New uses for gallium arsenide: page 82
Read-only memories to perform logic: page 111
A maser designed for radar: page 115
We’ve used an ordinary pilot lamp to prove a point: Our new Type 1026 Standard-Signal Generator puts out lots of power — ½ watt into 50 ohms, 10 volts behind 50 ohms (5 volts when modulated). It also puts out as little as 0.1 µV and anything in between these limits.

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This instrument is made to order for a-m receiver testing, and its high-level output makes it most suitable for antenna-pattern and impedance measurements, receiver overload and cross-modulation tests, and measurements of large insertion losses. The ease of operation and outstanding performance of the 1026 in the most critical applications must be experienced to be appreciated.

For complete information or a demonstration of the 1026, write General Radio Company, W. Concord, Massachusetts 01781; telephone (617) 369-4400; TWX (710) 347-1051.
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For complete information, contact your local HP field engineer, or write Hewlett-Packard, Palo Alto, California 94304; Europe: 54 Route des Acacias, Geneva.

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Plot density (plots/inch): 200, 100, 50, 20, 10
Increment size (in./advance): 0.005", 0.01", 0.02", 0.05", 0.10"

**Frame advance mode**
Advance distance: 24"
Accuracy: ±0.005" (non-accumulative)
Advance time: <14 sec.

**Time base mode**
Chart speeds: 1, 5, 10, 50, 100 sec/in.
Accuracy: ±2%

**Major division advance mode**
Advance distance: Major divs. in 3" increments
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Advance time: 2 sec.

Other advance increments available

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resistors in the decade and range dividers, plus a
temperature-compensated Zener diode reference
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and short-circuit protection. Calibration labs save
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tance of less than 5 pf reduces loading errors and
circuit instabilities during measurement. Input im­
pedance is 1 megohm.

DC DIFFERENTIAL VOLTMETER, 90-DAY CYCLE
±0.02% or ±0.002% FS (whichever is greater) from
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characteristic for drift measurements when null can­
not be maintained. TC is less than 3 ppm/°C from
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AC-DC VOLTMETER / POWER AMPLIFIER provides
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this calibration lab instrument provides a ±0.02%
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DC DIFFERENTIAL VOLTMETER OPTION 7418
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Using memories to generate Boolean algebra changes conventional computer concepts
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Microwaves 115 A maser that works in radar by avoiding saturation
A frequency-shifting technique prevents saturation of a maser so it can be used in radar systems
Simpson B. Adler, Radio Corp. of America
To the Editor:
As a "brain drain" engineer, I would like to comment on your editorial "Engineers abroad flee . . . .", [March 20, p. 23; also Comment, April 17, p. 4].

You opine that the solution to this problem lies in remedying the lack of technical scope and the backward attitudes of management, etc., in brain-drain countries. But why does this sorry state of affairs exist? Might it not be that it is exactly the ideology which refuses to recognize the individual's right to his own life, liberty and the pursuit of happiness—and seeks the solution to every problem by means of force, by the wielding of a legislative club (and eventually a literal one)—that is responsible for the condition of which a brain drain is but one symptom?

The implication of these discussions is that engineers are the property of the governments of their respective countries of origin; and indeed, what those governments are in effect clamoring for is a Berlin Wall, to prevent their productive cattle from escaping. The issue here is none other than that of human slavery, camouflaged by euphemisms and equivocation.

What engineers come to America for is to live and function in a country founded on the ideals and principles of the American constitution and the political philosophy of such men as Thomas Jefferson, whether they are aware of this (the minority), or only of its effects (the majority) in the form of wider professional opportunity, a more courageous attitude toward progress, and a higher standard of living.

Bernard S. Super
Elmhurst, N.Y.
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how “an indefinite number of words” are represented in an eight-bit code.

Steve Sells
Kansas City, Mo.

- In the Dorsett machine, the number of words to which the eight-bit code responds is “indefinite” because the coding doesn’t have to distinguish every word in the English language, but only among those that make sense as a response in the context of a given program. For example, the machine may respond in the same way to the words “potato” and “transformer”. However, only one of these words is apt in a programed course in electronics.

Dim view

To the Editor:

Your editorial on the “dim picture” for color television in Europe [May 29, p. 23] assumes that Europeans will disregard the problems which Americans uncovered during the early days of color receiver design and broadcasting in the States.

We Frenchmen have generally repudiated our famous M. Chauvin, who held that anything not French was not good and that what is done in France should be the model for other countries. There is a mistake from which Americans cannot profit. You seem to assume that foreigners will retrace the technical steps of their American counterparts, repeating the same flaws in the color fidelity of broadcasts and in the crude early methods of tuning television sets. However innocently arrived at, this assumption is offensive.

The American techniques and equipment, while first to reach commercial success, are not the ultimate. May I remind you that the French Secam system is superior to the American NTSC system in that it avoids phase distortion problems during transmission of color signals. Another example of European improvement in television technology is the British color-television camera, reported on page 168 of your Dec. 26, 1966 issue.

Of course prices for the first European receivers will be high and the amount of color broadcasting will be low, since a large sales volume would take time to establish, but not enjoying a billion-dollar market at the outset is no tragedy.

The slim schedules of color programs may inhibit the general sale of sets, but Europeans, like Americans, who can afford this new status symbol will buy a color TV set and enjoy the programs that do come in color. Our black-and-white television broadcasting schedules, for example, are only a fraction of those in the United States but that hasn’t kept Europeans from buying TV sets and enjoying what is available to them.

Lille, France

Paul Rion

Army aid

To the Editor:

In “Computer aided design: A model approach to IC’s” [May 1, p. 56], I neglected to point out that the research reported was sponsored by the U.S. Army Picatinny Arsenal under contract number DA-28-017-AMC-3187(A).

Gerald J. Herskowitz
Associate Professor
of Electrical Engineering
Stevens Institute of Technology
Hoboken, N.J.
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People

Less than a week after winning the SAM-D missile contract from the Army, the Raytheon Co. appointed the program's project manager, 45-year-old Floyd T. Wimberly, to the post of vice president. It was Wimberly's design package for the missile that beat out the Hughes Aircraft Co. and the Radio Corp. of America for the advanced development order.

According to Wimberly, the new ground-to-air missile will take a new approach to guidance and make heavy use of integrated circuits. In fact, he adds, some degree of large-scale integration will be applied. By the time the SAM-D work gets into the engineering development stage, Wimberly explains, Raytheon will have had enough experience with LSI to use it in hardware prototypes.

Winning the contract could mean as much as $2.5 billion to Raytheon if the decision is made to move into production. Raytheon's prime contract for the Hawk missile system has brought in more than $1.5 billion over the past 13 years. The company also produces the Sparrow 3 for the Navy.

Other uses. While SAM-D is primarily intended for defense of field forces in the 1970's against high-performance aircraft and short-range missiles, it also has a potential application for continental air defense. Because some components of the system could also be used for air defense aboard ship, the Navy is participating in the development program.

Playing a significant role in Raytheon's victory, Wimberly says, was the company's development of ferrite arrays [Electronics, Jan. 9, p. 172]. The company-funded program was begun after Army studies indicated the need for multitarget multifunction arrays. SAM-D will be capable of simultaneously acquiring, tracking, identifying, and destroying multiple targets.

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  - Buffer Amplifier: UD-4037

People

"To expand our role in electronics and antisubmarine-warfare systems, we'll investigate digital computation and electro-optical techniques," says Simeon E. Watson, new vice president for research and engineering at the Loral Corp.'s Electronic Systems division. Watson's position is a new one for Loral. Moving over from Teledyne Inc., he brings to his new job a doctorate in electrical engineering and the experience gained from his previous associations with the McDonnell Aircraft Corp. (now the McDonnell Douglas Corp.) and the Collins Radio Co.

The 44-year-old Watson will push for large-scale integration to upgrade Loral's computer capabilities. His plans call for purchasing logic chips and then interconnecting and packaging them in-house to generate a hybrid LSI-circuit family. He envisions small special-purpose digital computers for use in signal-recognition and digital-control applications. First units could be operating in a year.

According to Watson, electro-optics research, although directed toward military-sensor applications, might eventually bolster the company's existing display capability. Loral now sells general-purpose and ASW situation display systems.
AC line regulation problems?

—check the Sorensen line.

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<td>Need Quick Response? — All models of our FR Series respond to line and load changes within 50 µs — less than 1 cycle.</td>
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However demanding your AC regulator checklist, the Sorensen line can bear a good hard look. Whatever your needs, chances are Sorensen has a unit for your application. We offer a broad range of off-the-shelf line regulators to choose from in the range 150VA to 15kVA. Our ACR Series, for example, feature silicon controlled rectifier regulation, printed circuit maintainability, and require minimal rack space. The .01 Series provides high precision regulation, ±0.01%, for applications demanding the strictest accuracy and stability. Where fast response is an important consideration, the FR Series is unsurpassed. Sorensen's magnetic-amplifier S Series offers excellent low-cost regulation for a variety of applications.

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<th>DC DIFFERENTIAL VOLTMETERS</th>
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<td>±0.025%</td>
<td>±0.025% dc, ±0.1% AC</td>
<td>$1,215.00 + $150.00 for rechargeable battery pack</td>
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<tr>
<td>881A*</td>
<td>0-1100 VDC</td>
<td>±0.005%</td>
<td>±0.005% dc, ±0.1% AC</td>
<td>$1,375.00 + $150.00 for rechargeable battery pack</td>
</tr>
<tr>
<td>885A*</td>
<td>0-1100 VDC</td>
<td>±0.0025%</td>
<td>±0.0025% dc, ±0.05% AC</td>
<td>$1,495.00 + $20 for rack models</td>
</tr>
<tr>
<td>895A*</td>
<td>0-1100 VDC</td>
<td>±0.0025%</td>
<td>±0.0025% dc, ±0.05% AC</td>
<td>$1,575.00 + $150.00 for rechargeable battery pack</td>
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**Meeting preview**

**Noise and IC's**

Although integrated circuits reduce the volume of electronic devices, they also compound electromagnetic compatibility (EMC) problems. Their small size makes them more susceptible to external electromagnetic fields and increases the chance of interaction between circuits and elements within circuits. This aspect of IC's will be one of the major topics at this year's IEEE Symposium on Electromagnetic Compatibility at the Shoreham Hotel in Washington, July 18 to 20.

A paper on electromagnetic compatibility in IC's will be delivered by A.R. Valentino, research engineer with the IRT Research Institute in Chicago. He will outline his work with logic circuits, such as diode-transistor logic and transistor-transistor logic, describing how to predict the effect of spurious electromagnetic fields on the logic operations of modules and individual circuits.

Such data, Valentino says, is useful in the design and packaging of systems by helping the engineer to decide on the most effective wiring routes and methods for distribution of power.

Two of the symposium's 10 sessions will deal with the prediction and analysis of EMC. At one session, John Sell, an engineer with the institute's Electromagnetic Compatibility Analysis Center, Annapolis, Md., will describe his work to define and identify spurious response. In the second session, Maj. Anthony F. Albright, chief of the Army's data research branch of the frequency management directorate, will discuss an attempt to better utilize the overcrowded electromagnetic spectrum.

After the IEEE symposium, the Defense Department will hold its two-session electromagnetic compatibility conference. An unclassified meeting is scheduled for the afternoon of July 20, at which representatives from the Army, Navy, Air Force, and Electromagnetic Compatibility Analysis Center will discuss electromagnetic compatibility specifications required for equipment, and how they get these specifications.
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5½" units:
- 2.5-4.5V/70A; 4.8-6.8V/70A; 6.5-9.5V/50A; 8.5-11.5V/50A; 11-14V/50A; 13.5-19.5V/40A; 18.5-26.5V/30A; 24-32V/25A. Priced from $535 to $580. 0-8V/70A with overvoltage protection-$525.

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(and in less time)!

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2. It's easier than ever to eliminate costly over-design by plugging in 87.5 watts of TO-3 power-handling capability—a "power gap" area up to now necessarily filled by higher-priced, higher-current units—for only a few cents more than the price for power-limited (25 W) TO-66 devices!

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<table>
<thead>
<tr>
<th>Type</th>
<th>Polarity</th>
<th>$P_s$ @ 25°C</th>
<th>$I_C$ (cont.)</th>
<th>$V_{CEO}$ (max)</th>
<th>$h_{FE}$ (min @ $I_C$)</th>
<th>$f_T$ (min)</th>
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<td>25 @ 100°C</td>
<td>25 @ 25 A</td>
<td>80 V</td>
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<td>5 A</td>
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<td>NPN</td>
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Now's the time to see your franchised Motorola distributor about them.

<table>
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<tr>
<th>Frequency Requirement</th>
<th>V_{bm}</th>
<th>I_s</th>
<th>T_r (typ)</th>
<th>Motorola Preferred Rectifier Line</th>
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<tr>
<td>250 to 500 kHz</td>
<td>50 to 600 volts</td>
<td>¾ to 30 amps</td>
<td>100 ns</td>
<td>58 High-Speed Units</td>
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<tr>
<td>50 to 100 kHz</td>
<td>50 to 600 volts</td>
<td>¾ to 30 amps</td>
<td>0.5 \mu s</td>
<td>30 Medium-Speed Units</td>
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<tr>
<td>10 to 15 kHz</td>
<td>50 to 1,000 volts</td>
<td>1 to 1,000 amps</td>
<td>5 \mu s</td>
<td>284 Standard-Speed Units</td>
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The near miss

There’s a neat bit of irony connected with the development of the first practical gallium arsenide transistor [page 82]. The sponsor of the research gave up on it because it looked futile, only to see it achieved successfully a couple of months later.

Working under an Air Force contract to create a gallium arsenide transistor, engineers at the Radio Corp. of America’s Princeton Research Laboratories built structure after structure in vain. During a routine review of the work, Air Force contract officers bluntly asked the engineers how chances for success looked. When the disheartened engineers replied, “not very good,” the Air Force ended its support, to put its money on something that might prove more fruitful.

A few months later, working and thinking on their own, the same engineers hit on the idea of trying silicon nitride as an insulator instead of the traditional silicon dioxide. Bingo! Success. Now the RCA accomplishment promises to lead to families of new discrete devices and integrated circuits capable of handling higher power and higher frequencies than silicon ones can.

There may yet be a happy note for the Air Force, however. RCA engineers are telling Air Force contract officers about their work this week, and the Air Force may sponsor some of the next steps.

...and how to avoid it

But for many research and development projects there is no happy ending. Either they go on interminably and unsuccessfully, with good money following bad, or they are shut off too soon, and a competitor takes the next step and grabs the market.

With all their shiny new scientific management tools, executives still have not learned how to manage a research and development program efficiently. Nobody seems sure how to answer two fundamental questions: when do you shut off a project that looks as if it’s headed nowhere? And how do you motivate researchers to reach into a new vein, out of the ordinary stream of technology?

Ten years ago company executives felt sure they would reap a harvest of exciting new products merely by pouring large sums into research and development programs. Unhappily, they found that R&D expenditure showed up only as expenses—few worthwhile products resulted—so today some large companies have cut back their spending. Their rationale is this: if R&D cannot be managed wisely and efficiently, with guaranteed successes, at least the company will waste fewer dollars if the effort is smaller.

A critical ingredient that has been missing in the management of many R&D programs has been serious participation by top executives. The best advice that can be offered sounds like a cliché: successful management of R&D takes alert, imaginative executives prepared to learn the fundamentals of technology, the technical direction of the research effort, and how the company’s efforts fit in with what has been done before.

Too few managers are willing or able to do this difficult homework. It is not easy for the average president of a corporation to wrestle with the logic organization of his company’s computer product line or the details of dielectric isolation used in his semiconductor products or the design of an active filter his products should use. Most executives like to tell you that these are details to be worked out by the engineers, while the executives are concerned with policy and the big picture.

Yet top management’s intimate understanding of the details can make or break an R&D program. It cannot be delegated, even though industry is full of bright young engineers who have risen to vice-presidential level because they can translate technology to the president and board of directors.

The average top executive doesn’t feel comfortable in a meeting that delves deeply into technology. Rarely do company presidents expand their technical knowledge. Often they feel their role in the company demands a concentration on financial matters, organization, and occasional visits to the company’s biggest customers.

Although the president of a large company may spend weeks working with accountants and lawyers to set the stock price for an acquisition, he’ll give his vice president for research and development only 20 minutes to explain the company’s technological plans for the coming year, even though these plans might involve two or three times the money spent on the acquisition.

J. Northcote Parkinson, the noted satirist, spotted this phenomena years ago. In his book “Parkinson’s Law,” he wrote that a board of directors will spend hours discussing whether to give the men an extra five minutes for tea time but will approve the purchase of a multimillion dollar nuclear reactor in five minutes.

In such an environment, technology has leaped far ahead of management’s ability to cope with it.

This deficiency shows up in more ways than just poor management of R&D. It causes companies to lose markets they have dominated for years, to introduce the wrong new product, to misunderstand the servicing technically oriented customers require, and to suffer with problems within the company when the difficulties could be solved by the application of new technology.

Even in the electronics industry, where the stakes are greater because almost every move requires technical understanding, most top executives are only a little more willing to do their technical homework than their counterparts in less technically based fields.

New techniques in communications, integrated electronics, and computer-aided design are changing the structure of the industry. In this atmosphere, a thorough knowledge of technology is essential for top executives not only to evaluate R&D programs, but to assure the company’s very continuance.
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The over-all microwave semiconductor market should climb to $25 million by 1970, more than 12 times the current sales level, says a Texas Instruments marketing forecast. And by 1977, TI adds privately, sales should reach $410 million. Of this figure, $300 million would go for integrated circuit assemblies, $80 million for IC's, and $30 million for discrete devices.

TI plans to be selling microwave IC's off the shelf by the end of 1967 and already has been marketing custom models for nearly a year.

Also gearing up for the expected sales spurt is Sylvania Electric Products, which is now developing a custom microwave IC capability at its Woburn, Mass., plant. Marvin Groll, product manager, says Sylvania expects to be selling an X-band (5.2 to 10.9 gigahertz) mixer by year's end. The concern will double its microwave device production space with the opening of a new plant in Woburn in August.

The FAA's air-traffic control beacon system for commercial aircraft, which is just getting under way, has run into a traffic jam of its own. Ground transmitters, other than the agency's, are interrogating airplanes as they pass overhead, resulting in FAA control centers being overloaded with extraneous beacon responses. Aircraft beacon signals provide such information as a plane's identification, altitude, bearing, and heading.

A major violator is the Government itself, through its Nike missile installations, which use interrogators to identify friendly aircraft. Also creating problems are the manufacturers of interrogators because they test the gear at full power in open fields. Now the FAA is calling for limits on interrogator transmitting power.

Under the agency plan, enroute air-traffic centers and Air Defense Command radar would cut peak power to about 175,000 watts—enough to transmit for about 200 miles. Nike sites with shorter range radar would go lower than that, and airports would dip to 200 watts maximum for 50-mile-radius coverage.

The Air Force and Army have awarded separate contracts for terminals in the nation's first tactical satellite communications system. Collins Radio will get $7.2 million from the Air Force Electronic Systems Division for 43 ground, shipboard, and airborne terminals operating in ultrahigh-frequency bands, while RCA won the Army Electronics Command's $3.4-million contract for 18 superhigh-frequency terminals. Both contracts call for first deliveries early next year.

