\mu$V to $\pm 20$ V. The all-silicon chopper can be driven from dc to 100 kHz. Unfiltered output noise is approximately 100 $\mu$V rms and linearity deviates $\pm 0.5\%$ max. Temperature coefficient is 5 $\mu$Vrms/°C at 5 $\mu$Vrms, 400 Hz output.

P&A: $79; stock. Solid State Electronics, 15321 Rayen St., Sepulveda, Calif. Phone: (213) 785-4473.

*Circle No. 271*




## Germanium transistors

Packaged in a TO-1 case, these pnp germanium alloy transistors feature low noise (4 dB) with a gain of 100 to 700. They provide low leakage and are rated at 30 V (2N2613) and 40 V (2N2614).

Total power dissipation is 200 mW at 25° ambient and 120 mW at 55°C derating linearly at 2.6 mW/°C. $V_{EB}$ is $-25$ V and $I_C$ is 100 mA.

Nucleonic Products Co. Inc., 3133 E. 12th St., Los Angeles. Phone: (213) 268-3464.

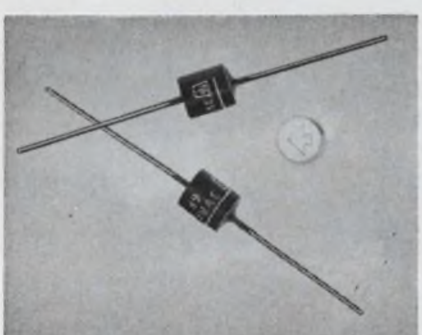
*Circle No. 272*

## Photo-mixing diode

A high-speed germanium diode demodulates laser outputs in optical communication systems operating in the 0.5 to 1.8 micron range. The photo-mixing diode L-4520 has a peak spectral response at 1.4 microns, a light sensitive area of 0.03 mm$^2$ and typical diode cutoff frequency of 1.5 GHz. A dc reverse bias greater than 6 V operates the diode in its most efficient high frequency detecting mode. The coherent minimum detectable power capability is estimated as less than $10^{-16}$ W. The L-4500 diode series covers the spectral range from 0.4 to 5.7 microns with cutoff frequencies extending beyond 20 GHz.

Price: $98 (over 100). Philco Corp., Tioga & C Sts., Philadelphia. Phone: (215) 443-5325.

*Circle No. 273*



## 3-W zener diode

A plastic-cased zener voltage-regulating diode dissipates 3 W rated at 25°C. The diodes are available with breakdown voltages from 6 to 200 V, in 13 steps, with standard voltage tolerance of 10%. Tolerances of 5 and 20% are available for all voltage ratings. Dynamic impedance is 1 Ω for the 6-V unit.

Price: $1.05 (1000 lots). Sarkes Tarzian Inc., 415 N. College Ave., Bloomington, Ind. Phone: (812) 332-1435.

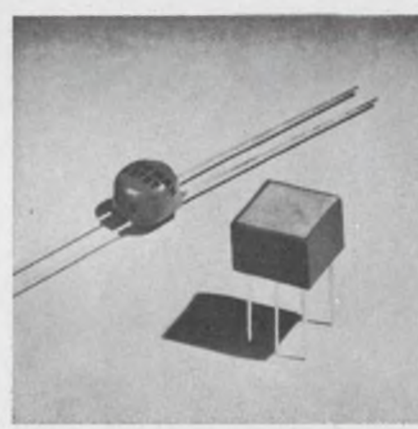
*Circle No. 274*

## Low-noise FETs

Two n-channel FETs are designed for RF and audio amplifiers. Noise figure of the 2N4220 is 2 dB (typ) at 100 Hz. The high input impedance is indicated by the 0.1-nA $I_{GSS}$ value at 15 V. Types 2N4223-24 offer low cross-modulation and intermodulation distortion, a 200-MHz noise figure of 5 dB (max) and a minimum gain of 10 dB at 200 MHz. Both are supplied in TO-72 cans.

P&A: $1.90 to $2.45 (100 to 999); stock. Motorola Semiconductor Products, Box 955, Phoenix, Ariz. Phone: (602) 273-6900.

*Circle No. 275*



## SCR trigger transformers

SCR trigger transformers are rated for operation with line voltages to 550 Vac. Two epoxy encapsulated case styles are available. The radial lead is for hand wired circuits and a single-ended type is for PC applications.

Two- and three-winding unity ratio types are standard. Others are available.

P&A: under $4; stock to 3 wks. Gudeman Co., 340 W. Huron St., Chicago. Phone: (312) 337-7400.

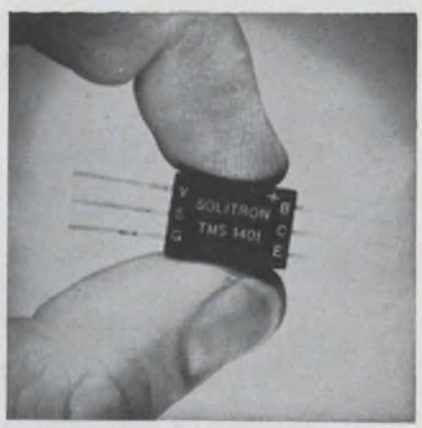
*Circle No. 276*

## Dual-in-line sockets

Three new sockets provide high-density packaging of dual-in-line ICs for production, life or sampling tests and for aging and breadboarding. Two hold dual-in-lines have up to 14 pins in two rows spaced 0.3-in. The 24-pin unit holds devices having up to 8 pins per row with either 0.2- or 0.3-in. row spacing. Contact resistance is less than 0.01 Ω. Typical interlead capacitance is 0.26 pF for adjacent terminals and 0.10 pF for opposite ones at 1 MHz.

Barnes Development Co., Lansdowne, Pa. Phone: (215) 622-1525.