The U.S. is negotiating with an overseas nation for a site for a second LASA (large-aperture seismic array). The installation would be similar in concept to the 525-sensor array in Montana [Electronics, Sept. 19, 1966, p. 25]. Officials at the Defense Department's Advanced Research Projects Agency explain that LASA can't be used fully to distinguish between seismic events and man-made nuclear detonations until a second large array is available to provide corroborating data. Even detection of low-magnitude seismic and nuclear events by LASA can't be verified by any existing network of stations.
Cloudcroft project to make comeback

The Air Force will invest another $2 million to $3 million and two to three years in an electro-optical satellite tracking system that barely worked after $5 million and five years was spent on development. The Electronic Systems Division has requested a proposal from RCA for revival of the FSR-2 program at Cloudcroft, N.M. RCA's Aerospace Systems division, Burlington, Mass., was prime contractor in the original effort to develop an optical sensor capable of operating beyond the range of radar. The Cloudcroft facility has been shut down for almost two years.

In addition to further development of image tubes for the system [Electronics, April 3, p. 168], the Air Force wants substantial advances in the fiber optics used to transmit light from the collecting telescope to the tubes. The design calls for 12 curved optical-fiber bundles, each nearly 1 1/2 inches square and about 20 inches long. An attempt will be made to build flexible bundles so that they can be tuned to the telescope at one end and the image tubes at the other.

How to find a cop when you need one

New York City's Police Department is hot on the trail of a computerized command and control network [Electronics, May 1, p. 105] even though a major question has yet to be answered: How can patrol cars be monitored constantly for computer assignment? A scientific task force attached to the President's Commission on Law Enforcement and Criminal Justice, which urged highest priority for computerized networks, has dubbed four car-location schemes "technically feasible."

Most promising, says the task force, is a plan to equip each car with an acoustic or electromagnetic device emitting signals to receivers in police and fire call boxes, which would be linked to a control center via land lines. Inspector William Kanz, in charge of communications for the New York police, leans toward that scheme. In fact, he explains, "we're planning to extend our emergency call system by adapting 14,000 fire call boxes for police use. We might just be able to add a location system at the same time."

The three other plans include the use of radar transponders, radio direction-finding equipment, and a simplified inertial navigation system that would keep track of a car's location.

Solid state, 3-axis accelerometer planned for missile

A solid state, three-axis accelerometer is about to be delivered for a classified missile application by Conrac Corp. The device uses six diffused silicon strain gauges instead of conventional electromagnetic pickoffs and can measure accelerations as large as 500 G's with 0.25% to 1.0% accuracy.

All three axes pass through a single point, thus eliminating the need for compensating electronics. Three rods are drilled and passed through each other at right angles to form a cross with arms in x, y, and z axes; strain gauges support the ends of each rod.

The strain gauge device has no moving parts and requires no servo loops for operation. Most electromagnetic accelerometers detect acceleration by measuring the current needed to keep a captive pellet or pendulum in position. With the Conrac device, the resistance of the strain gauge changes under acceleration, giving an analog voltage proportional to the rate of change of velocity. The whole accelerometer package, including 12 integrated circuit amplifiers and one IC differential amplifier, is only 3 cubic inches.
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**Sliced laser**

Most of today's high-powered crystal lasers are cooled by water flowing around the circumference of the laser rod, but even so the crystals often overheat before reaching their full potential output powers and repetition rates. At best, excess heat reduces laser efficiency; at worst, heat can destroy the laser rod.

But there's a better way, says Edwin Matovich, a researcher at the Autonetics division of North American Aviation Inc. Autonetics' trick is to slice the ruby or glass rod into several slices as small as 1/4 inch long and place them in a double-walled quartz tube. Teflon spacers separate the faces of the slices, allowing coolant to flow across the faces rather than around them. The inner quartz tube doubles as the plumbing needed to get coolant from face to face.

Since the slices are cooled on their faces rather than their rims, the temperature gradients no longer cause thermal distortions that can result in internal focusing. This can melt small areas within a solid slice or reduce efficiency by defocusing the laser cavity.

**Bit by bit.** Use of small crystals to build large lasers is an advantage in the push toward higher output. Large solid crystals are nearly always flawed by bubbles, misaligned molecular lattices, or uneven dopant concentration. High optical quality is easier to attain in cheaper, smaller crystals. By stringing small slices together, laser builders can produce systems with lower thresholds and narrower output beams simply because each inch of the laser can be selected for optical quality.

Autonetics has found that for 5 inches of ruby, 5/8 inch in diameter, a 1/4-inch sliced laser required only 1 kilojoule of pump energy to reach threshold while a solid crystal required 1.5 kj. Beamwidth was only 1 milliradian for the sliced ruby, but 3 mrad for the solid crystal. Even the best commercially available lasers specify about 1.5 mrad beam divergence. Matovich attributes the boost to the better overall optical characteristics achieved through slice-by-slice construction.

The ruby device has produced 100 megawatts peak power with no loss of efficiency due to heating and, according to Matovich, at 100 mw, it was nowhere near the limit of its thermal dissipation capability. This laser will replace a standard type in a digital range finder at the Naval Ordnance Test Station, China Lake, Calif.

Autonetics has already begun working with neodymium doped glass and plans to start experiments with 1 1/4-inch thick slices of Nd-doped yttrium aluminum garnet. An experimental Nd glass laser is expected to develop 4.25-joule pulses at 20 pulses per second; average power should be about 90 watts. Matovich claims a solid Nd glass laser of the same active length would yield only 12 to 15 watts without rod damage.

**Communications**

**Out of the past**

Field-sequential color television is making a comeback. The CBS approach that in 1953 lost its place as the national standard to the compatible system has been applied by CBS Laboratories to the design of an 8-pound, low-light-level color camera. Ironically, the man who pushed the Columbia Broadcasting System to return to
field-sequential techniques and designed the new camera is one of the engineers who helped develop the National Broadcasting Co.'s version of the color compatible system.

With only one vidicon and a third as many components as a standard color camera, the new unit is inexpensive; there is no color registration problem and no need for beam splitters or prisms to feed separate vidicons in the lightweight camera.

The camera CBS proposed for network TV in the early 50's had a wheel with red, blue, and green fields that was spun before a vidicon. Color information was transmitted in sequence as the color filters passed in front of the tube. But because this setup required home sets to have color wheels too, the Federal Communications Commission opted for the three-vidicon compatible-color system, which could transmit pictures to sets already in the home.

**Full cycle.** Nbc's color system was partly designed by Renville McMann, who moved to CBS Laboratories in 1955. And now McMann, currently vice president and director of engineering at the CBS division, has dusted off the field-sequential approach.

Though developed with CBS funds, the camera was designed with a University of Pennsylvania medical program in mind. It will initially be used to view internal parts of the human body through fiber-optic probes. Other applications for the low-light unit could come in tactical command-and-control networks, night surveillance, and perhaps weather satellites.

The camera uses either a Plumbicon tube or a new secondary emission conduction (sec) vidicon made by Westinghouse Electric Corp.—both highly sensitive, small tubes with aperture sizes of less than 1.5 inches.

The camera has been designed to deal with problems that plagued the original CBS system. One of these is color lag—faulty color information transmitted by the tube because slow decay time caused the retention of image data from scan to scan.

The fast decay times of the Plumbicon and sec vidicon reduce this lag, but to minimize it, McMann uses noninterlaced scan. In this technique, the tube scans the same raster lines on each cycle, erasing any data that hasn't decayed.

To further clean up the signal, glass acoustic delay lines store the information in the raster lines adjacent to the one being scanned. Other circuits compare this data with the content of the line being scanned, and generate and amplify a difference signal that accentuates line-to-line variations. A threshold-sensitive amplifier sharpens contrast by responding only to signals above a given strength.

**Low cost.** The whole transistorized package, including synchronizer, costs about $10,000. The only competition in this country would come from three-vidicon color systems built by the Packard Bell Electronics Corp. and Cohu Electronics Inc. and costing $18,000 to $25,000 excluding sync and encoding equipment.

The CBS camera's price makes it a natural for closed-circuit color applications, but even more interesting are the jobs it might do for the military and the National Aeronautics and Space Administration. According to McMann, the system might be used to detect camouflage soldiers at night. CBS has found it possible to tell the difference between live and dead foliage by noting the difference in absorption at red wavelengths; the same sort of detection technique could probably be applied to camouflage.

The space agency is interested in satellite applications for the camera, according to John Manniello, marketing vice president for CBS Laboratories. Aboard a weather satellite, the color camera could give a better representation of storm severity, ocean turbulence, or river pollution than black and white TV, he says.

With the little camera, field-sequential color might even find its way back into the national TV networks. CBS will probably use the camera as a "creepy-peepy" to cover the 1968 political conventions. The company has already developed a scan converter to change field-sequential signals to the national standard. With the scan converter and six "creepy-peepies," McMann says that on-the-spot floor coverage could be accomplished for only $100,000. With standard three-vidicon cameras, the cost would double.

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**Military electronics**

**Lighter link**

It takes two dozen huge vans, crammed with air-conditioning equipment and large power generators, to control batteries of surface-to-air missiles. In addition to tying up a considerable amount of heavy equipment, the control links
create maintenance and repair problems — qualified technicians and a large supply of spare parts are required in the field to support the system. In a move to streamline such an operation, the Army has awarded Litton Industries Inc., a $10-million contract to build 128-pound digital processors to replace the 2-ton control units now in use.

The new unit, called AN/CSA-77 and commonly referred to as battery terminal equipment, is about the size of a small steamer trunk, consumes 170 watts, and employs integrated circuitry.

What makes the terminals particularly attractive to the military is their self-testing, fault-location, and quick-repair capability. Litton estimates that an unskilled operator in the field will be able, with a few instructions, to find and repair a fault in less than 15 minutes.

Whiz bang. The system automatically tests itself every three minutes by circulating loop test messages in parallel. Should a failure be detected, a horn alarm sounds, warning lights go on, and the unit shuts itself off. The operator opens the front panel of the processor to view 20 failure lights and a decal showing the circuit card numbers that correspond to the lights. After locating the failure, he checks the cards with a pistol-grip tester; there are leads from each card so that they do not have to be removed for testing. Two blocking diodes on each card isolate the card from the rest of the system during fault location. Another array of lights indicates the status of the card being checked and signals, for example, if a microcircuit is faulty or if the operator has made a testing error. Spare circuit cards are stored in a tier at the rear of the control unit. Four standard digital cards make up 80% of the circuitry. Mean time between failure for the unit is rated in excess of 2,500 hours.

Self-healing. Hawk, Hercules, and Nike missile installations will be linked by the new control unit and, should certain batteries or the control center be knocked out, new communication routes for control of the system will be automatically established. Usually, the control center coordinates a group of batteries, but if it should be damaged, the new processors will automatically switch to establish communications with each other.

The contract for the processors came from the Army Missile Command in Huntsville, Ala. Prototypes from Litton and the Aerospace group of the Martin-Marietta Corp., the only other bidder for the contract, were tested by the Army for more than a year. Litton's units bettered many of the Army specifications, and that apparently was a factor in winning the order. For example, the Litton processor weighs 172 pounds less than specified, is more than 2 cubic feet smaller, consumes 330 fewer watts, and can be repaired more rapidly.

Circuit design

On line

Engineers at Autonetics have come up with the first practical, large-scale system for computer-aided design used by a major aerospace company. The system is based on a dual set of computer codes for circuit analysis developed at the division of North American Aviation Inc.

The two codes—SCAN (for system of codes for analysis of circuits and systems) and TRAC (for transient radiation analysis by computer)—stem from the firm's extensive commitments to microelectronics in such programs as the Mark 2 avionics system for the F-111 aircraft and the Minuteman 2 guidance computer. The advent of large-scale integration has provided further impetus for engineers to turn to computer methods of circuit analysis, according to Walter Hochwald, chief of the product analysis section in the division's advanced analysis and applications research department.

A year ahead. Hochwald believes the codes have put Autonetics as much as a year ahead of others in the industry in circuit analysis "not because we're any smarter, but because we've had Minuteman contracts that have given us both the money and the need" to predict the performance of microcircuits throughout their lifetime. Company officials claim the codes—developed by C.T. Kleiner, E.D. Johnson, and L.R. McMurray—give them design data in one-tenth the time of codes used elsewhere in industry.

Normal tolerance variations of circuit components through use of the digital computer codes are be-
ing sought. The capability ranges from an evaluation of a steady-state condition of an integrated circuit to an evaluation of an entire system subjected to transient phenomena. "For example," Hochwald says, "we can simulate fairly large portions of the Minuteman 2 guidance computer."

At each step, the conditions cranked into the computer are compared with behavior of circuit models stored in the computer's memory. The engineer gets both a printout and a graphic representation, on a cathode-ray tube, of the waveform he's analyzing.

He may, for example, want to find out what happens to the circuit he's studying if noise is introduced. He then tells the computer mathematically the value of the noise he's adding, and the computer compares the noise figure with the acceptable noise tolerance for the circuit model under investigation. The engineer has only to compare the waveform he gets back from the printout with the model to predict how the noise affects the circuit.

**Quick services.** The crt is situated at the central computer—an International Business Machines Corp. System 360 model 65. If the problem is urgent enough, the engineer can go to the computer and enter his data, and in a relatively short time get a display of the waveform that describes the conditions he's introduced. In practice, however, this is rare at Autonetics. Direct access is reserved only for those cases in which security might be compromised by sending the problem from a remote location. Standard procedure is for the computer to batch-process the problems.

The engineer generally feeds his problems to the computer at the end of the workday, and has the solutions—both computer printout and crt plot—the next morning. This turnaround time can be reduced to three or four hours during the workday if the problem is urgent enough. If the computer was used solely for circuit analysis, says Hochwald, the delay could be reduced even further.

The codes can accommodate nonlinear circuit models. For example, Hochwald picked a free-running flux oscillator with nonlinear transformer cores and nonlinear transistors. With such a model, he says, "you rule out all but about 10" computer programs in existence, including net-1 (network analysis program) and ecap (electronic circuit analysis program). Of the remaining programs, he says, the scan-trac family is the fastest by a ratio of between 3 and 10 to 1. Circuit analyses that would take between two and three hours with other programs have been run off in five to 10 minutes, Hochwald points out.

After receiving numerous queries about the codes from industry and Government, Autonetics toyed with the idea of developing a sales program. But the plan has apparently been dropped for now. At present, says W. H. Hafstrom, a company vice president and head of the commercial development office, there are no plans for any commercialization of the codes.

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**Avionics**

**3-D radar, continued**

At the Government's sprawling avionics test facility at Atlantic City, N.J., stands a 165-foot-high monument to the frustrating search for an air traffic control system capable of keeping pace with the tremendous growth in air travel. It's an experimental three-dimensional radar built in 1961 at the behest of the Federal Aviation Administration; the project was subsequently dropped in favor of a system now becoming operational requiring commercial aircraft to carry transponders that signal the plane's identity, bearing, altitude, and other data to ground controllers. But the company that built the tower, the Maxson Electronics Corp. of Great River, N.Y., hasn't given up. It's now trying to sell the FAA on the idea of using improved 3-D radar to complement the beacon transponder system.

**Not good enough?** Maxson agrees the beacon transponder concept is good—but only when there is a lot of airspace around the craft being tracked; in crowded skies—like over busy airports—even the best computer-operated systems, which gather the beacon signals and process them, often confuse one plane with another nearby.

Whether this is a problem serious enough to warrant the use of 3-D radar in addition to the beacon technique is for the FAA to decide. But thus far the agency has maintained that the beacon system is sufficiently accurate for present needs.

Despite this apparent lack of interest by the FAA, Maxson is pushing the 3-D concept, claiming that it need operate only around the major airports. Maxson says the size and price would be sharply reduced by the application of solid state techniques developed since the first tower was designed. The company's engineers contend the size could be cut by a third, but they decline to speculate on the price.

**Coarse and fine.** Under the proposed system, the 3-D radar signals would provide coarse information on a plane's bearing and altitude; this data would then be used to direct the computer to lock onto the plane's beacon signal—eliminating the possibility of the computer's confusing signals of nearby planes.

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**Components**

**Another Nixie challenger**

Two companies are now challenging the supremacy of gas-discharge digital readout tubes for small computers by turning to unique variations of the cathode-ray tube.

The Tung-Sol division of Wagner Electric Corp., Bloomfield, N.J., showed a pilot model of its new Digivac at the Society for Information Display meeting in San Francisco just as Japan's Ike Electronics Corp. was announcing its new in-

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**Electronics Review**

**June 12, 1967**

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36
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houses the package in cheap and reliable glass tubes, a standard Compactron (12-pin) stem with a bottom-off configuration in a T-9 bulb.

The fixed anode voltage does not exceed 200 volts and grid-switching voltage is not more than 6 volts d-c.

Without ambiguity, the Digivac can generate the letters a, c, e, f, g, h, j, l, p, u, and y. By adding eight more grids the whole alphabet and about 64,000 characters more can be generated.

A company spokesman pointed out that the present glass package is a space waster; package height could be reduced to 3/16 inch by using a windowed, rectangular metal case.

Consumer electronics

The IC push

Manufacturers of television receivers and other consumer electronics products will be buttonholed this week by representatives from the integrated circuit industry. The first major move to replace vacuum tube and discrete semiconductor stages with ic's is now under way. Independently, four ic makers, Texas Instruments, Motorola Semiconductor Products, Fairchild Semiconductor, and General Electric unveiled new linear ic's for consumer applications at the Chicago IEEE Spring Conference on Broadcast & Television Receivers, which runs from June 12 to 13.

TI is displaying five hybrid ic's—one for television f-m sound systems and four audio output circuits for driving speakers.

Motorola introduced a monolithic ic for video r-f and i-f stages, and Fairchild has come up with three monolithics—one for tv sound i-f systems and two general purpose high-frequency amplifying units.

GE is introducing five monolithic circuits for tv and radio applications.

Each ic firm claims the ic's are the first products of their kind priced to compete with devices now occupying tv sockets and boards. Few ic's have found their way into tv receivers, primarily because of prohibitive prices. To accelerate the invasion, the new linear ic's will retail for a few dollars each in production quantities; some will sell for under $2. None of the four vendors gave evidence that a large consumer electronics contract is in the wings.

The new ti tv hybrid contains monolithic active elements, thick-film resistors and conductors, and, inverted discrete chips (flip chips). The inverted elements include bipolar small-signal and power units, field effect transistors and zener diodes. Designated the HC1001, the ic contains a wideband i-f amplifier, an f-m detector and an audio preamplifier. It accepts 4.5 Mhz i-f signals and directly drives vacuum tube or transistor audio power stages in tv sets.

The other four new hybrids are audio-output amplifiers with up to 1-watt capabilities for a-m radios and f-m radios and phonographs. Pricing of the five ic's is in the $2 range. One of the chips is rated for direct operation in standard 130-volt lines.

Easily aligned. Motorola's ic will ease alignment problems in black-and-white and color-tv's at the assembly-test line, and will prevent detuning when the user switches channels. These benefits are traceable to the chip's high isolation and a built-in, modified automatic gain-control (age) action.

Jerry Robertson, manager of Motorola's ic applications engineering, credits the chip's combination of cascoded input stage and Darlington configurations with higher isolation than discrete stages can offer. Age is applied at the collector of an internal transistor instead of at its input—preventing the input impedance of tuned stages from changing with age bias—a cause of detuning.

The linear ic contains multistage high-frequency amplifiers, an age stage, biasing networks, and an output stage; tuning elements are outboarded. Other applications for the circuit include stagger-tuned amplifiers, wideband and narrow-
How to get more satisfaction from your metal film resistors—without switching brands

It's easy. Just ask your supplier to incorporate his resistors into packaged networks or assemblies.

With pre-assembled networks, you can obtain packaging densities far greater than those obtainable with individual metal film resistors. In fact, volume savings of up to 80% can be achieved.

Please try to ignore the surplus performance that components sometimes deliver

You probably read the editorial on this subject that one of the industry magazines published not long ago. Nevertheless, the message is worth repeating:

A component designed to meet one set of specifications may also test out to more rigid specifications. And engineers have been known to cut costs by designing such a component into equipment for which it wasn’t intended.