*Circle No. 277*

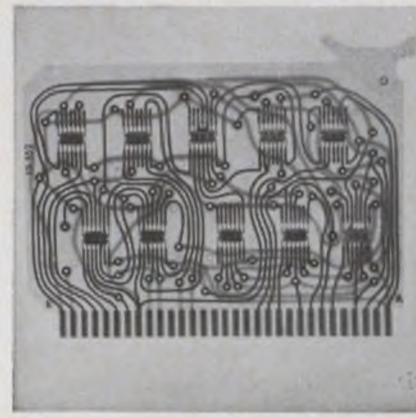



## Relay driver module

A microelectronic relay driver module is capable of driving any relay up to 28 Vdc and 500 mA. Drive circuitry contains an AND function with a choice of 2 inputs. The output incorporates a silicon planar transistor. Noise rejection is approximately 1 V. Package size is 0.41 x 0.625 x 0.35 in.

Price: $15 to $50. Solitron Devices Inc., 256 Oak Tree Rd., Tappan, N. Y. Phone: (914) 359-5050.

*Circle No. 278*



## 4-bit up-down counter

A 1-digit (4-bit) up-down counter is designed for standard binary or BCD applications and can be cascaded in any number of successive bit-groups with internal clock restore. Model 13-552 includes 4 flip-flops with true and false outputs, preset and reset inputs and all gating. It accepts separate "count-up" and "count-down" pulses at inverted logic levels. Max count rate is 5 MHz and count pulse is 40 μs min. Logic true is +6 V and false is 0 V. The counter uses silicon-planar-epitaxial monolithic ICs in the form of 14-lead flat packs. Chips are resistance soldered to the glass epoxy board. The edge connector contains 62 rhodium-over-nickel plated contacts.

Canoga Electronics Corp., 8966 Comanche Ave., Chatsworth, Calif. Phone: (213) 341-3010.

*Circle No. 279*

## IC audio amplifier

An 8-transistor balanced circuit with internal dc feedback is fabricated on a single monolithic silicon chip. Three-stage class A preamplifiers providing high gain are followed by class B output stages for 55% over-all efficiency. The WC 183 IC low-level audio amplifier has a quiescent current of 1 mA max, and it achieves 72-dB gain using a single one-cell battery for power. An optional roll-off capacitor makes the amplifier suitable for voice communications equipment. A simple external feedback network extends the flat frequency response well beyond the audio range.

P&A: $10.50 (1 to 49), $7.50 (50 to 499); stock. Westinghouse, Molecular Electronics Div., P.O. Box 7377, Elkridge, Md. Phone: (301) 796-3666.

*Circle No. 280*

## TWT amplifier

A low-noise, single-reversal, permanent magnet traveling-wave tube amplifier is designed for the 8 to 12 GHz band. Specifications include a 9-dB maximum noise figure, a 25-dB minimum small signal gain and 13-dBm minimum power output. Input and output vswr are 2 max. Primary voltage is 115 ±3 Vac.

Watkins Johnson Co., 3333 Hillview Ave., Stanford Industrial Pk., Palo Alto, Calif. Phone: (415) 326-8830.

*Circle No. 281*

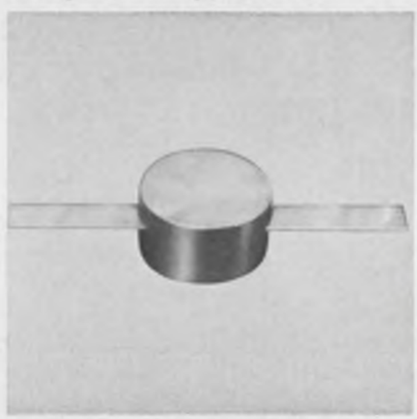
## 1-kw beacon magnetron

A positively-pulsed, 1 kW, Ku-band tunable beacon magnetron tunes over the 16 to 16.5 GHz range with a 0.5-μs pulse width and a 0.001 duty ratio. Peak anode voltage is 3 kV and peak anode current is 1.6 A. Input connections are made through flexible leads or solder lugs and the output connector mates with a UG-541/-U choke flange.

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

*Circle No. 282*

## Stripline capacitors



Capacitors for microwave stripline use are offered in a range from 10 to 1000 pF. Available for 1/4- or 1/8-in. ground plane spacing, the devices are rated at 0.5 W dissipation at 25°C and have a maximum voltage of 100 V. They have ribbon leads spaced midway between the ground planes. All contact areas are gold-plated.

P&A: $2 (production quantities); stock to 4 wks. EMC Technology Inc., 1133-35 Arch St., Philadelphia. Phone: (215) 563-1340.

*Circle No. 283*

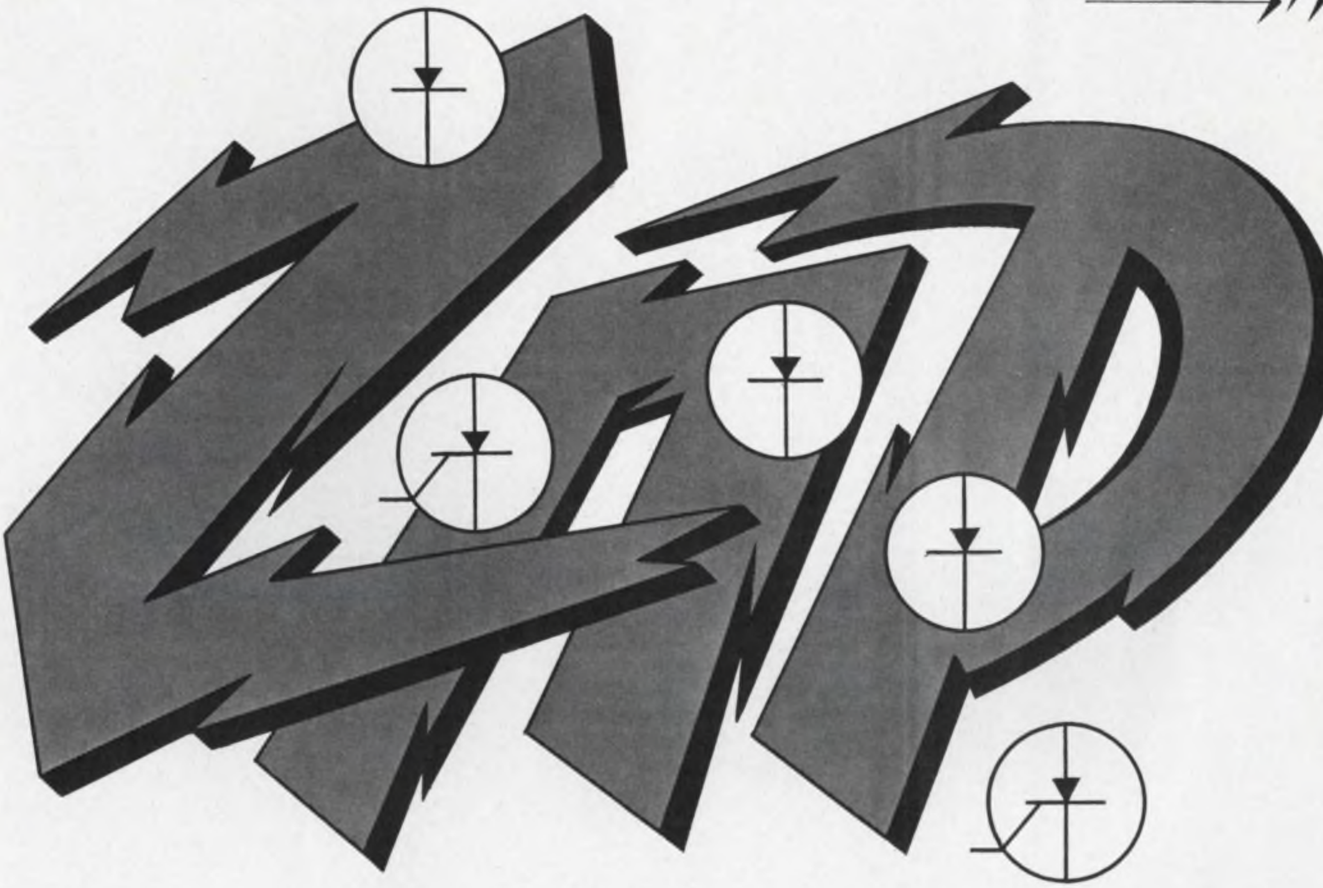
## E-plane waveguide tee

This iridited aluminum X-band waveguide E-plane tee is readily adapted as a holder for oscillating, limiting, and spst and spdt switching microwave diodes. Frequency range is 8.2 to 12.4 GHz. Model X160 has 3 cover-type flanges with 8-32 tapped holes that mate with UG-39/U waveguide.

P&A: $66; stock. Somerset Radiation Lab., Inc., P.O. Box 201, Edison, Pa. Phone: (215) 348-8883.

*Circle No. 284*

ELECTRONIC INNOVATIONS IN ACTION



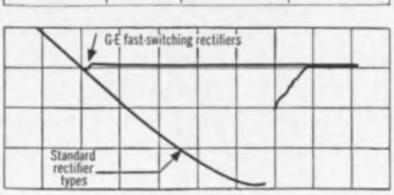

# Holy power devices, Batman! G-E SCR's and rectifiers sure switch fast

**HIGH SPEED SCR TYPES AVAILABLE**

| Series | Rating | Max. Turn-off Time | Configuration |
|---|---|---|---|
| C12U-D | 7.4 amps | 12 $\mu$-sec. | TO-48 |
| C40U-E | 35 amps | 12 $\mu$-sec. | TO-48 |
| C140/141F-D | 25 amps | 15/10 $\mu$-sec. | TO-48 |
| C55U-M | 110 amps | 20 $\mu$-sec. | TO-49 |
| C154/155A-E | 110 amps | 10/20 $\mu$-sec. | TO-49 |
| C185A-E | 235 amps | 20 $\mu$-sec. | TO-49 |

**HIGH SPEED RECTIFIER DIODE TYPES AVAILABLE**

| Series | Rating | Max. Reverse Recovery Time | Configuration |
|---|---|---|---|
| 1N3879-83 | 6 amps | 200 ns | DO-4 |
| 1N3884-89 | 12 amps | 200 ns | DO-4 |
| A28F-D | 12 amps | 100 ns | DO-4 |
| 1N3901-08 | 20 amps | 200 ns | DO-5 |
| 1N3909-13 | 30 amps | 200 ns | DO-5 |




**Comparison of reverse recovery performance**

■ So fast, even Batman can't keep up with them.

High-power SCR's—like G-E 235-amp-RMS C185 devices, for example—give you typical turnoff times of only 15 microseconds. 110-amp C154's and C156's, just 10 microseconds. And the 25-amp C140's and C141's give you not only quick turnoff times, but also the rated capability to switch at frequencies as high as 25 kilocycles per second.

Son-of-a-diode! That must mean G.E. has some awfully fast-switching rectifier lines, too.

Right! No fewer than 5 different G-E rectifier lines are available—all with reverse recovery speeds at least as fast as 200 nanoseconds. Lightning speeds like these let your circuits work at much higher frequencies, generate less RFI even in 60 Hz circuits, develop less transient voltage problems, and improve circuit efficiencies, too. And quite often, they can even lower your circuit costs.