The only trouble is—they're putting themselves out on a limb (not to mention their supplier). Subsequent lots of the component may very well turn out to perform much closer to the claimed specifications—for a variety of reasons.

Speer components are among those that sometimes deliver this surplus performance. (The operative word here is “sometimes,” incidentally. There are also areas in which our components always outperform their specifications. But that’s another story—one we’ll get into in a future issue.)

Your continued cooperation in this matter of under-specifying is much appreciated. We suspect that it’s a little chilly out there on that limb.

Typical Error #8 in the testing of inductors

We’re referring specifically to the testing procedures for measuring inductance and Q, as outlined in MIL-C-15305.

We heartily recommend these procedures for all commercial, industrial and military users of inductors (even users of our superb Jeffers inductors). But, as our headline suggests, there are more than a couple of commonly made test errors to watch out for.

There are eight.

Error #8, for example, consists of extreme variations in test area environment. Solution? Make sure that your measurements are made at room ambient temperature, relative humidity and pressure.

In future issues, we’ll cover the other seven errors and indicate how to avoid them also.

So watch this space.

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Back to tubes

While television-set makers rely increasingly on solid state devices to pare their product prices, the General Electric Co. is suggesting a return to vacuum tubes. GE claims that a black-and-white 16-inch receiver designed around a new kit of its Compactron tubes can be priced below $50, against the current low of about $100 for such sets.

A demonstration GE television set will be shown at the IEEE's Conference on Broadcast and Television Receivers, June 12 and 13. Besides the customary tuner tubes, the set employs four Compactrons and a standard miniature tube to perform 12 circuit functions. The five tubes, in kit form, are being offered by the company to TV set makers.

New work. In fact, so optimistic is GE in the tube concept that it's investing a considerable sum in the development of a new kind of Compactron tube, called the Moduletron, which should lower a TV's cost even more. According to James Holeman, a director of marketing at GE's Owensboro, Ky., facilities, the Moduletron will contain from 20 to 23 passive elements, reducing the number of external wiring connections.

Two of the tubes in the kit, the 33GY7A and 17BF11, have been in use for some time; the 33GY7A is employed in a self-oscillating circuit in the test receiver and serves as the horizontal output amplifier, while the 17BF11 functions as an f-m discriminator and audio output amplifier. Two other Compactrons are developmental models—the Y1607B acts as a combined video i-f amplifier and video output stage, and the Y1699B is used as the vertical output amplifier in a self-oscillating circuit, as the sync separator and amplifier, and as the keyed automatic gain control. The miniature tube, the 1BC2, is used as the high-voltage rectifier.

A GE spokesman says that except for a small deterioration in sensitivity due to the use of a single i-f amplifier stage, the pilot set is comparable in quality to similarly sized receivers containing twice as many tubes.

Tuning in TV

Tiny printed circuits may soon replace the bulkier wire-wound coils in tuner assemblies for television receivers. Developed by the Oak Manufacturing Co., Crystal Lake, Ill., a division of Oak Electro/Netics Corp., the printed inductors are expected to be included in the firm's standard tuner line in the near future. Oak, a major supplier of tuners to the TV industry, expects the printed units to provide increased reliability without increased cost.

Printed inductors have long been possible, says Walter Meyer, an engineering section manager at Oak. But the precise dimensions necessary were difficult to achieve inexpensively. Oak has turned to a silk-screen process, however, to produce spiral-type inductors having a ±0.001-inch line-width tolerance.

The printed coils would control interstage coupling when the tuner is switched from channel to channel. The wire coils now used must be adjusted during final assembly. "With printed inductances," says Meyer, "more of the adjustments are built in." The technique also reduces the amount of hardware to about half that in wired assemblies.

Meanwhile, Motorola Inc.'s Motorola Semiconductor Products Inc. subsidiary unveiled a diode-tuning technique for a-m radios. Using voltage-variable-capacitance diodes, radios could be built without the large "butterfly capacitors" now found on most a-m chassis.

Quiet playback

Less than a year ago, Ray M. Dolby, an American engineer working in England, introduced a device for reducing noise in audio systems; he called it a signal-to-noise stretcher. Dolby designed it for professional recording studios, using attenuation and amplification circuitry to get rid of tape hiss, recording rumble, and other noise. The system has been redesigned by Dolby and is now being applied to home-entertainment devices by a 10-year-old U.S. company specializing in high-perform-
Everyone knows that to make a Triac to control 720 watts you have to use an expensive press-fit package.

Well, everyone is wrong!

RCA designed the low-cost two-lead 40485 TO-5 package to control 720 watts when used with an associated heat spreader!

The 40485 Triac is designed for 120V line operation for the phase control of ac loads in applications such as light dimming, universal and induction motor control, and heater control. It sells for only $1.50*. The 40486 Triac can control 1440 watts, 240V line operation, and it sells for only $1.98*. Both new Triacs are delivered in hermetically sealed, all-welded, tin-plated modified TO-5 packages which offer the advantage of small size where space restrictions are a primary consideration. And because they are tin-plated, they can be soldered directly to a heat spreader as illustrated. This allows the use of mass produced, pre-punched parts, and batch soldering techniques, and simplifies mechanical mounting and heat sinking. The process is a simple one. RCA salesmen are ready to demonstrate in your own office just how easy it is.

So save the money you'd spend for a comparable press fit unit, and take advantage of the small size and superior performance of RCA 40485 and 40486 Triacs. Your RCA Field Representative can give you all the information, including delivery. For additional technical data, write RCA Commercial Engineering, Section RN6-2, Harrison, N.J. 07029. See your RCA Distributor for his price and delivery.

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All these advantages available in a compact, light-weight component expressly engineered for systems use in close quartered printed circuit board applications. Unit prices range from $140 to $249 depending on type and quantity.

But tape hiss and other unwanted noise in the recording are also reduced, giving the low volume signals a 10-db edge over the noise.

The device is connected between the microphone and tape machine for recording and between the tape head and amplifier on playback. Thus, only the noise added by recording electronics is affected, not the recorded matter. Also, by dividing the frequency spectrum into four sections, the Dolby device can operate on any section with a low-level input, high levels in any of the remaining three channels can’t prevent noise reduction in a channel that needs it.

Solid state

Raising the noise barrier

Most integrated-circuit manufacturers are content to supply the industrial market with low-cost plastic-packaged versions of their standard military ic’s. But Motorola Semiconductor Products Inc. isn’t; it has evolved a family of industrial ic’s with electrical characteristics tailored to the noisy environments prevailing in some industrial applications.

Called high threshold logic (htl) circuits, the new ic’s—dual four-input gates and two flip-flops—feature noise-immunity levels on the order of 6 volts. They also have a wide operating-temperature range (+30 to +75°C), high fan-out (10) and wide logic swing (12 volts).

Tradeoffs. Speed is modest (55 nanosecond propagation delay) and power needs (30 milliwatts per gate) are slightly higher than those of diode transistor logic (dtl) units, for example. However, Motorola engineers believe that in industrial applications the wide noise tolerance—six to seven times as high as dtl circuits—more than offsets the secondary speed and power characteristics.

The high noise immunity is achieved by using a zener diode instead of the offset diode dtl ic’s employ. Htl, basically an offshoot of dtl, is an improvement over an
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Electronics Review

earlier Motorola entry, variable-threshold-logic (vTL). Introduced in 1966, vTL was designed for industrial applications and situations requiring a variable logic swing. But the circuits require two power supplies, are relatively difficult to fabricate, and occupy a larger chip than vTT IC's. Noise immunity is 3 to 5 volts, depending on the bias used. VTL never quite caught on; it's now available only on demand and isn't a catalog item.

Predecessors. vTT is a late-comer of sorts; it closely resembles circuits introduced in 1966 by the Amelco Semiconductor division of Teledyne Inc. and Telefunken of Germany. Motorola's new IC's are 20% slower than Amelco's plastic-packaged devices, but have a slightly higher immunity to noise.

For the record

Doctoring the illness. A glassfiber torso at the George Washington University Medical Center in Washington is helping medical students learn how to diagnose illnesses. Called Terry, the latex-covered dummy has eight small speakers from which recorded sounds of the heart and lungs are heard. The teaching aid is connected to a console that contains an eight-channel tape recorder and a transistorized printed-circuit card for each speaker.

Venus visit. Mariner 5, scheduled for launch this week, will pass within 2,000 miles of Venus and peer into the dense shroud covering the planet to gather environmental data. The 540-pound craft differs from Mariner 2, which passed Venus in 1962, in that it will carry a new high-gain antenna and a system to reduce experiment results to a common digital form.

Better red. A simple technique for achieving a truer red from electroluminescent displays has been developed by a team of engineers at North American Aviation Inc. Red phosphors—the usual red source—are dispensed with and replaced by a constant red generated from an outside source. Called chromatic biasing, the technique balances the intensity of blue-green emission against a constant red light—much like biasing electric current.

On the move. As part of its master plan to become a major factor in the semiconductor business, vTT Semiconductors is wooing high-level engineering officials to its fold. Latest to sign on are Raymond Warner, Texas Instruments' metal oxide semiconductor operations manager, and Jack Belove, Fairchild Semiconductor's manager of proprietary integrated-circuit production. Warner becomes the firm's technical director for the U.S. and Belove becomes operations manager at the West Palm Beach, Fla., facilities.

Picking your spots. Most of the more than 200 process-control computers installed by nxr have been delivered within the last year. One 14r official ascribed the sales spurt to the growing practice of using computer control only to handle critical process variables. The difference is illustrated by a system at a Mobil Oil refinery where 250 variables are monitored but only analog loops in the catalytic cracker's reactor and kiln are computer-controlled. Even without total process control, Mobil spokesmen report an efficiency gain of more than 10%.

Business ahead. The Electronics Industries Association is predicting total 1967 electronic-equipment sales of $22.4 billion, up 10% from the 1966 level and higher than Electronics magazine's 1967 forecast [Electronics, Jan. 9, p. 129] of $21.5 billion. However, Robert Galvin, the EIA president, says the outlook for color television sales isn't so bright as it was in January. The official put 1967 volume at 6 million to 6.5 million sets, off from industry estimates six months ago of 7 million to 8 million, but still about 1 million above last year's total. Component sales are seen climbing 12% from a year before to $6.3 billion, while replacement component volume is expected to edge up 1.6% to $650 million. The EIA predicts an 11% gain in industrial electronics sales, and attributes this mainly to continued expansion of the market for computers.
TWO NEW FET IDEAS FROM MOTOROLA!

1 "Zero Power" Switching Complementary MOSFETs

Now, you can design ultra low-power complementary switching circuits, or circuits with switching times in the nanoseconds region using Motorola types 2N4351 (n-channel) and 2N4352 (p-channel) MOSFETs. In addition to exhibiting leakage currents of only 10 pA, they also show very low capacitance values. The combination provides a very high input impedance resulting in a large fan-out capability and almost no loading of the driving source. Both units are designed for enhancement-mode, or normally "off" operation.

Available in the standard TO-72 package, each device is 100-up priced at just $4.50 (compared with prices in the $7.00 range for most of today’s MOSFETs). Here are more detailed specifications for these two new state-of-the-art devices:

<table>
<thead>
<tr>
<th>CHARACTERISTIC (2N4351-2N4352)</th>
<th>SYMBOL</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
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<td></td>
<td>1.3</td>
<td>pF</td>
</tr>
<tr>
<td>Input Capacitance</td>
<td>Cxx</td>
<td></td>
<td>5.0</td>
<td>pF</td>
</tr>
<tr>
<td>&quot;ON&quot; Drain Current</td>
<td>Ios</td>
<td></td>
<td>3.0</td>
<td>mA</td>
</tr>
<tr>
<td>Gate Leakage Current</td>
<td>Ioss</td>
<td></td>
<td>±10</td>
<td>mA</td>
</tr>
<tr>
<td>Zero-Gate-Voltage Drain Current</td>
<td>Ioss</td>
<td></td>
<td>10</td>
<td>mA</td>
</tr>
<tr>
<td>Drain-Source &quot;ON&quot; Voltage</td>
<td>Voss</td>
<td></td>
<td>1.0</td>
<td>V</td>
</tr>
</tbody>
</table>

*Trademark of Motorola Inc.

2 Low-Cost, Low-Noise Plastic RF FET

Here's a new low-cost junction FET (type MPF102) that's priced at just 45 cents each (1000-up), making it economical for FM-tuner front-ends, yet with such high quality performance it's also well suited for a variety of sockets in industrial communications equipment — for both mixer and amplifier applications! The MPF102, housed in Motorola's reliable Unibloc® plastic package, combines a low 200-MHz typical noise figure of only 2.5 dB with exceptionally high gain — prime qualities for all RF applications! Here are other top specs that show the all-around performance of the MPF102:

<table>
<thead>
<tr>
<th>CHARACTERISTICS (MPF102)</th>
<th>SYMBOL</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate Reverse Current</td>
<td>Ioss</td>
<td></td>
<td>2.0</td>
<td>mA</td>
</tr>
<tr>
<td>Zero-Gate-Voltage Drain Current</td>
<td>Ioss</td>
<td></td>
<td>20</td>
<td>mA</td>
</tr>
<tr>
<td>Input Capacitance</td>
<td>Cxx</td>
<td></td>
<td>7.0</td>
<td>pF</td>
</tr>
<tr>
<td>Reverse Transfer Capacitance</td>
<td>Cxx</td>
<td></td>
<td>3.0</td>
<td>pF</td>
</tr>
<tr>
<td>Forward Transfer Admittance</td>
<td></td>
<td>2000</td>
<td></td>
<td>μmhos</td>
</tr>
<tr>
<td>Noise Figure</td>
<td>NF</td>
<td>2.5</td>
<td>(typ)</td>
<td>dB</td>
</tr>
</tbody>
</table>

Write for complete data sheets on the MPF102 and 2N4351-52. We'll also send you our latest application notes on complementary FET switching and RF FET circuit design. Then, for sample devices you can try right now, contact your nearby franchised Motorola Semiconductor distributor or district sales office.
One watt at 70°C!
Sealed for pennies extra!

2 very good reasons why Dale sells so many Commercial Wirewound Trimmers

**PERFORMANCE:** Dale's 2100 and 2200 series are the commercial counterparts of RT-11 and RT-10 respectively. They can be sealed for just a few cents per unit, yielding mil-level performance in all areas except temperature.

**PRICE:** Competitive and then some! Check Dale's new lower commercial prices. They were made possible through an extensive value analysis program which actually improved overall unit quality.

**DELIVERY:** New automated production facilities plus a factory stocking program combine to put your order in your plant without delay.

Simplify trimmer ordering—a call to Dale will do it. Phone 564-3131, Area Code 402

Write for Catalog B

---

<table>
<thead>
<tr>
<th>CASE DIMENSIONS</th>
<th>2100</th>
<th>2200</th>
</tr>
</thead>
<tbody>
<tr>
<td>.28 high x .31 wide x 1.25 long</td>
<td>1.8 wide x .32 high x 1.00 long</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STANDARD MODELS</th>
<th>2187 - printed circuit pins, 21 AWG gold plated.</th>
<th>2280 - printed circuit pins, 22 AWG gold plated.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2188 - 28 AWG stranded vinyl leads.</td>
<td>2282 - solid wire, 26 AWG gold plated.</td>
<td></td>
</tr>
<tr>
<td>2199 - solder lug, gold plated.</td>
<td>2297 - 28 AWG stranded vinyl leads.</td>
<td></td>
</tr>
</tbody>
</table>

| POWER RATING | 1 watt at 70°C, derating to 0 at 125°C |
| OPERATING TEMPERATURE RANGE | -65°C to +125°C |
| ADJUSTMENT TURNS | 25 + 2 | 15 + 2 |
| RESISTANCE RANGE | 10 ohms to 100K ohms | 10 ohms to 50K ohms |
| STANDARD TOLERANCE | ± 10% standard (lower tolerances available) |

---

Dale Electronics, Inc.
1300 28th Avenue, Columbus, Nebraska
In Canada: Dale Electronics, Canada, Ltd.

Electronics | June 12, 1967
Most everyone these days touts systems engineering as the answer to such complex nonmilitary problems as pollution, crime, and mass transportation. But a report to Congress from the National Academy of Science suggests that it won’t pay off. The study was made by the academy’s influential committee on science and public policy for the House Committee on Science and Astronautics, whose chairman, George Miller (D., Calif.), is a backer of the systems approach to civilian problems.

In the report—to be released next month—Hendrik W. Bode, a vice president of Bell Telephone Laboratories, says the “gap between military systems engineering and proposed civilian applications” is greater than most people realize. Systems engineering is “unlikely to contribute anything that wouldn’t have been discovered anyway,” he adds, and—in the civilian sphere—perhaps amounts to “little more than a decision to do a careful and thorough engineering job.”

High reliability requirements were relaxed temporarily last year on Minuteman 2 components, and what happened cast doubt for a time on the reliability of the entire strategic missile system. Two test launchings failed—one due to a faulty resistor and the other because of a bad capacitor. A frantic search revealed that the faulty components hadn’t gone through the normal high-reliability process—burn-in and lifetime tests, documentation, and strictly controlled production. The Air Force then started a crash program to replace all suspect components with units produced to original requirements.

The cheaper components were in a modification kit being installed to improve the Minuteman’s guidance system. The problem came to light last October in the Long Life 2 project, an attempt to launch a firststage burn missile from an operational silo near Grand Forks, N.D.

Plans for an ambitious, worldwide scientific and technical data retrieval system may be pushed if the top science job at the Department of Commerce goes to Chalmers W. Sherwin, deputy assistant secretary of commerce. Sherwin now seems the most likely candidate to succeed J. Herbert Hollomon as assistant secretary for science and technology. Hollomon, after an active and controversial tour of duty, goes to the University of Oklahoma in August as president.

Growing out of a yet-to-be-released study, Sherwin’s plans call for a machine-language-compatible system capable of linking all independent information systems in the world. He says it would drastically cut the cost of local libraries and of extensive literature searches. Such a decentralized system, with 2,000 stations and a major international center, would cost about $200 million annually, Sherwin estimates.

FCC approval of over-the-air pay television is finally in sight. Indications are that the FCC’s subscription television committee will send its recommendations to the full commission in 30 to 60 days, and Robert E. Lee, one of the three commissioners on the panel, sees a “good chance” for a go-ahead. Regarding pay tv by cable, it’s doubtful that the FCC will press its claim of jurisdiction.

Zenith and two other firms petitioned 15 years ago for an amendment
of FCC rules to include pay tv, but the commission declined to make a ruling until experiments had been carried out. Tests, using Zenith equipment, have been conducted over the air in Hartford, Conn., for six years by an RKO General subsidiary. With trial data in its hands, Zenith last year again petitioned the FCC.

ARPA sees system of billion elements drawing few watts

A system with a billion active elements and a power consumption of only a few watts is potentially attainable with techniques developed in work for the Advanced Research Projects Agency. The development came to light in recently released Congressional testimony by Charles M. Herzfeld, ARPA director. He said the nanowatt circuits, being designed for use in special sensor instrumentation, will have transistors with a collector area of 3 square microns each, resistors with a linewidth of less than 1 micron and length of less than 100 microns, and a sheet resistance as high as 100 megohms per 100 square microns.

Assault ship pact no guarantee of automated yard

A new U.S. automated shipyard doesn’t seem to be in the cards for the Navy when it awards a “total package” contract to build five to 10 multipurpose assault ships (LHA) next year. The Pentagon had expected to get an automated yard by contracting with one company for a substantial number of identical vessels. But Congress recently turned down the 30-ship Fast Deployment Logistics (FDL) program which would have been large enough to make this possible. The LHA program—expected to cost from $300 million to $600 million—is not a large enough order, although the winning company may be persuaded to modernize an existing yard.