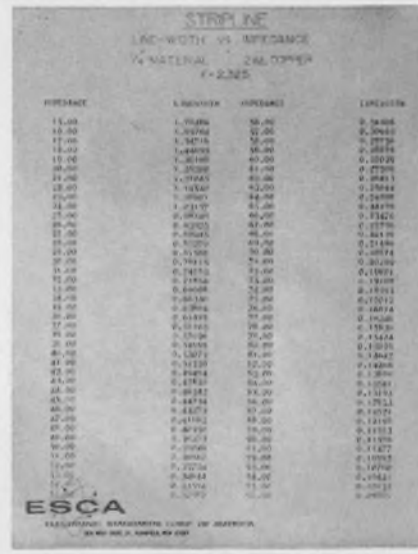
It would be criminal if you didn't try this dynamic duo in at least a few of your high frequency applications. This is one more example of General Electric's total electronic capability. Ask your G-E engineer/salesman or semiconductor distributor about G.E.'s leadership line of fast-switching power devices. Or write to Section 220-33, General Electric Company, Schenectady, N.Y. In Canada: Canadian General Electric, 189 Dufferin St., Toronto, Ont. Export: Electronic Component Sales, IGE Export Division, 159 Madison Ave., New York, New York.

SEMICONDUCTOR PRODUCTS DEPARTMENT

**GENERAL ELECTRIC**

ON READER-SERVICE CARD CIRCLE 43

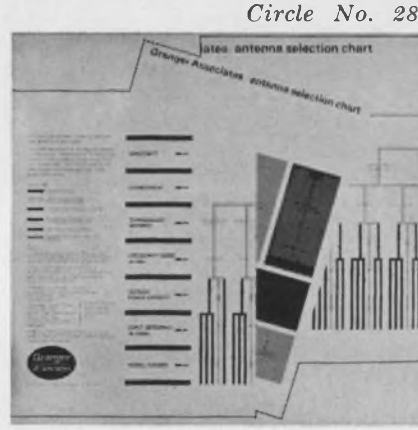
# Design Aids




## Stripline impedance

Strip width versus impedance is listed in tabular form for single-board thicknesses of 1/16-, 1/8- and 1/4-in. (b=1/8-, 1/4-, and 1/2-in.) and the popular dielectric constant of 2.32. The seven pages of tables are accompanied by a reference sheet of coaxial components. Electronic Standards Corp. of America.

*Circle No. 285*

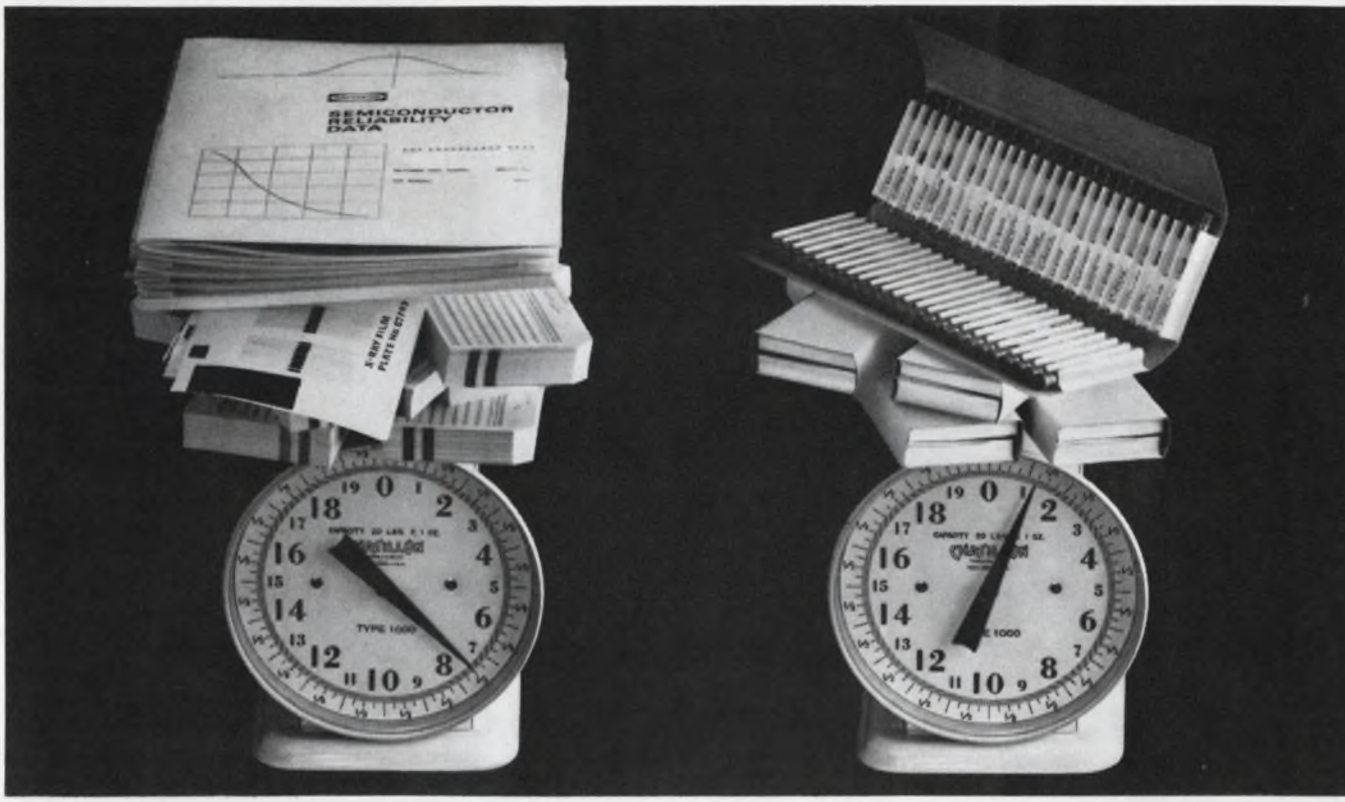



## Hf antenna selection

A full-color high-frequency antenna selection chart aids in selection of an antenna to meet nearly any combination of environmental and transmission requirements in the 2- to 32-MHz range. The 188 antennas are arranged according to requirements for directivity, transmission, frequency range, power capacity, input impedance and ability to withstand wind and ice. Among the standard antennas listed are: point-to-point, sector-coverage, broadcast, transportable, steerable and diversity-reception types. Granger Associates.

*Circle No. 286*

# Why our reports usually outweigh our high reliability shipments




We document everything about our semiconductors—logging-in data from diffusion furnaces to multiple burn-ins. We supply complete reports including computer print-outs, X-rays—just as we do with our shipments of semiconductors for Apollo, Gemini and Minuteman.

**Complete documentation is readily available.** Because, *all* Raytheon transistors and diodes are processed under our *exclusive diffusion lot control system* rather than time lot control. We log all data beginning with the processing of each group of wafers through the diffusion furnace, and continue accurate documentation through every stage of manufacture. This *ensures complete traceability of each diffusion lot.*

**Standard and special high reliability programs.** We meet all reliability requirements to your precise specifications, no matter how stringent. We also provide standard high reliability programs: our Mark X and XII, X-L and Trace programs can save you thousands of hours and dollars—as they have for many of our customers.

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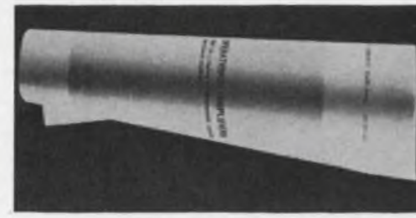
# Application Notes



## Operational amplifiers

A 9-page application note (Part III in a continuing series), outlines the basic characteristics of 5 major operational amplifier types. General purpose differential, IC, wideband fast response, high input impedance, low input current and chopper-stabilized op amps are covered. The brochure discusses availability, listing names and addresses of 28 manufacturers. Five specification charts—one for each type—list published specifications and prices for each firm's product line.

Part I of the series covers principles of operation and error analysis. Part II details inverting, non-inverting and differential configurations. Analog Devices.

*Circle No. 287*

## Thermistors

This eight-page brochure provides some insight into the mechanisms of failure of various types of thermistors along with summary data for design and application purposes. Thermistor characteristics such as stability and preconditioning are fully covered. Victory Engineering Corp.

*Circle No. 288*

## SCR gate drives

Some solutions to the problems of precise control of motor shaft speed, power supply output voltage and heavy current flow are given in this 24-page application note. The paper describes a three-phase SCR gate drive for three-phase circuits using 6 SCRs. The drive consists of 3 matched single phase circuits. A detailed analysis of the full-wave bridge is illustrated with oscillograms showing SCR gate pulses, anode voltage and current and load voltage. Graphs present various parameters as a percentage of output. Sprague Electric Co.

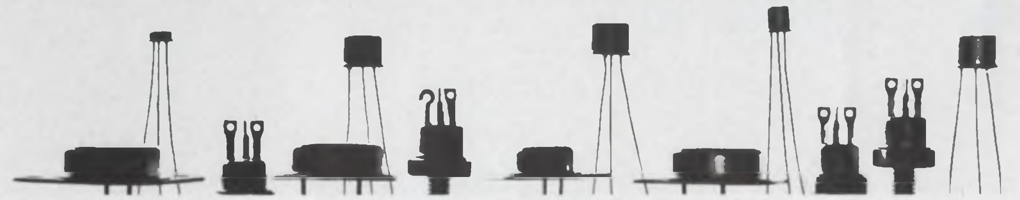
*Circle No. 289*

# PLANAR SCRs 0-400V, 0-10A, 150°C

**PNPN Planar Switching SCRs** A complete line of silicon controlled rectifiers for switching applications is now available from Fairchild. We guarantee performance to 125°C, up to 150°C in some instances. We cover the range from 0 to 400 volts, from 0 to 10 amps, in six package types (TO-3, TO-5, TO-18, TO-46, TO-59, and TO-66), for consumer, industrial, and military applications.

Whether you need a device for sensor control, for miniature motor control, for a counter or a timer, a solenoid or light dimmer, or for any of a dozen other applications, it will pay you to check with Fairchild. Our devices perform better, have lower forward and reverse leakages, and are competitively priced. And you get Planar reliability as a bonus. Sample specifications are shown below. For complete information drop us a note, or check with a Fairchild Distributor.

FAIRCHILD SEMICONDUCTOR



**SAMPLE SPECIFICATIONS**

**2N1595-98, 2N2322-28, 2N3559-62**

| | |
|---|---|
| $I_{FM}$ | 1.6A @ 85°C case |
| $I_{FO}$ & $I_{RO}$ | 100nA max. @ 50-300V |
| $I_{GT}$ | 100μA max. |
| $V_{GT}$ | 0.8V max. |
| $I_H$ | 1.0mA max. |
| $V_F$ | 1.6V max. @ 1.0A |
| $T_j$ | 125°C max. |
| Package | TO-5 |

**OTHER FAIRCHILD SCR FAMILIES**

| | |
|---|---|
| 2N4316-19 | 0 to 400V, 0 to 10A in TO-66 packaging. |
| 2N3228 | 0 to 400V, 0 to 10A in TO-66 packaging. |
| 2N3525 | 0 to 400V, 0 to 10A in TO-66 packaging. |
| SE9030-33 | 0 to 400V, 0 to 10A in TO-3 packaging. |
| 2N4096-4098 | 0 to 200V, 0 to 500mA in TO-46 packaging. |
| 2N4108-4110 | 0 to 200V, 0 to 500mA in TO-18 packaging. |

Planar is a patented Fairchild process.