The Navy will pick two or three bidders to compete in a contract definition beginning next month and running through January. The winner will be chosen in mid-1968.

U.S. renews effort for patent system

The Johnson Administration, determined to get a universal patent system for as many as 77 nations, this month unveiled a proposed international patent treaty. But the treaty will be academic unless Congress first goes along with U.S. patent reform. However, the reform bill appears dead for this session of Congress [Electronics, May 29, p. 60]. One of the stumbling blocks is a change from “first to invent” to “first to file” criteria for granting patents, something necessary for an international system since nearly all other nations have such a standard.

Addenda

First operational air communications centers for the Marine Corps Tactical Data System will be built by Philco-Ford’s Western Development Laboratories. Cost of the four AN/TYQ-1 centers—one for each Marine air wing—will be around $20 million . . . One of the four traveling-wave-tube amplifiers on Comsat’s Intelsat-2 Pacific satellite has failed. That leaves the satellite without a backup tube. The tube failure, plus the fact that the communications satellite is operating at capacity, has prompted Comsat to spend $7 million to put another Hughes-built Intelsat-2 satellite over the Pacific . . . Two new counter-infiltration systems are now being deployed in Vietnam. The AN/PSR-1, using four buried geophones and a control unit having an audio readout, has an 800-foot range; the AN/GSS-9 is a breakwire system. Expected later this year is a third system—the AN/PSS-5 pulse doppler radar, which has a three-mile range.
FET CHOPPERS ARE THE ONLY ANSWER

MODEL 8000

Booze is the only answer at my house, but they frown down at the office when I suggest there is more than one way to solve problems. They should have my mother-in-law—they'd stick to booze, not electronics.

It turns out that an FET chopper is a distinct improvement over photo-choppers, what with 6 volts being enough drive instead of a couple hundred. Now the photo-chopper was better than the transistor choppers, because it looked like a resistor instead of a diode. So there ain't any voltage drops that have to cancel out. Mostly they don't. (Cancel, that is.)

As matters stand on noise and offset—and we sell choppers for only one purpose, which is to allow D.C. amplifiers with very little offset—the best of FET choppers are only two to three orders of magnitude worse than the best of mechanical choppers. Which is real progress. Last week it was three to four orders—before we invented this model 8000 FET chopper. The offset available is below 10 microvolts at 10,000 ohms, and would be lower if there weren't such weird alloys inside the FET that have to come out eventually to copper.

So today's best mechanical choppers reach down below some 50 nanovolts, the FET chopper gets to about 5 microvolts. That's two orders of magnitude and crowding. Good thing we make solid-state choppers too.

Speaking only of offset, and anyway, what else is speakable about a chopper? I suppose you could say Mechanical Choppers << FET Choppers << Photo Choppers < Transistor Choppers.

AIRPAK ELECTRONICS
Cambridge, Maryland 21613
15 ohms ON resistance with only 8.0 pf drain to gate capacitance solved critical FET switch applications

SPECIFICATIONS—TYPE 2N4977

- ON Resistance: 15 ohms max
- Drain to Gate Capacitance: 8.0 pf max
- Input Capacitance: 35 pf max
- Reverse Transfer Capacitance: 8.0 pf max
- Temperature Range: Operating —55°C to 150°C Storage —55°C to 200°C

Price:
- 1-99 $21.50
- 100-999 $14.00
- Breakdown Voltage Drain to Gate: 30v min
- Drain Current, Zero Gate Voltage: 50mA min
- Pinch-off Voltage: 10v max
- Gate Leakage Current: 0.5 nA max

Available from stock in TO-18 package

AMELCO SEMICONDUCTOR
Leadership

Power gain greater than 12 db @ 400 mc from our FET RF Amplifier

SPECIFICATIONS—TYPE 2N5078

- Power Gain @ 400 mc: 12 db min
- Noise Figure @ 400 mc: 4.0 db max
- Input Capacitance: 6.0 pf max
- Reverse Transfer Capacitance: 2.0 pf max
- Breakdown Voltage Drain to Gate: 30v min
- Drain Current, Zero Gate Voltage: 4 to 25mA
- Pinch-off Voltage: 8.0v max
- Gate Leakage Current: 0.25nA max
- Temperature Range
  Operating −55 °C to 150 °C
  Storage −65 °C to 200 °C

Price:

<table>
<thead>
<tr>
<th>1-99</th>
<th>100-999</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.00</td>
<td>3.35</td>
</tr>
</tbody>
</table>

Available from stock in TO-72 package

AMELCO SEMICONDUCTOR


Electronics | June 12, 1967
The simple DC regulator shown supplies 290 volts to a load of 50 to 600 milliamperes. Regulation is better than ± .05 percent with an input voltage variation of 15%. Delco high voltage silicon makes this possible with just one series transistor—the DTS-413—priced at just $3.95 each in 1000-and-up quantities.

This circuit also can be scaled to the capabilities of any of the other cost saving Delco DTS transistors, including the new DTS-424 and DTS-425. And no matter which Delco high voltage transistor you use, reduction of weight, size, and component cost is part of the bargain. Circuit complexity and number of components are reduced and so assembly costs go down, too. And fewer components mean higher reliability.

Right now, Delco silicon power transistors are adding these benefits in such high energy circuits as: DC-DC converters, ultrasonic power supplies, VLF class C amplifiers, off-line class A audio output and magnetic CRT deflection (several major TV manufacturers use them in big screen horizontal and vertical sweep circuits).

How soon can you get Delco silicon power transistors? How soon do you need them? With our experience and new plant facilities, samples or production quantities can be shipped promptly. Call one of our distributors or a Delco sales office now.

For full details on the DC regulator circuit, ask for application note number 38.
Application of Delco high voltage silicon power transistors: a DC voltage regulator.

DELCO RADIO
DIVISION OF GENERAL MOTORS • KOKOMO, INDIANA

Circle 53 on reader service card
New FETs, UJT's and SCRs from TI to optimize your circuit designs

Improve your products, create new designs with these "firsts" from Texas Instruments: • six new families of FETs • six unijunctions • four low-cost SCRs.

Most of these devices are available in the exclusive SILECT™ package with TO-18 pin-circle lead configuration. SILECT transistors are backed up by more than 10,000,000 hours of testing. A preliminary report concludes that SILECT transistors are capable of meeting military specifications and are as reliable as metal can devices tested under the same conditions.

Circle 281 for Reliability Report.

New low-cost, high-voltage FET replaces vacuum tubes

The new TIXS78 silicon n-channel FET offers a 300-volt minimum breakdown voltage, making it a one-for-one replacement for vacuum tubes in such applications as high-voltage switching and large-signal amplification.

The new FET is priced for computer, industrial, communications and entertainment usage.

Circle 282 for data sheet.

New tetrode FET features industry's highest transconductance to capacitance ratio

The TIXS80 is a high-frequency metal-can tetrode FET that has a minimum transconductance of 5,000 μmhos with a maximum reverse transfer capacitance of 0.8 pF.

A second gate simplifies biasing, AGC, and oscillator injection circuitry. The TIXS80 is designed for
mixer and automatic gain-control applications.

In rf amplifiers, it provides high, stable gain at frequencies of 30 to 300 MHz without neutralizing. Circle 283 for data sheet.

Industry's first plastic-encapsulated MOS FET

The TIXS67 is a p-channel silicon enhancement-mode field-effect transistor. It is the first such device to be encapsulated in plastic.

The unit features high transconductance (3500 to 6500 μmhos), low feedback capacitance (4 pF), and the lowest leakage characteristic to be found in a plastic-encapsulated device (50 pA). These characteristics make it suitable for switching and high-input-impedance amplifier applications from dc through medium-frequencies.

Circle 284 for data sheet.

New economy matched-pair FETs

Here is a low-cost matched-pair FET assembly for analog computers, comparators, and differential amplifiers. The n-channel TIS68 pair, similar to the 2N3819, is matched for gate-leakage current and gate-source voltage. \( I_{\text{DSS}} \) and transconductance are matched within 5%. Minimum transconductance is 1000 μmhos, maximum input capacitance is 8 pF, and reverse-transfer capacitance is 4 pF maximum.

A metal clip is furnished for banding devices together.

Circle 285 for data sheet.

Matched dual FETs have high common-mode rejection capability

This is the first dual FET having matched output admittances as well as matched transconductances for improved common-mode rejection capability. Designated 2N5045, this TO-18 type metal-can dual is ideal for general-purpose differential amplifier applications. Output admittance differential is within 1 μmho; transconductance and \( I_{\text{DSS}} \) are matched within 5%. The 2N5045 is priced below comparable pairs which are matched to a lesser degree.

Circle 286 for data sheet.

Nine new FET switches feature lowest on-resistance

Here are industry's first low on-resistance switching FETs. The TIS73-75 series is offered in the SILECT package, while a metal-case TO-18 series is designated 2N14856-61.

Low on-resistance (25 to 60 ohms max.) and extremely low leakage (0.25 and 2.0 nA max.), make these devices unusually versatile.

Circle 287 for data sheet.

New planar UJT's offer optimized characteristics for specific applications

The 2N4892-94 series of planar silicon UJTs in SILECT packages and the 2N4947-49 family of metal-case equivalents are the first such devices on the market which are characterized for specific applications. They are designed for use as long-time-delays, SCR triggers, or high-frequency relaxation oscillators.

Leakage is typically 0.1 nA... one-thousand times lower than comparable alloy types. Other advantages are low base-emitter saturation voltage and high pulse-output voltage.

Circle 288 for data sheet.

Smallest, lowest-cost SCR

TI's new TIC44-47 SCRs are priced only one-third as much as the metal-can equivalents. They are also the smallest SCRs available. The series is rated for 600 mA continuous dc current at 30, 60, 100 and 200 volts. A maximum gate-triggering current of 200 μA provides high turn-on gain.

Applications include motor speed controls, ignition systems, light flashers, light dimmers and a-c phase control systems.

Circle 289 for data sheet.

Call your nearest TI sales representatives or authorized distributor for more information. If you prefer, write us at P. O. Box 5012, Dallas, Texas 75222.

Texas Instruments INCORPORATED
The completely **NEW** Hi-G BN series meets all applicable requirements of Mil-R-5757, weighs .95 oz. in a .875" x .800" x .400" crystal can. All standard configurations and header styles are available for fast delivery.

Write or call Hi-G for new bulletins which provide full details on this high quality line of 5 amp. crystal-can relays. Test data and performance capabilities are available on request. Tel: 203-623-2481
Now Westinghouse has a pin-for-pin replacement for the industry-accepted TTL.

But don’t think of us only as a second source.

There’s a very good reason why you should make Westinghouse TTL your first source.

Because this is the TTL line that is available now.

It's a direct mechanical and electrical replacement for the industry-accepted SUHL II. And all circuits are available in industry-standard dual-in-line and flat packages.

They include: 6G260 Single 8-input NAND/NOR Gate, 6G241 Dual 4-input NAND/NOR Gate, 6G221 Quadruple 2-input NAND/NOR Gate, 6G210 Dual Expandable OR/NAND Gate, 6G250 Quadruple Expandable OR/NAND Gate, 6G130 Dual 4-input Driver, 6G270 Dual OR Expander, 6F251 AND input JK Flip-Flop, 6F261 OR input JK Flip-Flop.

In fact, it makes good sense to make Westinghouse first choice for all your IC's. Because our goal is to help keep your products competitive now and into the 1970's.

For evaluation quantities, contact your Westinghouse Electronic salesman, Or phone Westinghouse at (301) 796-3666. Or write Westinghouse Molecular Electronics Division, Box 7377, Elkridge, Maryland 21227.

You can be sure if it's Westinghouse
“Why do more and more executives say MICHIGAN has more of everything?”

“One reason is: year-around sports and recreation assure a full, rewarding life for all.”

For executives and their families who relocate in Michigan, the state offers a wonderland of enjoyment. The abundance of outdoor activities throughout the year enhances family living. Inland lakes and rivers and 3,000 miles of Great Lakes shoreline provide fishing, swimming and boating — besides assuring a wealth of fresh water for industrial use. For labor, as well, Michigan’s superb sports and recreation facilities contribute to contentment.

Interested in moving to where the good life is? Contact Consumers Power for detailed, confidential information on plant sites in Michigan’s Lower Peninsula.

Consumers Power Company
W. N. McClelland, Director of Area Development

Electronics | June 12, 1967
Tracks down envelope delay...

Undetected envelope (or group) delay can easily derail a digital data transmission. Bit-by-bit that pristine formation crumples, Down the line, someone ends up with a mess instead of a message. To keep the data train properly coupled, you need precise information about phase-shift-versus-frequency characteristics of your carrier. The kind of information you can get express from a Sierra Model 3408 Envelope Delay Test Set.

Model 3408 pinpoints relative delay to ±20,000 $\mu$sec on a big, direct single-range digital counter. Resolves it to 1.0 $\mu$sec. On a second digital counter, it displays frequency with 10-Hz resolution. Range of 300 Hz to 110 kHz spans voice channel through group frequencies. Measurement modes include end-to-end, loop-back, or end-to-end with return reference path.

Modulation frequency of 25 Hz, usable over full range, resolves fine-grain deviations separated by as little as 50 Hz. Alternative 250-Hz modulation resolves delay to 0.1 $\mu$sec. Price, with one modulation frequency, $4,750.

Ask for more data, and watch us pour on the coal. Write Sierra, 3885 Bohannon Drive, Menlo Park, California 94025.
New...
3 instruments in 1
for $950

DIGITAL METER Model DM 5000
1. Five operating modes: (1) 0.1% DC digital voltmeter; (2) analog integration; (3) rate and frequency measurement; (4) period and interval measurement; and (5) electronic counter.
2. Four-digit buffered display: with automatic polarity, 100 µV resolution, no flicker, over-range and mode indications.
3. DC voltages in five ranges: ±1.000 V, ±1.00 V, ±10.00 V, ±100.0 V, and ±1000. V; calibrated over-range to 40%.
4. Integration: five full scale ranges—1, 10, 100, 1000, and 10,000 CPM/volt.
5. Rate and frequency: four full scale ranges—10, 100, 1000, and 10,000 kHz.
7. Counter: from 0 to greater than 250 kHz with 1 count in $10^4$ resolution.

Other features: no adapters or plug-ins required...10 megohm floating input.

Write today for free Bulletin 701-A.

TECHNOLOGY INCORPORATED
7400 Colonel Glenn Highway, Dayton, Ohio 45431
Phone: (513) 426-2405
NEW LOWER PRICES

NEW TEST DATA
FOR CTS INDESTRUCTIBLE CERMET
SEMI-PRECISION RESISTOR NETWORKS

The data speaks for itself. Examine and judge its value for your application:

- Extreme Stability and Reliability
- High Power Capability: (Up to 1 watt per resistor)
- Space saving—a single module replaces up to 7 discrete resistors.
- Available in an infinite number of circuit combinations.
- Custom-built to your exact requirement.
- Ideally suited for cost-saving automatic handling.
- Cover coating unaffected by solvents.

<table>
<thead>
<tr>
<th>Series 750</th>
<th>2-Pin (1 Resistor)</th>
<th>4-Pin (3 Resistors)</th>
<th>6-Pin (5 Resistors)</th>
<th>8-Pin (7 Resistors)</th>
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<td>Total Module Load</td>
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<td>1.0 Watts</td>
<td>1.5 Watts</td>
<td>2.0 Watts</td>
</tr>
<tr>
<td>Approx. 10,000 cost</td>
<td>17¢</td>
<td>18¢</td>
<td>21¢</td>
<td>26¢</td>
</tr>
</tbody>
</table>

STANDARD MODULE SPECIFICATIONS
FOR ALL SIZES

- Resistance Range: 50 Ω to 100K Ω
- Resistive Tolerance: ±5.0%
- Load Life: 0.1 W per resistor at 70°C, 1000 hrs. (Over 4,000,000 resistor hours)
  - ≤0.40% Δ R max.
  - ≤0.20% Δ R av.
- Moisture Resistance: 1 rated wattage at 70°C, 90-98% humidity, 1000 hrs.
  - ≤0.50% Δ R max.
  - ≤0.20% Δ R av.
- Insulation Resistance: measured wet after moisture resistance test, 200 VDC
  - 500 meg. Ω
- Thermal Shock: 5 cycles, -63°C to +125°C, ±0.10% Δ R max.
  - ±0.03% Δ R av.
- Short Time Overload: 2.5 times rated voltage, 5 sec.
  - ±0.25% Δ R max.
  - ±0.05% Δ R av.
- Low Temperature Exposure: -63°C, 4 hrs.
  - ±0.10% Δ R max.
  - ±0.04% Δ R av.
- Terminal Strength: 5 lb. tensile & compression, 30 sec.
  - ±0.10% Δ R max.
  - ±0.03% Δ R av.
- Effect of Soldering: 63/37 solder, 246°C, 2 sec.
  - ±0.10% Δ R max.
  - ±0.05% Δ R av.

Extra cost options

| Resistance Range | 10 to 49 Ω, 10K to 1 meg. Ω |
| Resistance Spread | Over 10 to 1 |
| Resistive Tolerance | ±0.5%, 1%, 2.5% |
| TC | ±150 ppm/°C |

Request Cermet Catalog

CTS of Berne, Inc.
Berne, Indiana

Electronics | June 12, 1967
Nobody but AE makes a Class E relay with all these terminals.

Take your pick:

1. **Solderless Wrap Terminals** eliminate the hazards of soldering. No splashes, heat or clippings. Faster, easier connections. And the technique is easy to learn.

2. **Taper Tab Terminals** accept solderless, slip-on connections which are crimped to each wire lead. Easy to connect or disconnect. Simplify circuit changes and relay substitutions.

3. **Solder Terminals**—the conventional way. For chassis and rack mounting where quick-connect methods aren't needed.

4. **Printed Circuit Terminals** can be inserted directly into PC cards or boards. All terminals are soldered at one time by "flowing." This process can be automated.

You can get AE Class E relay with several types of plug-in sockets, too—that further increase the number of mounting options.

But don't select the Class E relay because of wiring convenience alone. This is a miniaturized version of the premium-quality Class B—with most of its best features. Perfect contact reliability exceeding 200 million operations is common. That's why, even with ordinary solder terminals, the Class E is the most popular quality relay of its size!

For helpful information on the full line, ask for Circular 1942. Just write the Director, Relay Control Equipment Sales, Automatic Electric Company, Northlake, Illinois 60164.

**AUTOMATIC ELECTRIC**

SUBSIDIARY OF
**GENERAL TELEPHONE & ELECTRONICS**

GT&E

Circle 62 on reader service card
We'll send you one by return mail.
If you'll circle Reader Service #25,

Your 1967 Catalog Enclosed
DURANT'S NEWEST!

... in a growing line of count/control instruments

49600 UNISYSTEM®

New, single-level predetermined count/control system developed to meet the need for a small, inexpensive digital counter or timer. It provides direct digital reading, eliminating dial interpolation. Ideal for installation on control panels for machine tools, textile machinery, wire machinery, metering and scaling equipment. This exceptionally compact unit is available as a standard unit equipped with 2, 3 or 4 Unipulser decades. Design permits it to be used equally well as a desk or panel mount without change. Important advantages include ease of presetting and resetting (panel or remote) ... set-up and wiring simplicity ... pre-determined visual setting is always retained. Count life and reset life proven for over 100 million counts. Count speed up to 30 cps. 115V - 230V, 50-60 cycles.

For more information circle No. 491 on Reader Service Card

6 YE SERIES ELECTRIC COUNTERS

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High accuracy and reliability are assured by an exclusive Durant drive feature: the power impulse cocks, power release counts, resulting in a uniform indexing force and smooth counting action.

Count speed is 2400 cpm DC — 1800 cpm AC (rectified). Models available for 115V, 230V AC or DC — other voltages on request.

For more information circle No. 493 on Reader Service Card

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Durant Unipulsers are now compatible with count/control equipment using binary coded decimal systems. They are especially suited for use in data processing equipment, medical instrumentation, business machinery and more.

BCD Unipulsers use the 0-1-2-4-8 code and hook up easily with only 5 wires using standard connectors. Drive and visual readout is digital. Electrical readout is automatically encoded from digital to binary, eliminating the need and expense of code converters.

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For more information circle No. 492 on Reader Service Card

DIGITAL CLOCK — ELECTRICAL READOUT

Hours, minutes, seconds or decimal combinations of any time period can be readout visually and electrically by this highly dependable unit. It can be used in data reduction systems ... for controlling batching where timed mixing is important ... to aid in computing piece rate in all production processes ... for use in all types of data or material handling where a time base is required.

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For more information circle No. 494 on Reader Service Card
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Here’s the new little toggle that’s big in the features you need. Space-saving size—only ⅛” behind the panel. Good operating feel—positive detents, optimum forces, positive return spring on momentary versions. Full versatility, too—ten versions offering SPDT or DPDT, 2 or 3 positions, maintained or momentary contact, 30 vdc or 115 vac, 5 amps resistive, 2 amps inductive.

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Frequency range: 1 kHz-27.5 MHz digital readout
Scan widths: 50 kHz-5 MHz, or 500 Hz-50 kHz phase locked, digital readout, preset 0-25 MHz full dispersion
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Sensitivity: 30 µV linear full scale
Residual distortion: > 50 db down
Log display: 40 db calibrated
Display flatness: ±1 db
Frequency calibration: ±0.02% internal crystal markers
Main frames: rack-mount or portable
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In ten years of manufacturing crystal filters—from 5 kc to 125 mc—McCoy has accumulated a wealth of filter manufacturing knowledge. Coupled with complete crystal manufacturing facilities, this background of filter know-how has established McCoy as a leader in the industry.
When sophisticated designs and miniaturization are required, practically everyone insists on McCoy, where sophisticated filters are routine.
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General Electric recently redesigned the sweep transformer for many of their TV models. They changed from a wax impregnated paper coil insulation to "Scotchpar" polyester film. They benefited by 25% more transformer power, greater reliability and cost savings.

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TRW again breaks the Gigahertz barrier with this new 2 GHz addition to the TRW family of Ultra High Frequency transistors! They are the finest broadband transistors you can buy—the only power transistors capable of GHz operation in simple, straight through circuits.

As doublers or triplers these transistors will reach 3 GHz with cool efficiency. In the 600 to 700 MHz range their gain and efficiency are phenomenal!

And you get this remarkable performance from a 28 volt power source, 1 Watt output, 5 dB gain!

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SUGGESTED APPLICATION

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heavy weight!

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The current carrying capability of this new product makes possible reduction in cell sizes never before achieved.

Available in all cell sizes with voltage ratings as high as 45 volts.

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General Electric MHD's are just as reliable

Proved by 3½ years of manufacturing experience

They're the next logical step forward in GE signal diode innovations. Nearly 40% smaller than the DHD we introduced 5 years ago, tiny GE Milli-Heatsink diodes feature the same “springless” construction ... the same proved, inherent reliability. MHD's are perfect for high-density circuit card and memory applications, and for “cordwood” construction. Each Milli-Heatsink diode features high conductance and nano-second switching time. New General Electric MHD's are available in JEDEC types 1N4531-34 and 1N4536.

MHD's are just one more example of the total electronic capability you get only from General Electric. For more information, call your GE engineer/salesman or authorized distributor. Or write: General Electric Company, Section 220-56, Schenectady, New York, 12305. In Canada: Canadian General Electric, 189 Dufferin St., Toronto, Ontario. Export: Electronic Component Sales, IGE Export Division, 159 Madison Ave., New York, N. Y., U.S.A.
GET FAST SIX-WAY RELIEF.....

from irritation due to circuit design problems

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And best of all, prices for the QFT series are extremely soothing. Write today for complete specifications and price information on the QFT series.


New NEXUS QFT capsules give "best-you-can-buy" op amp performance
1. FET input . . . 10^11 ohms Z, differential and common-mode
2. High output in small package . . . ±10mA @ ±11.5V
3. Low input bias current . . . 10pA, typical
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**2854 WIDEBAND AMPLIFIER** — A high gain, low noise, video amplifier used to detect low level wideband signals. Solid-state electronics; 1kHz — 10MHz frequency range.$1070

**2855 ASSOCIATED PREAMPLIFIER** — For matching rod antenna impedance to 50 ohm input of receivers or amplifiers (typically Honeywell 2854). Low noise solid-state electronics with self-contained battery; 300Hz — 1OMHz frequency range.$485

**4857 LOW FREQUENCY IMPULSE GENERATOR** — Provides flat spectrum of calibrated amplitude signals in 120Hz — 250kHz range for signal substitution or calibration of receivers and field intensity meters. Solid-state electronics.$550

**3858 — 3861 LOW FREQUENCY POWER LINE IMPEDANCE STABILIZATION NETWORKS** — Used for conducted interference testing of equipment requiring high level input power line current. Frequency range: 14kHz-6MHz; 50ohm line impedance.$230 — $290

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in the state-of-the-art

1.0 MFD. 25 VDC molded case Ceralam in CK06 style

Just the ticket for those solid-state applications...greatly increased capacitance ranges at a reduced voltage. This Aerovox breakthrough features a 1.0 mfd, CK06 made with Ceralam established reliability, semi-stable Characteristic "C" material (±15% temperature coefficient).

In addition to the CK06, greater capacitance is made available in all Aerovox configurations and standard ceramic compositions. These include a 0.1 mfd CKR12, a 0.33 mfd CK05, and values up to 7.5 mfd in the Aerovox MC89 tubular series.

Aerovox's well established reliability has been a prime consideration in the development of these new units and careful adherence to conservative voltage stress limits has been maintained. Although rated at 25 volts, units are life tested at twice rated voltage. Capacitors of similar low voltage rating such as electrolytics are tested only at rated voltage. Units may also be screened by "burning-in" at twice rated voltage for periods up to 250 hours without shortening the life of the capacitor and thereby bringing quality to the levels specified in MIL-C-39014.

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Electronics | June 12, 1967
Why buy price at any cost

To pay too little is to obviously speculate. To spend too much is to be foolishly extravagant. The real value of any purchase is determined in performance, not price. Resistors are like this also.

For years, Stackpole fixed composition resistors have been the standard of value for many leading manufacturers of electrical and electronic equipment. Engineers have become familiar with the testing and evaluation that go into each Stackpole resistor order. Purchasing people know they can expect prompt delivery. And management is assured of complete, in-depth service backed by sixty years of experience.

It's for reasons like these that Stackpole resistors are selected to maintain top performance on so many established products and on a growing number of brand new ones. Such confidence and loyalty cannot be based on price alone, but instead come from the kind of dependability that builds a reputation for your product.

Uniformity is a known characteristic of Stackpole resistors. Unique production methods coupled with thorough testing assure you absolute performance. You can rest assured that the Stackpole resistors you order today will be identical in every way, order after order.

Are you getting what you pay for in a resistor? Why not investigate the value Stackpole resistors can give you. Quality, economically priced and backed by the recognized name... Stackpole. There are four sizes to choose from: 2, 1, 1/2 and 1/4 watts.

For samples or a copy of our new booklet, "How to spot a quality resistor", write: Stackpole Carbon Company, Electronic Components Division, Kane, Pa. 16735. Phone: 814-837-7000 — TWX: 510-695-8404.
For nearly 10 years engineers have been trying to improve the processing of gallium arsenide and design new devices that can use it. The long tedious work appears ready to pay off. At RCA, researchers have successfully built transistors on gallium arsenide by using a silicon nitride insulator instead of silicon dioxide [p. 82]. The FET's produced perform better than equivalent silicon metal oxide semiconductor devices. On the cover is a photograph of the first gallium arsenide MIS transistor. At Bell Telephone Laboratories, researchers are pushing ahead with the limited space accumulation mode of operation for bulk effect devices made of gallium arsenide, and the work appears to be more promising than that being done with any other kind of bulk phenomenon [p. 91].

Breakdown is turned into an advantage when the device is operated beyond its cutoff frequency. The breakdown limit rises above its static and low-frequency values so the device can withstand transient peaks up to twice the data sheet rating. The payoff is less expensive r-f amplifier circuitry.

Integrated electronics have made the read-only memory look more attractive by cutting its cost substantially. More and more computer users and makers are applying the read-only memory to control sequence or to provide a subroutine that doesn’t have to change. Now the concept of large-scale integration, putting hundreds of elements on a slice of silicon, makes possible a radical change in computer organization: the use of read-only memories to generate Boolean logic to increase the arithmetic capability of computers.

Masers aren't used often in radar systems because high-energy radar pulses can leak into the maser and damage it or saturate it so it doesn't amplify. A new technique of shifting the frequency keeps the maser from saturating and increases its use in radar systems.
Advanced technology

Gallium arsenide FET’s outperform conventional silicon MOS devices

With silicon nitride as the insulator, transistors made of an epitaxial layer of GaAs are capable of better response at higher frequencies and temperatures, and could lead the way to gallium arsenide IC’s

By Hans W. Becke and Joseph P. White
Radio Corp. of America, Electronic Components and Devices Division, Somerville, N.J.

The time, talent, and money lavished on gallium arsenide for more than a decade is on the verge of paying off in a field effect transistor that is far superior to its counterparts made of silicon.

The transistor, which is a metal insulator semiconductor (MIS) device, outshines the silicon MOS (oxide insulator) device in power gain, frequency response, and temperature range. It is the offspring of a marriage of two new processes in materials technology—growing epitaxial GaAs from the vapor phase and using silicon nitride as an insulator. The result: high-quality devices that can be produced with high yields.

Better transistor performance at higher frequencies and temperatures calls for an extension of semiconductor materials technology beyond germanium and silicon into the area of Group III-V compounds. Of these, gallium arsenide now offers the most promise—it has high electron mobility, for high frequency response, and a wide-energy band gap, for high temperature operation.

The improvement that can be obtained with gallium arsenide was demonstrated by comparing the operation of two groups of insulated-gate FET’s, one of GaAs and the other of silicon, with identical geometries. Measurements of the devices operating in the same circuit showed that GaAs has higher power gain ranging from a factor of 2 to a factor of 4. Improvement by as much as a factor of 10 appears possible. At high temperatures, GaAs MIS transistors performed far beyond the silicon devices. The GaAs devices fell off by only 3 decibels between 25° and 250°C, and showed a useful gain up to 350°C. Silicon devices were down 3 db at 130°C and dropped to 0 gain before 300°C was reached.

GaAs MIS epitaxial structures also lend themselves to integration and offer the advantages of an easy method of device isolation. In integrated form, isolation between devices could be achieved with a semi-insulating GaAs substrate, which is produced by doping GaAs with iron or chromium to yield resistivities in the 10⁶ ohm-centimeter range (resistivity of glass, for example, is in the 10² ohm-cm range). Since GaAs is widely used in optical devices such as light-emitting diodes and lasers, integrated solid-state displays offer an attractive application.

Early attempts to develop GaAs bipolar transistors that could live up to the theoretical performance were frustrated by poor material quality and processing difficulties. However, in recent years,
Transistor.

More has been learned about GaAs processing, and the crystal's defects and traps have little effect on the device, has an intrinsic advantage over the bipolar devices such as tunnel diodes, light emitters, junction lasers, and Gunn oscillators. Now that much more has been learned about GaAs processing, transistors can be built that take advantage of gallium arsenide's unusual properties.

**FET vs. bipolar, GaAs vs. Silicon**

The field effect transistor, as a majority-carrier device, has an intrinsic advantage over the bipolar transistor, which is a minority-carrier device. In the FET, the channel acts almost as a bulk resistor, and the crystal's defects and traps have little effect on the charge carriers. In the bipolar transistor, the carriers from the emitter are injected as minority carriers into the base, where they must avoid recombination to reach the collector.

The upper frequency limitation of the field effect transistor is set mainly by the ratio of transconductance, $g_m$, to the product of input and output admittances. With a fixed $g_m$, the input and output capacitances limit the frequency performance. However, with a fixed geometry, increases in $g_m$ improve the frequency response.

The $g_m$ includes a carrier-mobility term and is substantially increased when gallium arsenide is used in place of silicon—GaAs has at least a 5:1 advantage in electron mobility over silicon. Gallium arsenide thus is ideally suited for an $n$-channel field effect transistor.

In the bipolar transistor, the maximum frequency depends on several time constants, with the transit time across the base width usually being the dominant one. Transit time depends on the diffusion constant and the base width. The diffusion constant is a function of carrier mobility, and the upper frequency limit is proportional to the square root of the product of minority and majority carrier mobilities. Again, gallium arsenide displays superiority over silicon—in this case, nearly a 4:1 improvement.

**Insulated gate vs. junction gate**

Insulated-gate field effect transistors—MIS type have several advantages over junction-gate types. They can be operated with negative and positive gate drive (depletion and enhancement modes); they can have narrower channels for higher gain; and they can have an input impedance essentially that of an insulator.

High-frequency junction-gate FET's are still feasible, however. Work on such devices is currently in progress at Britain's Plessey Co. and Switzerland's Battelle Memorial Institute.

Battelle researchers have reported on diffused-channel devices with an aspect ratio (channel width/channel length = $W/L$) of 15 to 1. These devices exhibit a low frequency transconductance of about 0.1 millimho with an effective channel mobility of 3,000 $\text{cm}^2\/\text{v-sec}$. An interesting effect was observed for transistors with saturation currents greater than about 25 milliamperes. Strong vhf oscillations occurred at threshold fields of the same magnitude necessary to induce the Gunn effect. Oscillations of this type have also been observed on insulated-gate devices fabricated at the Radio Corp. of America's Electronic Components and Devices division laboratory in Somerville, N.J.

Higher frequency devices with an aspect ratio of 50 to 1 were fabricated at Plessey using an epitaxial channel 5 to 7 microns thick. These transistors had a transconductance as high as 0.8 millimhos and a cutoff frequency of 200 megahertz. A four-fold narrowing of the channel produced devices with cutoff frequencies up to 670 MHz.

A prerequisite to the successful construction of GaAs metal insulator semiconductor transistor.

![Structure of GaAs metal insulator semiconductor transistor](image)

Much work has been done on two-terminal GaAs devices such as tunnel diodes, light emitters, junction lasers, and Gunn oscillators. Now that much more has been learned about GaAs processing, transistors can be built that take advantage of gallium arsenide's unusual properties.

### Gallium arsenide and silicon insulated-gate FET's

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>GaAs</th>
<th>Silicon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain current, I_D</td>
<td>5 to 30 ma</td>
<td>5 to 10 ma</td>
</tr>
<tr>
<td>Operating voltage, V_D</td>
<td>5 to 9 v</td>
<td>8 to 12 v</td>
</tr>
<tr>
<td>Transconductance, g_m</td>
<td>10 to 25 mmhos</td>
<td>8 to 10 mmhos</td>
</tr>
<tr>
<td>Effective channel mobility, $\mu$</td>
<td>2,000 to 3,000 $\text{cm}^2/\text{v-sec}$</td>
<td>300 to 500 $\text{cm}^2/\text{v-sec}$</td>
</tr>
<tr>
<td>Power gain at 200 Mhz</td>
<td>17 to 22 db</td>
<td>14 to 16 db</td>
</tr>
<tr>
<td>Noise figure at 200 Mhz</td>
<td>4 to 5 db</td>
<td>3 to 4 db</td>
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</tbody>
</table>

Electronics | June 12, 1967 | 83
Hydride vapor technique paved the way

The key that opened the door to RCA’s gallium arsenide MIS transistor is the hydride vapor synthesis technique developed by James Tietjen and James Amick at the company’s research laboratories in Princeton, N.J.

Arsenic and doping impurities in hydride vapor form—for example, AsH₃, arsine gas or arsenic hydride—are introduced into the reaction chamber. Hydride vapors enable greater control of the concentration and reaction rate of the epitaxial layer. N-type layers have been grown with electron concentrations below 10¹⁵/cm³ and electron mobilities above 7,000 cm²/volt-second at room temperature—ideal properties for fabrication of GaAs transistors.

In comparison, bulk GaAs has carrier concentrations in the 10¹⁶-10¹⁷/cm³ range; it is difficult to control transistor properties when starting with such high conductivity material.

The epitaxial material, unlike bulk GaAs, isn’t appreciably compensated. Such impurities produce traps in the forbidden band and tend to make the conductivity low, which might suggest that a high-purity, low-conductivity material has been obtained. However, the material’s conductivity may actually be high, and only appear low due to compensation effects.

Hall-effect measurements on the epitaxial material at liquid nitrogen temperature (77°K) show about an order of magnitude increase in mobility with little change in concentration, indicating low compensation. Thermal conversion (change in concentration or conductivity type during a heating cycle) has always been a problem during device processing with bulk material and has prohibited initial concentrations in the range employed with germanium and silicon transistors. If contamination from undesirable impurities, like copper, is prevented, thermal conversion is eliminated with these new epitaxial layers even for concentration below 10¹⁵/cm³.

Several suitable acceptors and donors, listed below, are available.

<table>
<thead>
<tr>
<th>Acceptor</th>
<th>Donor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc</td>
<td>Tin</td>
</tr>
<tr>
<td>Manganese</td>
<td>Sulfur</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Selenium</td>
</tr>
<tr>
<td>Mercury</td>
<td>Tellurium</td>
</tr>
<tr>
<td>Mercury</td>
<td>Silicon</td>
</tr>
<tr>
<td>Manganese</td>
<td>Germanium</td>
</tr>
</tbody>
</table>

Silicon dioxide vs. silicon nitride

Initial work at RCA on gallium arsenide MOS devices showed that silicon dioxide had marginal results. Although intricate devices were constructed (aspect ratio of 200:1) the highest transconductances were 4.0 mmhos and the devices had only 10 dB power gain at 100 Mhz.

Analysis pointed up two factors restricting device performance: a high density of electron states at the SiO₂-GaAs interface, and excessive drain-to-substrate capacitance associated with the high conductivity of the compensated bulk p-type material used as a substrate. The substrate conductivity could be reduced by using an epitaxial layer or semi-insulating GaAs.

An insulator with improved properties was sought using an MIS capacitor technique to study the surface states. In this technique, the capacitance...
is measured across the insulator separating the substrate from the metal-gate conductor. If the capacitance changes significantly, by 50% or more, as the d-c voltage between gate and substrate is varied, then the electric field is known to be penetrating the semiconductor. With a high density of surface states, the field doesn’t penetrate as the voltage is changed, and the capacitance remains nearly constant.

Little improvement over SiO₂ was observed until a low-temperature deposition process for silicon nitride was developed. With SiN applied to GaAs, a low-state density interface is produced. Capacitance-voltage curves for SiO₂ and SiN on gallium arsenide show a large relative change of capacitance with voltage for silicon nitride and a significant improvement over silicon dioxide.

An epitaxial channel-silicon nitride insulated-gate transistor was developed and more than 100 samples were investigated, tested, and compared with conventional silicon MOS transistors with identical surface geometry. Comparisons were made of d-c, high-frequency, and high-temperature characteristics.