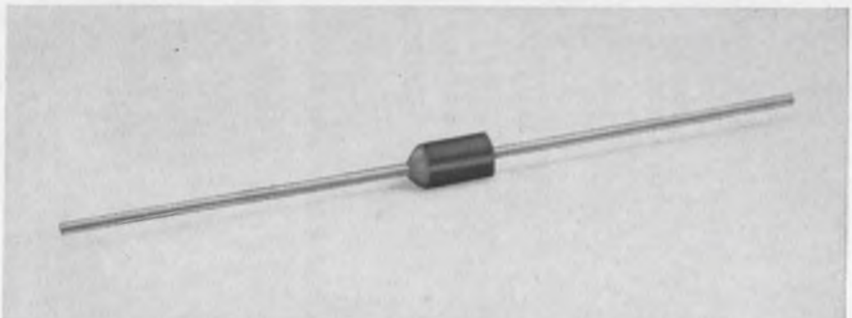
FAIRCHILD SEMICONDUCTOR / A Division of Fairchild Camera and Instrument Corporation ■ 313 Fairchild Drive, Mountain View, California (415) 962-5011 ■ TWX: 910-379-6435

ON READER-SERVICE CARD CIRCLE 47

# DESIGNER'S

P. R. MALLORY & CO. INC., INDIANAPOLIS, INDIANA 46206

## Molded Zener Diodes give high reliability at low prices



The Mallory Type ZA zeners are molded units which give performance and reliability equal to that required by military specifications —at about half the price of hermetically sealed zeners.

One reason for this unusual quality is that Mallory uses the same silicon cell in the Type ZA as in the zener diodes we make for military requirements. Another is the unique Mallory production technique, in which complete classification, screening and pre-testing can be done on silicon cells before packaging. And finally, there's the economy of the molded case—moisture-proof, electrically cold, and so compact that high-density circuit packages are readily accommodated.

The 1-watt Type ZA and 3-watt Type ZAC are available in zener ratings from 6.8 to 200 volts. Hermetically sealed and high wattage ratings are also available.

**CIRCLE 240 ON READER SERVICE CARD**

## New Hermetic Seal Tantalum Capacitors—Style CL55 of MIL-C-3965C

The new Mallory Type TL wet slug tantalum capacitor is a compact rectangular package designed for ability to withstand extreme environmental conditions. It has glass-to-metal terminal seals in a hermetic sealed outer case. Microfarad-volt ratings per unit volume are exceptionally high for this class of construction.


The TL offers the superior performance which is characteristic of Mallory wet slug capacitors. It has exceptional stability of capacitance and power factor, both over a broad temperature range from —55°C to +125°C, and throughout extended operating life and shelf tests. DC leakage is low; maximum values at top mfd-volt ratings are in the order of 10 microamps, with actual test values typically around 1 to 2 microamps.

Ratings available: 2400 mfd, 15 volts to 180 mfd, 150 volts. Temperature rating: —55°C to +125°C. The TL is designed to meet performance criteria of style CL55, per MIL-C-3965C and MIL-C-3965/21B.

**CIRCLE 242 ON READER SERVICE CARD**

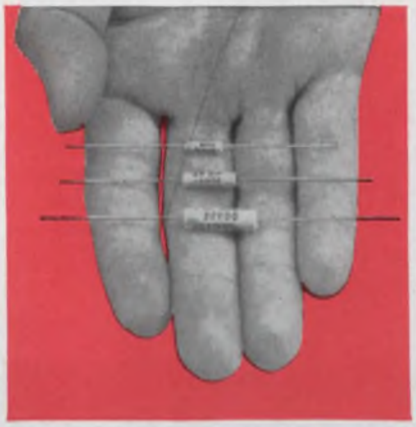
## Wire-Wound Controls with special Temperature Coefficients

When exceptional stability of resistance is needed over the normal operating temperature range, Mallory can supply custom-made wire-wound controls with special values of temperature coefficient. Selected types of resistance wire are used for the winding.

The minimum TC available is 20 parts per million per degree C . . . also stated as .002% or ±.00002 ohm/ohm/°C. All styles of Mallory wire-wound controls—2, 3, 4, 5, 7 and 12½ watts—can be supplied with special TC.

**CIRCLE 241 ON READER SERVICE CARD**

# FILE MALLORY 50th ANNIVERSARY



## No voltage de-rating needed on MTP wet slug tantalum capacitors

Many designers add their own "safety factor" by specifying a considerably higher voltage rating than actually needed for surge or steady state conditions in the circuit. With Mallory MTP miniature wet slug tantalum capacitors, you don't need to de-rate. And you can often save space and money by *not* de-rating.

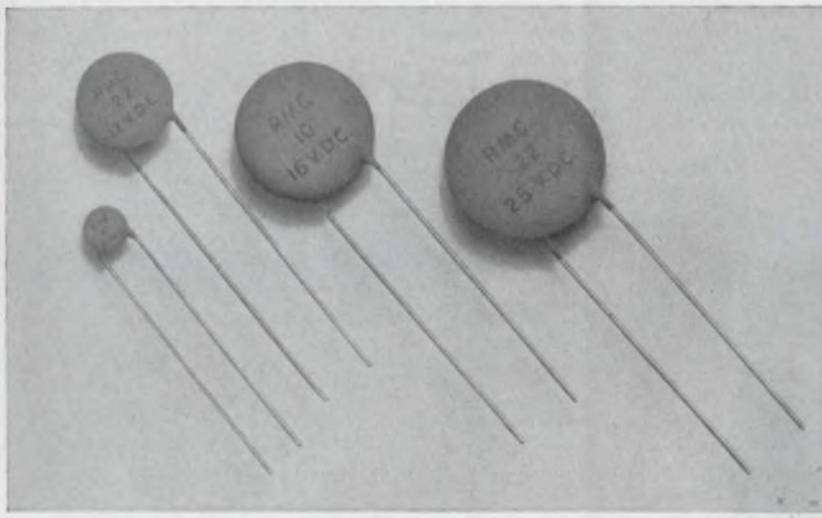
How come? In the first place, we've already built in a generous safety factor in the stated rating on the capacitor. And second, we've found out by tests that operating at reduced voltage neither improves nor impairs performance of the MTP. We have extensive data in a recent engineering report, which we'll be glad to send on request.