Curve tracer characteristics (drain current versus voltage for silicon nitride and a significant improvement over silicon dioxide.)
Traps—the pitfall of GaAs bipolar devices

The development of bipolar gallium arsenide transistors has generally followed the same course as silicon transistors: first, alloyed-emitter devices; then, double-diffused devices; and then, planar devices. The problem common to all has been the presence of traps in the structure that reduce the mobility of the carriers as they pass through the base region, thus limiting frequency.

**Alloyed emitter.** These mesa devices, with diffused bases, have been thoroughly investigated by Hans Strack of Texas Instruments Incorporated. Describing the difficulties with this type transistor, Strack says: "Typically, transistors can be operated in the vhf range rather than at 1 to 5 Ghz as predicted from mobility data. Few devices have been reported to have gain-bandwidth products of 0.5 to 1.0 Ghz. No reliable process has been developed so far to produce these devices in large quantities. Furthermore, the advantages of higher band gap couldn't be utilized because low melting tin-alloyed emitters were employed."

The performance was limited because of deep traps within the forbidden band, possibly due to oxygen contamination. These traps reduce the average velocity of the electrons in traversing the base region. Electrons are captured and remain stationary at the trap site for a certain relaxation time before moving to the next site, and eventually on to the collector region. Thus, the effective electron mobility is reduced, limiting the high frequency performance.

**Double diffused.** Mesa structures of this type, delivering 2 watts at 50 Mhz, were developed at RCA in 1963. These devices had a zinc-diffused base employing the three-cycle, low-concentration, solid-solid diffusion technique and tin-diffused emitters. Excellent control over junction planarity and penetration depths was achieved. With a zinc base of 0.8 microns, the tin emitter penetrated 0.5 microns, leaving a base width of only 0.3 microns.

The current gain of these transistors was generally low—less than 10. The current gain as a function of collector current is similar to that observed for silicon and germanium transistors. The reduction in current gain at low currents can be attributed to a high surface recombination velocity, and space charge recombination within the emitter junction depletion region. The fall-off at high current levels indicates the presence of base conductivity modulation and emitter edge injection as established for conventional transistors.

The beta-cutoff frequency (3 db down from the d-c value) occurs at about 40 Mhz. Beyond 200 Mhz, hβ falls off 6 db per octave and reaches unity at 300 Mhz. Thus, this transistor's fT is 300 Mhz.

This value of fT is significantly below that expected from mobility considerations and it is apparent that deep traps are also involved in the base transport processes of these devices.

For high-frequency amplifying devices, the power gain is normally more important than the voltage or current gain because of the finite input impedance. The power gain at 50 Mhz was as high as 11 db for several devices. In Class B operation, 1 watt r-f output was obtained from an input of

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**Comparison of iron-doped and iron-free transistors**

<table>
<thead>
<tr>
<th></th>
<th>Iron-doped transistor</th>
<th>Iron-free transistor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low frequency current gain</td>
<td>~15</td>
<td>&gt; 20</td>
</tr>
<tr>
<td>Gain-bandwidth product</td>
<td>~150 Mhz</td>
<td>&lt; 5 Mhz</td>
</tr>
<tr>
<td>r(1/G product</td>
<td>~700 psec</td>
<td>&gt; 2.000 psec</td>
</tr>
<tr>
<td>Saturation resistance</td>
<td>~60 ohms</td>
<td>&gt; 200 ohms</td>
</tr>
</tbody>
</table>

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**Process for GaAs double-diffused mesa transistor.**
typically 300 milliwatts, with a d-c dissipation of 1.6 w representing an efficiency of about 60%. A maximum r-f output of 2 w was observed on several units dissipating 3.5 w.

The temperature dependence of both the d-c current gain and the 50-Mhz small-signal power gain also were measured. Power gain decreases from 8.5 db at room temperature to approximately 5.5 db at 350°C. This excellent performance at high temperature can be expected for GaAs because of the high value of the band gap. Perhaps more striking was the device's unexpected behavior toward low temperatures.

There is no significant change in power gain down to liquid nitrogen temperatures and oscillators were built that worked well at liquid helium temperatures, $-269°C$. In contrast, conventional silicon and germanium transistors as well as GaAs devices having a diffused manganese base and an alloyed emitter exhibit a sharp drop in $h_{fe}$ and power gain below about $-60°C$.

More recently, double-diffused mesa-type devices were investigated at Britain's Standard Telecommunication Laboratories Ltd. These devices also had zinc-diffused bases and tin-diffused emitters. The base was diffused from a zinc-doped sputtered silica layer. STL scientists reported a significant improvement in current gain by using an epitaxial rather than a boat-grown bulk substrate. Transistors having current gains up to 1,200 were built. However, the frequency response was again well below theoretical expectations. From pulsed breakdown tests and the measurement of frequency performance versus temperature, researchers were able to conclusively demonstrate the presence of deep traps, which are believed to be oxygen centers introduced by water vapor diffusing through the silica layer.

A possible solution to the problem of deep traps has been investigated by Strack. Mesa-type devices were fabricated with a magnesium-diffused base and a sulphur-diffused emitter. Iron, which produces a deep acceptor level, was introduced during the sulphur diffusion to compensate the deep donor level. The iron-doped devices showed higher gain bandwidth products, lower saturation resistance, lower $r_{fe}$/C, time constant, and higher stability of the current gain at high temperatures.

Further improvement of the transistor characteristics was observed at TI when the silicon-dioxide diffusion mask was replaced by silicon nitride, eliminating a possible source of oxygen. For a base width of 1 micron, a gain-bandwidth product of 500 MHz was obtained.

**Planar.** Devices of this type have been developed at the International Business Machines Corp. in Boeblingen, Germany and at RCA. The planar transistors suffer from the same deficiencies as the mesa types.

In reporting on his results, IBM's H. von Muench concludes: "It is possible to produce npn transistors with beta values in the range of 20 to 30 with reasonable yield. The devices, however, fall short with respect to high-frequency performance as compared to theoretical predictions from mobility data. Trapping effects are dominant with most of the GaAs material presently available; these pose formidable limitations to large-scale fabrication with GaAs."

![Graph](image)

**Performance of npn double-diffused gallium arsenide bipolar transistors.**

It appears that further progress on bipolar GaAs transistors hinges on the elimination of the deep traps. The new hydride vapor synthesis technique for epitaxial growth, together with the use of silicon nitride as a diffusion mask, may offer a solution.

**References**

Effective capacitance as a function of channel concentration with interface state density as a parameter. The low values of K correspond to the high frequency case, since at high frequencies, fewer interface states can follow fast variations in gate signal.

Effective capacitance as a function of channel concentration with interface state density as a parameter. The low values of K correspond to the high frequency case, since at high frequencies, fewer interface states can follow fast variations in gate signal.

Gallium arsenide metal insulator semiconductor process.

drain voltage with gate voltage as parameter) at 120 hertz for medium-current GaAs and silicon devices appear quite similar. The transconductances for both devices are about 8.0 millimhos around zero bias. Both transistors have saturation voltages of about 1.5 volts. The gate-cutoff voltage of the silicon device is — 1.5 volts, equal to the saturation voltage, which agrees with first order theory. For the GaAs unit more gate voltage, — 2.5 volts, is required for cutoff.

The increased cutoff voltage occurs because the GaAs device has a low-concentration epitaxial channel; depletion from the substrate junction is comparable to the depletion from the insulated gate. In earlier MOS devices, the substrate depletion completely dominated the channel saturation because of high surface-state densities, and in general it was difficult to achieve cutoff from the gate at all.

**GaAs vs. Silicon— frequency**

A striking difference is observed when the transconductance for identical GaAs and silicon transistors is investigated as a function of frequency. The $g_m$ of the silicon MOS device is relatively constant while the $g_m$ of the GaAs MOS transistor shows a marked increase with frequency.

GaAs MOS transistors have a very small $g_m$ at zero frequency. At 100 Hz the $g_m$ is about the same as for silicon MOS transistors, and at 400 MHz the transconductance is two to three times higher than for silicon units, as expected on the basis of greater mobility in GaAs. This behavior is associated with the frequency response of interface states.

The active gate capacitance of an MOS device can be represented by a series-parallel combination of three capacitors: $C_{ins}$, the insulator (oxide) capacitance, is connected in series with the parallel combination of $C_s$, the semiconductor space-charge capacitance, and $C_{ss}$, the surface-state capacitance. $C_{ins}$ is a constant, $C_s$ is a function of bias and concentration, and $C_{ss}$ is dependent on surface-state density.

The approximate high-frequency transconductance is:

$$g_m \cong \mu \frac{V_{do}}{W/L} C_{ins}$$

if $C_{ins} < C_s$

$$C_{ss} = 0$$

where $V_{do}$ is the source-to-drain saturation voltage, $\mu$ is majority-carrier mobility and $W/L$ is the aspect ratio (channel width/channel length). With $C_{ins}$ a constant, then based on this approximation, $g_m$ should be a constant regardless of the frequency. At low frequencies, however, the surface-state effects become appreciable, and the insulator capacitance must be replaced by an effective gate capacitance

$$g_m \cong \mu \frac{V_{do}}{W/L} C_{eff}(\omega)$$
No schedule for breakthroughs

The Government is finding it as difficult as ever to match development program planning with the timing of technological breakthroughs. The latest example is the Air Force's experience with RCA's gallium arsenide field effect transistors.

Toward the end of the contract last fall, representatives of the advanced electronics branch, Electronic Technology division of the Avionics Laboratories at Wright-Patterson Air Force Base, which was underwriting RCA's efforts, asked how the project was coming along. RCA officials were not particularly optimistic about the prospects for success and told the Air Force so. As a result, the Avionics Laboratories decided not to continue the program beyond its scheduled cutoff point.

However, just before Christmas, RCA's Hans Becke, Joseph White and their associates succeeded in applying silicon nitride as an insulator to epitaxial GaAs grown from the vapor phase and produced high quality MIS devices.

Now, slightly abashed contract officers in the Air Force are considering supporting the work again.

Comparison of transconductance variations with frequency for GaAs and silicon FET's. The GaAs transconductance rises with frequency because surface states have less effect at high frequencies. If it were not for the surface states, the gallium arsenide would have higher transconductance across the frequency range, in keeping with its higher mobility. The silicon MOS curve is flat across the frequency range because the surface-state density in silicon is low and changes in frequency have little effect.

Semiconductor material properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Energy Gap (300°K) (eV)</th>
<th>Maximum operating temperature (°C)</th>
<th>Electron* mobility (300°K) (cm²/v-sec)</th>
<th>Hole* mobility (300°K) (cm²/v-sec)</th>
<th>Electron* mobility (300°K) (cm²/v-sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ge</td>
<td>0.78</td>
<td>100</td>
<td>2,100</td>
<td>800</td>
<td>4,000</td>
</tr>
<tr>
<td>Si</td>
<td>1.20</td>
<td>200</td>
<td>520</td>
<td>240</td>
<td>1,300</td>
</tr>
<tr>
<td>GaAs</td>
<td>1.52</td>
<td>400</td>
<td>5,300</td>
<td>350</td>
<td>11,000</td>
</tr>
</tbody>
</table>

* Mobility values in columns 4 and 5 correspond to the upper limit for a doping concentration of 10¹⁷/cm², the average concentration in the base of a bipolar transistor; the mobilities in column 6 are the corresponding values at C = 10¹⁵/cm², a low-concentration channel of a field effect transistor.
Comparison of temperature characteristics for GaAs and silicon FET's. The higher energy band gap for the GaAs provides the high temperature advantage over silicon.

Power gain comparison of GaAs and silicon FET's. The GaAs shows higher gain at higher frequencies because of increased mobility.

The effective gate capacitance is frequency dependent due to the frequency dependence of the interface states. The relationship between the net effective capacitance and the other capacities is given by

\[ C_{\text{eff}}(\omega) = \frac{C_s C_{\text{ins}}}{C_s + C_{\text{ins}} + C_{\text{ss}}(\omega)} \]

The density, or number, of interface states that is able to follow the changing gate signal decreases as the frequency increases. At low frequencies, the field set up by the gate voltage terminates on those surface states that can follow the frequency, and thus can't affect mobile charges in the channel.

For silicon, the effect is negligible because the channel concentration is high and oxide technology has progressed to the point where \( K \), the interface state density, is low—approximately \( 10^{11} \text{cm}^{-2} \). For these GaAs devices, however, there is a large number (\( 10^{13} \text{cm}^{-2} \)) of very slow states affecting the d-c response and a moderate density of fast states (\( 10^{12} \text{cm}^{-2} \)) that drop out with increasing frequency. MIS capacitor measurements have shown that the slow states can be eliminated with silicon nitride, but the faster states remain.

The power gain for a transistor can be expressed in terms of the admittance parameters as

\[ G = \frac{|Y_{21} - Y_{12}|^2}{4 \Re (Y_{11} + Y_{12}) \Re (Y_{22} + Y_{12})} \]

where \( Y_{21} \) is the transadmittance, \( Y_{12} \) the reverse transadmittance, and \( Y_{11} \) and \( Y_{22} \) are the input and output admittance, respectively.

The admittance parameters were measured on a transfer function bridge between 100 and 400 MHz, and the corresponding power gain was calculated for both the silicon and GaAs transistors. \( Y_{11} \) and \( Y_{22} \) are essentially the same for the GaAs and silicon devices. They are related to the input and output capacitances, which are functions of the physical device geometry. Power gains are about equal at 100 MHz. The GaAs devices have 3 db higher power gain at 200 MHz and 5 db higher gain at 400 MHz, at which point the devices become limited by the output time constant because they are medium-frequency structures. The projected cutoff frequency for the GaAs MIS transistors is 750 MHz while that for the comparative silicon structures is 550 MHz.

The improved performance of GaAs units at higher frequencies is a consequence of the increasing \( g_m \), which is the dominant part of \( Y_{21} \).

GaAs vs. Silicon—temperature

A 200-MHz amplifier circuit was used to investigate the temperature performance of several GaAs and silicon transistors. A small resistance heater, insulated from both the test circuit and the surrounding ambient, supplied the heat. A thermocouple was included in the enclosure to measure the temperature. In general, the circuit didn't require retuning to deliver maximum power gain across the entire temperature range.

At high temperature, the GaAs MIS transistors far exceeded the performance of silicon MOS transistors, as expected because of the wider band gap of GaAs. As temperature rises, GaAs gain improves until it reaches a peak at about 100°C and drops. For silicon devices, gain falls off immediately. The temperature at which the power gain was 3 db below the gain at room temperature was about 150°C for silicon and 250°C for GaAs. At 300°C the silicon devices exhibited little or no power gain, while the GaAs devices had power gains as high as 9 db.

References

Oscillator mounted in a millimeter-wave system. The adjustable waveguide short-circuit being tuned by the author, and the E-H tuner to the left of the diode holder are used to optimize the load. The tuner is separated from the diode by a length of transmission line to provide a delay before the full load is applied to the diode.

Advanced technology

GaAs bulk oscillators stir millimeter waves

Watts of power in this unexploited frequency range are promised by diodes operating in the limited space charge accumulation mode

By John A. Copeland
Bell Telephone Laboratories, Murray Hill, N.J.

A new source of power may be the long-sought key to the exploitation of millimeter waves. Limited space charge accumulation (LSA) diodes promise to open the way to levels of power and frequency unattainable with any other active semiconductor device.

In the not-too-distant future, engineers should be able to use these diodes, energized by relatively low d-c voltages, to achieve:

- Watts of continuous millimeter-wave (30-300 Ghz) power with about 20% efficiency;
- Hundreds of kilowatts of pulsed microwave power.

The LSA diode performs well in the microwave range between 1 Ghz and 20 Ghz, but its prime contribution will probably come in the millimeter range, where it has a clear field; no currently available solid-state power source can do the job here,
Size advantage of the LSA oscillator is evident in this comparison of it with an air-cooled, low-power klystron and its power supply.

and vacuum tubes have many shortcomings.

The millimeter region, still almost unexplored territory, is attractive for the large bandwidth capabilities it can give communications systems. The small antenna needed makes millimeter systems a natural for communications between space vehicles and for high-resolution radar.

Vacuum tubes for this frequency range are expensive, have lifetimes of only a few thousand hours, and need high voltages. The LSA diode promises lower cost, longer life, and the ability to operate on the low d-c voltages normally available in airborne vehicles.

Transistors, avalanche diodes, and Gunn diodes are transit-time devices, and their theoretical limitations hold maximum power levels to about 1,000 watts at 1 Ghz and 0.1 watt at 100 Ghz.

But the realization of high power in the LSA mode demands the production of either high-quality n-type gallium arsenide or such other compound semiconductors as cadmium telluride and indium phosphide. The best results so far in the LSA mode have been achieved with a GaAs device designed primarily as a Gunn oscillator. The device—the first to operate continuously in this mode—consists of an epitaxially grown active layer sandwiched between two highly conductive layers acting as low-resistance contacts to the active material. It produced 20 milliwatts between 44 and 88 Ghz with 2% efficiency. Operation of this diode was recently extended to 160 Ghz using a half-wave stub as part of the diode's package, a structure developed by Robert R. Spiwak at Bell Labs.

Other researchers, notably W.K. Kennedy Jr. and L.F. Eastman of Cornell University, have also reported LSA-mode high power at lower frequencies in the microwave region. The Cornell scientists measured a peak pulse power of 33 watts at X band with efficiencies as high as 3.4%.

Two paths

A block of n-type gallium arsenide can be used to generate high-frequency power either as a Gunn diode or an LSA diode, but the latter mode of operation produces the higher frequency oscillations. The LSA mode isn't a transit-time phenomenon; it generates power because of a negative resistance effect in a resonant circuit. Operating frequency in the Gunn mode depends on the time needed for a space charge layer to drift across the device. In the LSA mode, it depends primarily on the associated resonant circuit.

The property of n-type GaAs that is basic to both devices is a negative conductivity at electric fields exceeding about 3,000 volts per centimeter. Gallium arsenide is a "two-valley" semiconductor, having two electron-conduction band valleys at two different energy levels. The lower energy level band is the normal conduction band; electrons here have high mobility. The upper energy level band is normally not occupied, but when electrons are excited into this band, they have much less mobility. When the voltage across the diode is turned on, electrons generally remain in the lower band

LSA diode must be biased on the negative resistance portion of its characteristic, but the r-f electric field must be high enough to swing below a critical voltage level for a fraction of each cycle to prevent space charge from building up. Interval t₁ should be greater than the domain relaxation time to allow the space charge to disappear, while interval t₂ should be less than the domain growth time.
and the diode acts as a positive-resistivity component. As the electric field is increased, however, electrons begin to pick up energy and some are excited into the lower-mobility band. As the field is boosted still further, the current begins to decrease as the effect of a greater number of slower-moving electrons in the upper energy band becomes dominant. The voltage at which this negative resistivity effect sets in is about 3,000 volts per centimeter.

Cadmium telluride and indium phosphide have also exhibited this negative resistance effect, and there probably are many other group III-V and II-VI semiconductors that can act in the same way, but gallium arsenide is the only material now available with sufficient purity to make successful devices consistently.

The magnitude of the negative resistance effect in any of these materials depends on the inter-valley energy gap and on temperature. At high temperatures, enough electrons are excited into the upper energy band to cause a material to act as a normal resistive device. Cooling, however, may permit materials with a small intervalley gap and a high-threshold electric field to generate power at frequencies in the far infrared range—above 1,000 Ghz.

Although the critical electric field intensity is high, the actual voltage applied is only in the 6-to-28-volt range when the active region of the device is only about 10 to 50 microns thick. Because no transit-time requirement is involved, an LSA diode can be much longer than a Gunn device and thus deliver much higher power at a given...
frequency; a Gunn diode has to be short to operate in the millimeter-wave range, and a larger voltage across it would cause avalanche breakdown. An analysis of the limitation on power imposed by the restriction that the length of the diode be inversely proportional to frequency, \( f \), shows the Gunn-effect maximum power to be proportional to \( f^{-2.5} \). The maximum power of other transit-time devices follows the same proportion.

**Gunn effect**

Gunn-effect oscillations stem from the behavior of space charge within the bulk semiconductor material. In normal ohmic material, space charge will decay exponentially with a time constant equal to the dielectric constant divided by the conductivity (the bulk counterpart to a resistance-capacitance time constant). When the conductivity is negative, however, space charge grows exponentially with time until, if unchecked, a narrow high-field domain forms. Inside the high-field domain, the critical field level of 3,000 volts per centimeter is exceeded and the region maintains its negative conductivity. The field outside the domain drops below the critical value, so this region—most of the diode—has a positive conductivity.

The high-field domain therefore destroys most of the negative conductance that might appear at the diode terminals. This domain isn’t stationary, though; it drifts across the diode. As it disappears at the anode, another high-field domain forms at the cathode and begins its movement through the semiconductor. A cyclic current modulation is thus produced at microwave frequencies.

**Harnessing millimeter waves**

When LSA diodes become commercially available, their principal job will be to give millimeter-wave systems the same high reliability now associated with solid state systems in use at lower frequencies. One can only speculate on the new communications systems and scientific instruments that will spring from the use of these diodes.

Millimeter-wave communications systems will have a larger bandwidth than present microwave setups, and, therefore, a much larger information capacity. A little-appreciated fact is that because of the limited capacity of today’s base-band video circuitry, as much information as can currently be put on a laser beam can be put on a millimeter-wave carrier.

A 50-GHz carrier wave with 1-GHz bandwidth could carry about 100,000 voice communication channels or 100 television programs. Because of high attenuation in heavy rainstorms, however, long-range millimeter-wave surface communications signals will probably travel through buried waveguide rather than from tower to tower. An experimental guided-wave transmission system in this frequency range has been under study at Bell Telephone Laboratories for many years; LSA diodes recently made possible the first all-solid-state repeater for this system.

The use of millimeter waves can greatly increase the amount of communications carried by synchronous satellites. Since these satellites must be placed in a circle around the equator, and since those operating on the same frequency have to be far enough apart to prevent interference, there is a limit to the number that can use the same frequency (about 30). This means that the maximum number of satellite channels is roughly proportional to the available frequency range. The range of usable frequencies between 30 and 300 Ghz is more than 20 times as wide as the range below 30 Ghz. Also, frequencies above 30 Ghz are almost unused, whereas the lower frequencies are becoming saturated.

The rainfall attenuation problem in satellite communications can be solved by locating ground stations at distances from each other that make it improbable that they would all experience heavy rainfall at the same time.

Among the many other possible uses for the millimeter-wave region are:

- Spectrometers. Many solids, liquids, and gases exhibit high absorption at specific characteristic frequencies in the millimeter-wave region.
- Compact and inexpensive low-power radar systems for industrial applications and automotive traffic control.
- Point-to-point communications and high-resolution radar in the vacuum of interplanetary space.
The growth and decay of the space charge takes a finite time that is inversely proportional to the doping, or carrier density. Fortunately, the decay time when the electrical field is below 3,000 volts per centimeter is much shorter than the growth time when the field is well above that level. Thus, by swinging the field below the critical level for a small portion of the cycle, the space charge accumulated during operation on the negative resistance portion of the curve can be made to decay before the field again exceeds the critical level, causing space charge to build again.

Therefore, space-charge buildup can be prevented by biasing the diode at 5,000 volts per centimeter or more, and using a lightly loaded resonant circuit to swing the electric field well below the 3,000-volt-per-centimeter level for a fraction of each cycle.

The criterion for LSA mode operation is that the ratio of diode carrier concentration to operating frequency, \( n/f \), be in the range of \( 2 \times 10^4 \) to \( 2 \times 10^6 \), with an optimum value of about \( 6 \times 10^4 \). To operate at 100 Ghz, for instance, diode doping should be about \( 6 \times 10^{15} \) cm\(^{-3}\). This narrow range of permissible doping levels and frequencies stems from the need to prevent the negative resistance effect from causing Gunn-mode oscillations.

Operation in the LSA mode requires that the resonant circuit be lightly loaded at first so oscillations can start. The starting push can come from the harmonic energy of the lower-frequency Gunn oscillations, or from the negative resistance of the diode when a Gunn domain is present. If the ratio of doping to frequency is in the proper range, Gunn domains can't form when the r-f amplitude is large enough to swing the voltage below the critical level during part of each cycle, and the carriers in the material can contribute directly to the conversion of d-c to r-f power.

Once LSA oscillation has started, the resonant circuit load and the output power and efficiency can be increased appreciably. A transmission line between the resonant circuit and the load can provide an automatic loading delay. Initially, the load across the diode is equal to the characteristic impedance of the transmission line. Only after the signal has traveled to the load and back to the resonant circuit does the diode see the steady-state load—the load resistance transformed by the length of mismatched transmission line.

**Circuitry**

In the actual waveguide circuit used for the LSA diode, the primary resonance is composed of the capacitance of the device and the inductance of a stub that is slightly less than a half-wavelength long at the LSA frequency, and half as wide as the waveguide. The coupling between the primary resonance and the waveguide can be varied by changing the angle between the stub and the bottom wall of the waveguide.

A waveguide short-circuit and an E-H tuner comprise the loading circuit, which is adjusted for maximum output; the short and E-H tuner are each about five wavelengths from the diode. The 9% efficiency obtained with 300-nanosecond pulses is quite good considering that the maximum theoretical efficiency for GaAs is 18.5%. A circuit in RG-99/U waveguide was used for operation to 94 Ghz.

The operating frequency is primarily determined by the length of the stub, and it can be varied over a 15% range by bending the stub up and down, about 0.2% by tuning the E-H tuner, or about 0.5% by inserting a dielectric near the free tip of
the stub. A 20% voltage change generally changes the frequency by about one part, in 1,000.

The structure of the diodes in this circuit is similar to that of the Gunn diodes used previously in the range of 6 Ghz to 20 Ghz. The LSA diodes are thermal-compression bonded—with the active layer down—to the top of a copper cylindrical mounting pellet that fits flush with the bottom surface of the waveguide. The diode is pressure-contacted from above by the bias pin, which also supports the stub. The doping level of the active region is typically from $6 \times 10^{13}$ to $10^{16}$ cm$^{-3}$, and thickness runs from 5 to 20 microns. Heating has blocked the continuous operation of devices thicker than 10 microns.

**Diode structure**

Although the best results have been obtained with a diode in which the proper conductivity active layer is sandwiched between two highly conductive layers, this design isn’t the optimum one for LSA operation. To achieve higher continuous power throughout the millimeter range, it will be necessary to make diodes that are thin in a dimension perpendicular to the current so that heat can be removed “sideways.”

The diode’s thickness is also determined by the variation of electric field across it when it’s placed in a resonant cavity. The device should be placed at the center of the cavity. The diode, in order to hold the electric field within 10% of its maximum value, should be 0.12 wavelengths thick. However, since the wavelength in the diode is only about a third of the free-space wavelength, the diode should be $\frac{1}{2}$ times 0.12, or 0.04 free-space wavelengths thick. The other two dimensions can be made relatively large for high-power operation.

This type of diode can be fabricated from n-type GaAs grown on a semi-insulating GaAs substrate. Semi-insulating material, however, is just becoming available, and it’s difficult to grow low-resistivity n-type GaAs on such a substrate because of problems with the diffusion of p-type impurities from the substrate into the n-type epitaxial layer. The first growing of high-quality material on semi-insulating substrates was done in England in 1966 at Standard Telecommunication Laboratories and at Plessey Co.

The generation of high-power pulses requires pieces of uniform GaAs much larger than have yet been produced. For example, a 150-kilowatt, 10-Ghz diode (10,000 volts, 50 amp d-c input) should be about 1 by 1 by 0.1 centimeter. Diodes of this size will probably be made from bulk-grown material where the crystals are grown from molten GaAs, or from solution-grown material formed from gallium and arsenide ions in solution. Until now, the largest bulk-grown diodes operated in the LSA mode have been about 0.1 by 0.1 by 0.02 centimeter.

For the next few years, system designers will have to choose between LSA, Gunn, and avalanche diodes if they want a solid-state source of 0.1 to 10 watts at frequencies between 5 and 30 Ghz. For higher powers and frequencies, the LSA diode shows particular promise.

The avalanche diode is in the most complete state of development. Avalanche devices producing 0.01 watt at 10 Ghz have been put on the market by Microwave Associates Inc. and Sylvania Electric Products Inc.

Gunn diodes also turning out 0.01 watt at 10 Ghz have been made available for experimental purposes by Mullard Ltd. of Britain. At Bell Telephone Laboratories, experimental avalanche diodes have produced more than 1 watt at 10 Ghz and Gunn diodes have produced 0.1 watt of continuous power at that frequency.

Other considerations in choosing diodes will be noise and bias voltage. The LSA diode seems to be the quietest and the avalanche diode the noisiest.

At 10 Ghz, an avalanche diode requires from 50 to 100 volts, and a Gunn diode about 100 volts—100 volts divided by the frequency in gigahertz. An LSA diode can be designed to operate at any voltage from 25 volts to above 500 volts. The length and area can be adjusted to keep the same volume of GaAs, and therefore the same power (voltage x current), to achieve different bias resistances (voltage/current) and r-f resistances (about 10 times bias resistance).

**Bibliography**


**The author**

John A. Copeland joined Bell Labs two years ago after receiving his doctoral degree in physics from Georgia Institute of Technology. He has since been engaged in research on bulk-effect devices, and was the first to predict the possibility of LSA oscillations.
Solid state

R-f breakdown phenomenon improves the voltage capability of a transistor

Operating a device beyond its alpha-cutoff frequency increases the dynamic breakdown limit; transient voltage capabilities can be raised to twice the static value, and the payoff is cheaper r-f amplifier circuitry.

By Peter Schiff
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Designers of transistorized radio-frequency amplifiers need not spend premium prices for devices with especially high breakdown ratings. Nor need they series-up two low-breakdown-rated devices, or turn to elaborate protective circuitry to accommodate high voltage peaks. All they need do is exploit a little-known phenomenon whereby a transistor’s breakdown limit improves as the operating frequency extends into the r-f region.

When the device is operated above its specified alpha-cutoff frequency, fα, its breakdown limit rises above its static or low-frequency value to a point where it can withstand transient peaks far above the data sheet breakdown rating, VCEO(SUS). Thus, engineers may select a relatively low-cost vhf/uhf transistor with a 60-volt breakdown and with correspondingly good current-handling capability, and see it perform as well as a more expensive r-f amplifier designed to withstand 120-volt transients.

High transient peaks common

The majority of today’s transistorized r-f amplifiers, covering 10-megahertz to 2-gigahertz applications, typically operate with supply voltages ranging from 12 volts (for mobile equipment) to 28 volts (in airborne applications). With frequency, pulse, and other forms of modulation, the peak collector excursions are typically at least twice the supply voltage. Peak voltages exceeding four times the supply voltage are sometimes encountered in high-level amplitude modulated systems, thus serving as a worst case example (High-level a-m refers to modulation of the output stage by variation of the effective supply voltage. In low-level a-m, modulation is effected by bias level changes at either the oscillator or buffer stages and usually produces less severe transients.).

Class B and C operation of an a-m amplifier presents more severe transient conditions than Class A operation. For example, peak collector excursions as great as 120 volts are conceivable with a 28-volt supply in either B or C operation. But the d-c collector-to-emitter breakdown rating, nominally equal to the low-frequency sustained breakdown voltage, VCEO(SUS), of a device suitable for such a system, need only be 60 volts. Such a transistor will easily withstand the 120-volt transients, providing that the operating frequency exceeds the cutoff value and circuit conditions permit a realization of the r-f phenomenon.

If a device with a higher breakdown—costing as much as 20% more—were selected instead, its peak current capabilities would be lower, because with higher resistivity (and the same geometry) the wattage ratings remain unchanged. Thus, if one were unwilling to sacrifice power capabilities, still another device—one with higher power ratings—would be required. This alternative would cost even more than the previous transistor. However, both devices would have a lower gain bandwidth product, fβ. Thus, dynamic range would be sacrificed. The remaining alternative, designing in protective

The author

Peter Schiff has been with the industrial power transistor applications department at RCA’s Electronic Components and Devices division for the past four years. He has worked on second-breakdown effects and safe-operating areas of power devices. His present concern is electronic ballasts.

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circuitry to reduce transient levels at the collector of the transistor, would require increased component expenditures and considerably more engineering time. It would also aggravate over-all space and power problems on the circuit board.

Taking advantage of the improved breakdown characteristic at r-f is virtually a must for the designer. The phenomenon itself is innate, related to the static characteristics and not induced at the expense of some other performance parameter.

**Cause: avalanche multiplication**

Under static conditions, the collector-to-base or avalanche breakdown of a transistor is the result of avalanche multiplication in its collector depletion layer. The charge carrier multiplication factor, M, is given by:

\[ M = \frac{1}{1 - \left( \frac{V_{CB}}{V_A} \right)^n} \]  

where \( V_A \) is the bulk-breakdown or punch-through voltage, and \( n \) the rate of multiplication (a constant with values ranging from 2.5 to 4 for most transistors).

In the open-base common-emitter mode, avalanche breakdown occurs at the collector-to-base junction and part of the emitter junction becomes forward biased. This results in infinite common-emitter current gain as the transistor snaps back into the sustaining mode. The prevailing gain, \( \beta \), a function of \( M \) and the common-base current transfer ratio \( \alpha \), is given by:

\[ \beta = \frac{\alpha M}{1 - \alpha M} \]  

Since the base-to-emitter drop is negligible, \( V_{CB} \) can be substituted for \( V_{CE} \) in equation 1 and the

\[ V_{CEO(sus)} = \frac{V_A}{\sqrt{\beta} + 1} \]  

This equation can be used to calculate the break-
down voltage behavior of a transistor as the effective $\beta$ is altered by the base bias conditions that prevail at higher frequencies.

The beta-frequency relationship of the transistor shown at the top of page 98 is such that for frequencies above cutoff, the log-log plot of beta versus frequency follows a straight line.

Therefore, for $f > f_{ce}$,

$$\beta(f) = \frac{f}{f}$$

Combining equations 3 and 4 produces:

$$V_{CEO(SUS)} = \frac{V_A}{\sqrt{f/f} + 1}$$

Equation 5 indicates an increase in the breakdown characteristic from the $V_{CEO(SUS)}$ value at $f_{ce}$ to a value approaching $V_A$ at $f = f$. To determine the breakdown values between these limits it is necessary to either calculate or measure the value of $n$. But other device conditions must be considered first. The improvement in breakdown isn't without circuit constraints, particularly in the base.

Although the base is open, the collector-to-base feedback capacitance, $C_{OB}$, is still connected to it. This impedance would tend to forward bias the base as the r-f collector voltage increases. To overcome this, a low impedance bypass must be created between base and emitter.

A second constraint involves the operating mode. The derivations of the equations describing the r-f breakdown phenomenon are based upon a static relationship. They are valid only if the device is in the sustaining mode—when the emitter is injecting carriers where the beta mechanism comes into play.

**Solving the measurement problem**

Using pulse techniques to measure the r-f breakdown voltage is unsatisfactory. Because of the difficulty in separating the $C_{OB}$ currents from routine leakage and in order to simplify current and voltage readout, a continuous sine wave is used for peak and average measurements. The simplicity of this approach is demonstrated by the circuitry for such a measuring setup, shown on page 98.

The transistor under test is placed in a common-emitter circuit where a series LC network shunts the $C_{OB}$ currents between base and emitter. A reverse-biasing potential to the base to prevent Class A oscillations is supplied by the r-f choke. The device is driven at the desired frequency at its collector. Because the signal rides on a d-c voltage component, the collector base is not forward biased. Measurement is achieved by sampling both the average collector current from the d-c bias supply and the peak collector voltage swing, seen in the waveform on page 98. Here the voltage swing, $V_{UB}$, is rectified and filtered.

For high-volume testing, it is desirable to build the completely automated test set shown above. It can perform the r-f breakdown test in 30 milliseconds. The appropriate amplitude value and d-c bias (maintained at 60% of the peak voltage
Threshold detectors measure $V_{CE}$ and read out breakdown. Lamp is programed for go, no-go device evaluation.

As base-to-emitter bias of the transistor increases, the breakdown voltage increases, because this bias limits $C_{EB}$ feedback that lowers breakdown.

Comparison shows increase of r-f breakdown over static value. Curve a-a is $V_{CE}$ vs. $V_{BE}$ for a base-to-emitter drop of 1.5 volts and a load of 50 ohms; b-b depicts a 100-ohm case (same $V_{BE}$); c-c is for 100 ohms and 0 bias; d-d is with no load and 0 bias. Curves for a 2N3375.

swing) are automatically controlled for any breakdown current between 10 and 500 milliamperes. Readout is provided by five level detectors that indicate breakdown voltages between 90 and 135 volts. A typical threshold detector and its associated circuitry is shown above. Other generators and breakdown plug-in modules can be substituted to accommodate various transistor types and a wide range of r-f frequencies.

Confirming breakdown behavior

The instrumentation has been used to test two representative uhf power transistor types, the overlay 2N3375 and 2N3632. Sampling of 20 devices of each type was done at two r-f levels, 10 Mhz and 100 Mhz. Plots of average collector current versus peak r-f breakdown voltage show that low-current low-frequency operation tends to display better breakdown characteristics than high-frequency operation. This may be attributed to the high $C_{BE}$ currents that forward bias the base-emitter junction at high frequencies.

As the transistor enters the sustaining mode of operation and clamps collector voltage excursions, the lower $\beta$ at higher frequencies is evinced by the ensuing higher breakdown voltages. When the base reverse-bias voltage is altered as at left center, the r-f breakdown voltage will change. A comparison between static and r-f measurements at 100 Mhz for 20 2N3375’s, shown at left, points out the higher breakdown capabilities at r-f. The graph also shows that the r-f breakdown locus closely follows the $V_{CEO}$ characteristic of a transistor.

Relating static, r-f modes

The relation between the transistor’s static characteristics and r-f breakdown can now be developed by solving for the value of n.
Examine the breakdown modes

Since r-f breakdown is a beta mechanism, it can be better understood by a study of the transistor equivalent circuit. The circuit shows how \( \beta \) decreases with increasing frequency. The key parameters are \( r_{bb'} \), the base-spreading resistance; \( C_{bb'} \), the emitter-base capacitance; \( C_{cb'} \), the collector-base capacitance. Completing the transistor model, \( V_{be} \) is the signal voltage, \( g_m \) the transconductance, and \( r_{bb'} \) the a-c resistance between the active base and emitter.

At high frequencies, above \( f_n \), the \( r_{bb'}-C_{bb'} \) network limits current and voltage swings and the magnitude of incremental base current at the b'-e junction. Base drive is further reduced by the negative feed-back action of \( C_{bb'} \). Conduction is also retarded by the base width, which is insufficient to permit full transistor action of the finite-speed carriers. A base voltage gradient is induced by lateral currents in the base, flowing through \( r_{bb'} \). In turn, this produces a pinch-out of emitter current to the emitter periphery. This pinch-out is enhanced by the \( r_{bb'}-C_{bb'} \) combination; subsequent current crowding at the periphery reduces current gain.

\[ V_{ce}(r-f) = \frac{V_A}{\sqrt{K\beta + 1}} \]  

Equation 3 reveals that the collector-to-emitter breakdown varies directly with the punch-through voltage, \( V_A \), and inversely with the \( n \)th root of beta. Referring to the static characteristics of the 2N3375 from the data sheet, \( V_{CEO(ESR)} \) is 55 volts at a collector current of 100 ma. The device has a beta of 37 and a \( V_A \) of 165 volts.