As an example of the size savings possible, a 33 mfd, 60 volt MTP measures .225" in diameter by .775" long. But the same 33 mfd at *50* volts fits into the next smaller case size: .145" in diameter by .590" long. And the cost is about 13% lower.

The MTP, incidentally, has the most capacity per unit size of any tantalum capacitor—up to 178,000 mfd-volts/cubic inch, or about five times what you can get in any solid electrolyte type. And it's made in the same high-reliability facility as similar Mallory capacitors for Minuteman II.

**CIRCLE 243 ON READER SERVICE CARD**

## High capacity ceramic capacitors save space in transistor circuits



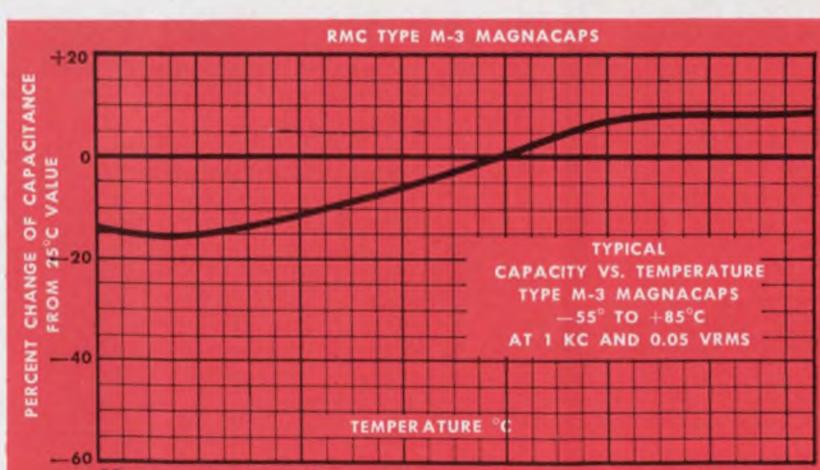
Whenever you need a lot of microfarads in a small space at transistor circuit voltages, use Magnacap® disc ceramic capacitors. Made by Radio Materials Company, a division of Mallory, Magnacaps are particularly applicable to by-pass and coupling in low impedance transistor circuits.

Because they maintain their impedance characteristics well into the radio frequency range, they are especially useful as emitter bypasses. They fill the range of capacitance values between standard RMC Discap® Capacitors and Mallory aluminum or tantalum electrolytics.

Insulation resistance is amply high to assure excellent operation in battery powered equipment. Magnacaps have outstanding stability of capacitance from −55°C to +85°C. They have a proven record of reliability, and are economically priced.

3, 12, 16 and 25 volt ratings are available. Maximum capacities: 2.2 mfd @ 3 volts; 1.0 mfd @ 12 volts; .22 mfd @ 16 volts and 25 volts.

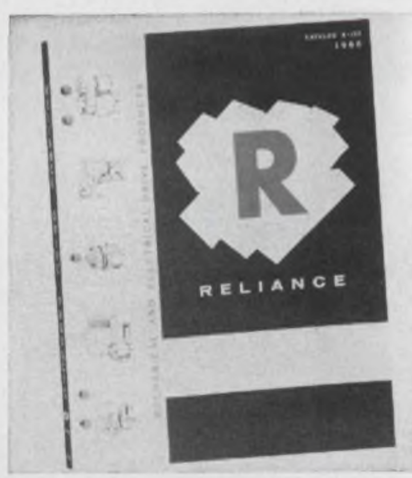
**CIRCLE 245 ON READER SERVICE CARD**



# New Literature


## Thermoelectrics

A news bulletin on thermoelectrics contains technical and performance data and a glossary of thermoelectric terms. Attention is given to applications, design procedure for determining temperature control requirements and installation considerations. Cambridge Thermionic Corp. *Circle No. 290*




## Drive systems

A 180-page, all-products, price and data catalog covers a line of mechanical and electrical drive products. It assists in selecting mechanical and electrical variable speed drives, gearmotors, separate reducers, and fractional and integral ac and dc motors. The catalog includes features, applications, selection tables, pricing and dimensional data. Reliance Electric & Engineering Co. *Circle No. 291*

## Computer programing

Programed instruction in computer programing is offered in the form of an illustrated booklet and an enclosed 33 1/3 rpm record. The record provides immediate feedback and paces the student through the exercises.

*Available for $0.85 from N.P.C. Inc., 5 Highlander Ave., Scotch Plains, N. J.*

## Fluidic elements

Description, operating characteristics, applications and specifications of a fluid state diode, a bistable and a monostable fluid amplifier are given in 3 data sheets. Aviation Electric Ltd.

*Circle No. 292*


## Glow lamp manual

This 118-page, spiral-bound manual contains data and testing instructions for evaluating neon glow lamps and includes a substitute lamp guide. Subjects covered are the physics and characteristics of glow lamps, relaxation oscillators, logic and computer applications, test methods and specifications. General Electric, Miniature Lamp Div.

*Circle No. 293*

## Diallyl phthalate

A guide to existing end-uses of diallyl phthalate resin-based molding compounds and reinforced plastics is offered. This 32-page booklet reproduces trade press and newspaper clippings that describe commercial end-uses of the thermosetting material. Each clipping covers a different end-product. Over 120 are listed. FMC Corp.

*Circle No. 294*

### Power supplies

"Power Suppiies Unlimited" describes and provides complete specification tables for the manufacturer's line of dc supplies. A chart cross-indexes model numbers with such factors as voltage range, current range, regulation, ripple and size. NJE Corp.

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### Solder alloys

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# Manufacturers

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### July 6-9

**Annual Meeting of the National Society of Professional Engineers** (Minneapolis, Minnesota) Sponsor: National Society of Professional Engineers; Kenneth E. Trombley, 2029 K St., N.W., Washington, D. C.

### July 11-13

**Electromagnetic Compatibility Symposium** (San Francisco, Calif.) Sponsor: IEEE, G-EMC; A. Fong, Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif.

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### July 18-20

**Microelectronics Symposium** (St. Louis, Mo.) Sponsor: IEEE; Dr. John W. Buttrey, McDonnell Aircraft Corp., P. O. Box 516, St. Louis, Mo.

### August 17-19

**Joint Automatic Control Conference** (Seattle, Wash.) Sponsor: AACC; Prof. Arthur Bryson, Dept. of A&A, MIT, Cambridge, Mass.

### August 23-26

**WESCON (Western Electronic Show & Convention)** (Los Angeles, Calif.) Sponsor: IEEE; Don Larson, WESCON, 3600 Wilshire Blvd., Los Angeles, Calif.


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| **RH-10** | RE-65 | 12.5 (10) | 10 | .1—47K | |
| **RH-25** | RE-70 | 25 | 20 | .1—95K | 5x7x2x.040 Aluminum Chassis |
| **RH-50** | RE-75 | 50 | 30 | .1—273K | 12x12x.059 Aluminum Panel |
| **RH-100** | RE-77 | 100 | 75 | .1—50K | 12x12x.125 Aluminum Panel |
| **RH-250** | RE-80 | 250 | 120 | .1—75K | |

**ELECTRICAL & ENVIRONMENTAL SPECIFICATIONS**

**Tolerance:** .05%, .10%, .25%, .5%, 1%, 3%

**Load Life:** 1% max.Δ R (RH-5 – 50) 3% max.Δ R (RH-100 – 250) in 1000-hour load life.

**Operating Temp:** –55° C to +275° C

**Overload:** ±.5% max.Δ R per MIL-R-18546D

*Power Rating based on 275° C max. internal hotspot temperature with resistor mounted on standard heat sink. Figures in parentheses indicate wattage printed on RH-5 and RH-10. New construction allows higher ratings as shown, but these resistors will be printed with the higher rating only on customer request.

***For complete housed resistor information including non-inductive and thru-chassis models--write for Catalog A.***

DALE®

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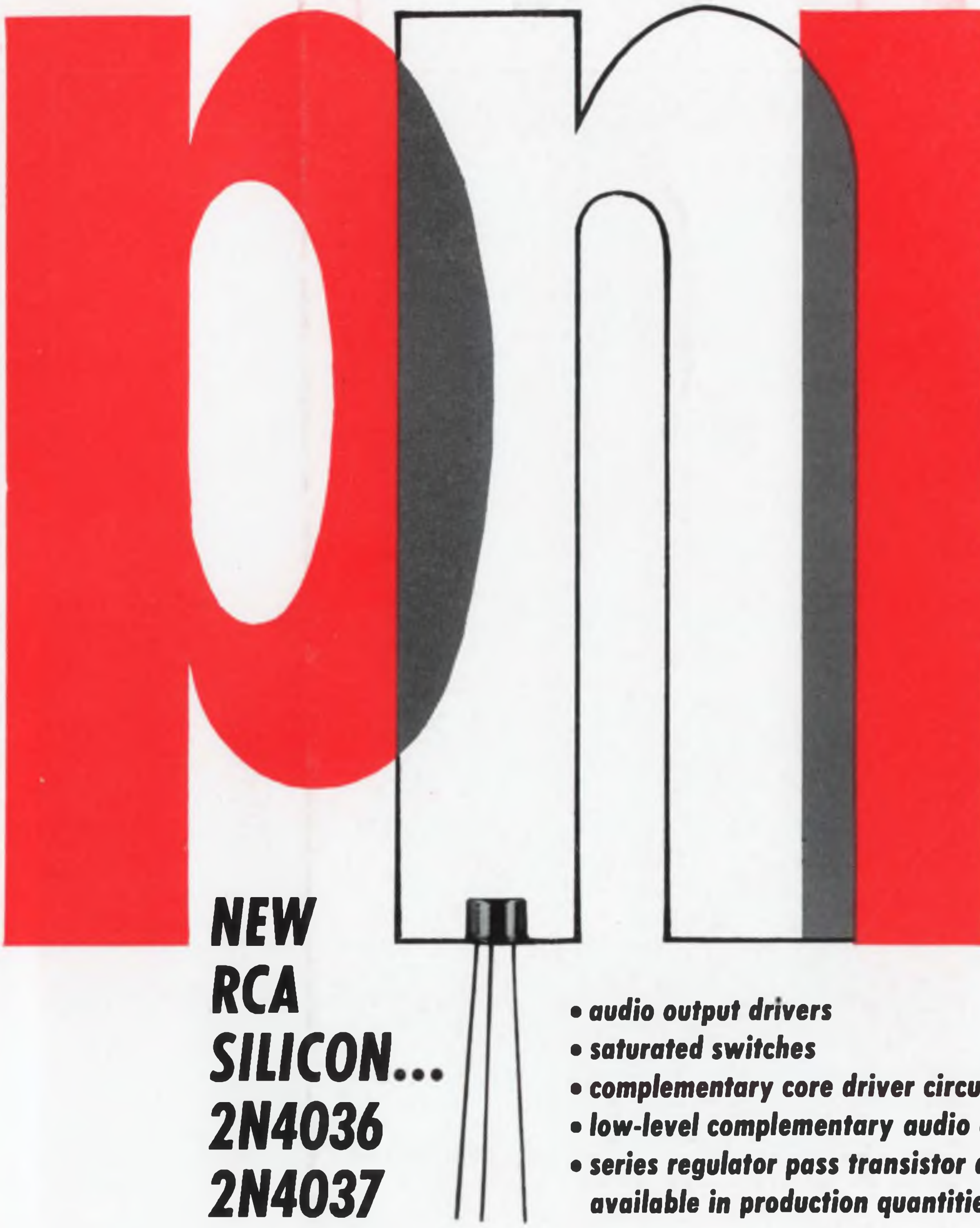


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| $V_{CEO}$ | —65V | —40V |
| $V_{EBO}$ | —7V | —7V |
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