Substituting in equation 3 yields:

\[ 55 = \frac{165}{\sqrt{37 + 1}} \]

\[ (\log{37 + 1}) \cdot n = \log{(165/55)} \]

\[ n = 3.3 \]

For the general case, two factors—the \( \beta \) value and the resulting breakdown at a specific r-f condition—are needed because both the current distribution and operating mode differ from the static case. Therefore, the \( \beta \) term in equation 3 is now modified to \( K\beta \), where \( K \) is a constant that modifies \( \beta \) for r-f:

\[ V_{CEX(r-f)} = \frac{V_A}{\sqrt{K\beta + 1}} \]  

The value of \( K \) may now be calculated. At 10 Mhz, beta is 33 and \( V_{CEX(r-f)} \) is 138. Using equation 6, 138 = \( 165^{3.3} \sqrt{(33 + 1)} \)

\[ K = 2.4 \times 10^{-2} \]

With \( K \) known, any other r-f breakdown can be calculated merely by inserting the values of \( V_A \) and \( \beta \) for a specific frequency. For example, if at 100 Mhz \( \beta \) is 4.7, then equation 6 produces

\[ V_{CEX(r-f)} = \frac{165}{3.3 \sqrt{(2.4 \times 10^{-2})(4.7) + 1}} \]

\[ = 158 \text{ volts} \]

To verify the accuracy of this computation, the r-f breakdown measurement equipment on page 98 was used. At 100 Mhz, with a \( V_{be} \) bias of 2.0 volts and a collector current of 100 ma, a breakdown of 156 volts is measured. This compares favorably with the value derived with equation 6.

Thus, for both r-f device evaluation and selection and r-f circuit design, engineers may use equation 6 or construct the instrumentation described and measure performance directly.

Bibliography

Circuit design

Designer's casebook

Single transistor protects power supply from overload

By Szabolcs Walko
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Overload protection for a series regulator can be achieved with the addition of a single transistor. Usually, such protection requires a flip-flop or silicon controlled rectifier and another d-c supply.

When the input voltage is applied to the regulator, the charging current of capacitor C_1 increases the base current of transistor Q_1. This, in turn, causes Q_2 to conduct, and a voltage, V_o, appears at the output terminals.

The charging current of capacitor C_2 forward-biases protective transistor Q_3, driving it into saturation. In the steady state of the regulator, the R_3-R_4 potential divider maintains Q_5 in saturation. The R_2C_2 time constant is much greater than R_1C_1, so that V_o is unaffected. Diode D_1 is back-biased under steady-state conditions, preventing the R_1C_1 time constant from influencing regulator operation. Transistors Q_3 and Q_4 form a differential amplifier that senses output voltage variations and supplies regulating signals to the base of Q_1.

With increasing output current, the voltage across resistor R_3 increases. When the current reaches a predetermined maximum level (2 amperes), the voltage across R_3 cuts off Q_3 through resistor R_4, turning off the regulator. The regulator is reset by depressing switch S_1, which provides a discharge path for C_1 and C_2.

Turning on the regulator under short circuit conditions may result in excessive output current. To limit this peak current, the value of R_1 is selected so that the R_1C_1 time constant is less than the thermal time constant of the series tran-

Under steady-state conditions, transistor Q_2 is held in saturation by potential divider R_2-R_1. When output current increases beyond a maximum value, the drop across R_3 cuts off Q_3, turning off the regulator.
sistors. In addition, the value of \( R_1 \) is dependent on the unregulated input voltage waveform. A capacitator across the output improves stability.

By placing a diode in parallel with resistor \( R_4 \), the regulator can also have a current-limited output characteristic.

The circuit has good temperature stability. For example, in the \( Q_3-Q_4 \) differential amplifier, the two temperature-dependent base-emitter voltages compensate each other; the emitter follower, \( Q_4 \), eliminates the effects of temperature on \( Q_5 \)'s collector-emitter saturation voltage.

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**Current feedback enhances phototransistor sensitivity**

By R. Sivaswamy

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Although phototransistors usually convert a light input into an electrical output, it isn't commonly known that they can simultaneously provide current gain for an electrical input. In the feedback amplifier shown, each phototransistor provides the other with an electrical signal that is a function of the illumination on the phototransistors.

With transistors \( Q_1 \) and \( Q_2 \) connected in cascade, light-induced electrical signals from \( Q_1 \) are amplified by \( Q_2 \), added to \( Q_2 \)'s light-generated signals, and then fed back to the base of \( Q_1 \) for further amplification; the regenerative feedback continues with the current from the collectors of both transistors driving the current-actuated control circuit.

The current gain of the circuit for signals induced by a typical illumination is 20 with these OCP71 transistors. Without the feedback circuit and interconnection, the gain induced by the same illumination was about 4.

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**R-f signals actuate transmit-receive switch**

By Keith C. Morton

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Whenever an r-f signal at a predetermined frequency exceeds 1 volt, the transmit-receive switch protects a receiver's input stage by grounding the antenna's input terminals and terminating the antenna in its characteristic impedance. The protection circuit is energized solely by the input r-f signals at the desired frequency; this eliminates expensive coaxial relays and associated disabling circuits which usually link the transmitter keying circuit to the receiver in conventional circuits.

Input radio-frequency signals pass through capacitor \( C_1 \) to the tank circuit, \( L, C_2, \) and \( C_3 \), which is tuned to a desired disabling frequency—7.3 megahertz for circuit values shown in the diagram. Capacitors \( C_2 \) and \( C_3 \) form a voltage divider that supplies detecting diodes \( D_1 \) and \( D_2 \). When the transmitter is radiating, the diodes conduct and develop a negative bias on the base of \( Q_1 \), turning \( Q_1 \) on. With \( Q_1 \) conducting, \( Q_2 \) turns on and energizes the relay. When the relay switches, it grounds the receiver antenna input and terminates the transmission line in impedance \( R_1 \).

Capacitor \( C_4 \) maintains its charge for a few
Radio-frequency signals greater than 1 volt at the disabling frequency determined by \( L \), \( C_1 \), and \( C_2 \) activate the relay that grounds the receiver antenna input and terminates the antenna in its characteristic impedance.

Moments after the transistors cut off, preventing chatter by slowing the relay’s switching. When operating in the continuous-wave mode, \( C_1 \) should be selected to match the average operating speed and desired cut-in characteristics. For slower release times, a still larger capacitor may be used for \( C_1 \).

The circuit can be modified to operate at other r-f signal levels by changing the ratio of \( C_2 \) to \( C_3 \) and \( R_1 \) to the emitter resistor, 470 ohms. Resistor \( R_2 \) can be eliminated by increasing the emitter resistor to approximately 5 kilohms. In high temperature environments, however, \( R_2 \) should be retained or even reduced; this may reduce the circuit sensitivity, which must be compensated for by adjusting the values of both capacitors \( C_2 \) and \( C_3 \).

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100% amplitude modulation with two transistors

By Andre Pichard
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A simple circuit capable of 100% amplitude modulation can be built with two transistors. The first transistor separates the modulation signal into two signals that are 180° out of phase, to develop the supply voltage for the second transistor, which amplifies the carrier. Although the circuit was designed to modulate a 2-kilohertz subcarrier with a sub-audio signal, the circuit can be modified to operate at radio frequencies, as illustrated.

In the circuit, transistor \( Q_1 \) amplifies the modulation signals while providing isolation and 180° phase separation. The modulation signals appear intact at the emitter of \( Q_1 \), but show up 180° out of phase at the collector of \( Q_1 \) due to the normal inversion in an amplifier. Since the emitter and collector of transistors \( Q_1 \) and \( Q_2 \) are coupled,
the phase-separated modulation signals form the supply voltage for $Q_2$. The circuit differs from a differential amplifier as the load resistors of $Q_1$ and $Q_2$ are not connected to the same supply voltage.

The amplifier carrier signal has its amplitude directly modulated by the output voltages from $Q_1$—the amplified and phase-separated modulation signals; these signals determine the amount of current through $Q_2$ and hence the magnitude of the output voltage at load resistor $R_2$. The values of resistors $R_1$ and $R_2$ are made small with respect to $R_2$ so that transistor $Q_1$ becomes a low-impedance supply source.

Two diodes remove pulse-width limitation

By Arthur J. Metz
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With two extra diodes, a multivibrator attains high noise immunity and fast recovery time without limiting its output pulse width. Usually, noise immunity requires heavy biasing of the switching transistors, while a small timing capacitance is needed for fast recovery times. These factors limit the output pulse width, which is directly proportional to timing capacitance and inversely proportional to the output transistor’s base current.

With $D_1$ and $D_2$ added, the saturating bias current of Darlington combination $Q_3$ and $Q_4$ can be set for maximum noise immunity, independent of timing considerations. Except for the diodes, the multivibrator is of conventional design. Transistor $Q_2$ provides a low-impedance recharging path for timing capacitor $C_1$, resulting in a duty cycle of nearly 90%. Transistor $Q_3$ and its associated components form a variable current source.

When the circuit is in its stable state, $Q_3$ is off, and $Q_3$ and $Q_4$ conduct heavily. Base current $I_2$ is established by the combination of resistor $R_1$ and $D_1$,'s zener voltage. When the circuit is triggered, the voltage across $D_1$ and $D_2$ falls below the zener voltage. The high resistance of $D_1$ under this condition effectively removes the diode path from the circuit, and the output pulse width is determined by the values of $C_1$ and $I_2$. Diode $D_2$ maintains the high impedance of the diode branch as the voltage across it reverses near the end of the pulse. The voltage at the base of $Q_3$ must reach approximately 1.2 volts for regeneration.

When $Q_1$ conducts, the voltage across diodes $D_1$ and $D_2$ falls below the zener level, making the output pulse width proportional to $C_1/I_2$. 

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**Diagram:**

A circuit diagram showing the connection of transistors, diodes, and capacitors in the multivibrator circuit. The voltage levels and connections are labeled for clarity.
Circuit design

One transistor sweeps clean

Simple generator that produces linear sweeps can be transformed into a timing or control subsystem capable of producing pulses and complex signals by merely adding a few components and flip-flops.

By Sumner Weisman

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In pursuit of sweep linearity, the designer often uses Miller sweeps, bootstrap circuits, phantastrons and other configurations that employ feedback to obtain the desired waveform. Strangely enough, a circuit rarely chosen is the single-transistor constant-current sweep generator, which, with a minimum of components, provides an output that compares favorably with the more complex feedback-type generators.

Good linearity offers a means of precisely measuring time for synchronization, counting, or control purposes, and is often required in television, radar, pulse, and digital circuitry.

Add a garden-variety flip-flop and a few components to this remarkably versatile circuit and it is transformed into a useful timing or control subsystem. It will produce linear sweeps, digital pulses, or complex, digitally controlled signals.

With one extra transistor, a silicon controlled rectifier, and a potentiometer, the two basic circuits form a frequency divider that puts out jitter-free pulses whose rate can be adjusted. These basic circuits can also form a pulse generator in which the width of the output pulse can be adjusted. Add one more silicon controlled rectifier, and time-delay relays can be controlled precisely.

By substituting digital input signals for the scr and potentiometer, the sweep waveform as well as its timing can be controlled digitally. The slope of each sweep can be varied by increments. Add extra flip-flops and the waveforms will become complex signals suitable for control functions in many different kinds of systems.

Basic sweep circuit

The sweep generator, at the top left of page 107, is a common-base configuration with capacitor \( C_1 \) as the collector load. When the base of transistor \( Q_1 \) is grounded, the emitter end of resistor \( R_1 \) is at a negative potential, equal to \( Q_1 \)'s base-emitter drop. The other end of \( R_1 \) is returned to a more negative voltage, \(-V\). Since the base-emitter drop is small compared with the drop across \( R_1 \), emitter current is established by the values of \( R_1 \) and \(-V\).

The grounded base holding the emitter voltage constant results in a constant-current generator.

If the small base current is neglected, the collector current equals the emitter current. The constant collector current develops a voltage across \( C_1 \) that is given by:

\[
\Delta v = \frac{I}{C_1} \delta t
\]

where

- \( v \) = voltage across \( C_1 \) (+V maximum)
- \( I \) = collector current \( \approx \) emitter current \((-V/R_1)\)
- \( t \) = sweep time

Sweep action is controlled at the emitter of \( Q_1 \) by the voltage applied to diode \( D_1 \). To turn on the sweep, a negative voltage is applied, reverse-biasing \( D_1 \) and allowing a constant collector current to flow. To turn off the sweep, a positive voltage is applied to \( D_1 \), making the emitter of \( Q_1 \) more positive than its base, and stopping current flow.
Linear sweeps are generated by charging capacitor $C_1$ with constant current flowing through the transistor.

The sweep slope can be altered by changing $R_1$. For adjustment, $R_1$ is a slope-controlling potentiometer in series with a fixed resistor (typically 1,000 ohms) that protects the transistor from damage when the potentiometer is completely shorted.

Pulse generators

The simple frequency divider, shown below, based on the generator and flip-flop, fills the need for synchronous generation of pulses in pulse or digital systems. The output pulses are always in time coincidence with the input pulse train. Because many applications require synchronous pulses at different frequencies, one variable frequency generator may be used to replace several fixed frequency dividers.

With the values shown and a 1-microfarad sweep capacitor, the output frequency can be varied from 10 to 1,000 hertz. The input frequency may typically be 10 kilohertz. Input-to-output ratios of 1,000:1 can be achieved with variations of this circuit.

In contrast, monostable multivibrator-type dividers are limited to ratios of 10:1 or 20:1. Unlike the output of the new circuit, which remains jitter-free at the higher ratios, the output of multivibrators generally runs into jitter problems at ratios greater than 20:1. To obtain jitter-free pulses over a wide range of ratios, some designers turn to multistage counters. However, the number of stages becomes large when high ratios are needed. Unless the ratio is a power of 2, complex feedback paths may be needed.

The flip-flop that is used with the single-transistor generator has the conventional design shown above at the right. A positive trigger pulse applied to the set input changes its state from a binary 1 to 0. If a positive trigger is applied to the reset input, the state changes from 0 to 1.

Assume the flip-flop is in a 1 state, with the output at 10 volts. The emitter of $Q_1$ holds off the

Frequency divider generates pulses synchronized to the pulse train input. The sweep begins when the flip-flop switches from a 1 to a 0 state, and ends when it switches back to the 1 state.
Pulses of variable width are produced at the 0 output of the flip-flop. Sweep length, which is
controlled by R₁, determines the pulse width.

sweep at 10 volts and SCR₁ is not conducting.

One pulse of the input train is applied to the
set input of the flip-flop through the AND circuit
formed by diode D₂, resistor R₄, and diode D₁.
Now, the flip-flop switches to the 0 state, and
ground potential is applied to Q₁'s base. The volt-
age holding off the sweep is removed, initiating
the sweep's negative excursion. The cathode of
SCR₁ follows the negative sweep through forward-
bias diode D₃. Resistors R₂ and R₃ form a voltage
divider that holds the gate of SCR₁ approximately
2 volts above ground.

As the sweep continues, a point is reached where
the cathode of SCR₁ is more negative than its gate,
and SCR₁ conducts. The conduction rapidly dis-
charges the capacitor in the sweep generator, and
the sweep output returns to 10 volts. The large
positive pulse at the gate of SCR₁ resets the flip-flop
to a 1 state, turning off the sweep generator's tran-
sistor. Since the src current flows through the
sweep transistor, interruption of transistor current
turns off SCR₁. The cycle begins again with the next
pulse of the train input.

The output is taken from the 0 side of the flip-
flop, and is synchronous with the input pulse.
Adjustment of potentiometer R₁ changes the sweep
slope to obtain the desired output pulse repetition
frequency (R₁ is part of the sweep generator cir-
cuit).

Changeable pulse width

The same basic components form a variable-
width pulse generator, shown above. Every input
trigger to the flip-flop generates a pulse whose

Turn-on time of relay is controlled by the length of the generated sweep. At the end of the sweep,
the flip-flop switches to the 1 state and SCR₁ conducts.
Digitally controlled outputs are generated when digital signals are applied to the sweep generator and the flip-flop. Sweep slopes can be changed to form complex control and timing signals.

width is controlled by the length of the sweep. The pulse width is a linear function of the control current—a function that’s not available in a monostable multivibrator. With a calibrated, multi-turn linear potentiometer, R1, as the control, very high resolution and linearity are obtained. The values shown, together with a 1-microfarad capacitor in the sweep generator circuit, allow pulse width to be linearly controlled from 1 to 100 milliseconds.

With the addition of SCR2 and its associated components, the pulse generator can accurately control the turn-on time of a time-delay relay. The circuit at the bottom of page 108 offers both linear control of the delay and repeatability—characteristics that aren’t available from either a resistor-capacitor network or a thermal time-delay circuit.

The total turn-on time is the sum of the adjustable sweep time and the fixed turn-on time of the relay used. With the values shown and a 50-microfarad sweep capacitor, the relay delay can be varied from 50 milliseconds to 5 seconds, plus the fixed relay turn-on time.

**Digitally controlled sweep**

The versatility of the sweep generator and flip-flop combination is again demonstrated when provision is made for digital control of the sweep output. Digital signals can reset the sweep, turn it off at any level, or change its slope. In the configuration displayed above, the application of a 1 (positive level) to any of the four inputs actuates that input.

A 1 at the sweep reset input is amplified by transistor Q1 and the sweep capacitor is discharged. A 1 at the sweep off input stops current flow in the sweep transistor, terminating the sweep at any desired d-c level. Sweep slope is determined by the resistance in the sweep transistor’s emitter circuit. With a 1 applied to the fast sweep input, the flip-flop is switched to a 0 state. This results in R2 being connected in parallel with R1, which increases the sweep slope by drawing more sweep transistor current. For slow sweep, a 1 is applied at the slow sweep input, and the flip-flop is reset to the 1 state, eliminating R2 from the circuit. Since the output is taken directly from the sweep capacitor, the load impedance should be high to preserve sweep linearity. A Darlington or field effect transistor amplifier, or an operational amplifier would satisfy the high-impedance requirement.

With a 1-microfarad sweep capacitor and the values shown, a slow sweep of 10 milliseconds and a fast sweep of 1 millisecond are obtained.

A series of typical digitally controlled sweeps are shown. With the addition of other flip-flops and more resistors in parallel with R1, greater variations in slope can be selected. The circuit can then be used to digitally simulate a wider variety of functions.

The sweep generator and flip-flop have been employed successfully in other configurations. One use was as a peak detector for low-duty-cycle pulse trains, where the sweep was turned off when its d-c level was equal to the pulse train peaks. The level was then measured by a digital voltmeter. This circuit performed better than a conventional capacitor peak detector, which is limited at low duty cycles because the capacitor won’t hold its charge between input pulses. Another use for the combination was in automatic band sweeping of a communications receiver. A slow linear sweep controlled the bias of a voltage-variable capacitor that controlled receiver frequency. Thus, both rate and range of frequency were easily variable.
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Electronics | June 12, 1967
A logical next step for read-only memories

One of the radical changes in computer concepts made possible by large-scale integration is the use of the memories to generate Boolean logic; with feedback, they can handle sequential operations

By John L. Nichols

Fairchild Semiconductor Division, Fairchild Camera & Instrument Corp., Mountain View, Calif.

Large-scale integration—the fabrication of hundreds or thousands of components in a single-chip silicon circuit—extends the applications of the read-only memory by making the cost of active devices inconsequential. One such extension—a major one—is the use of the memory as a Boolean logic generator.

In its conventional role in a computer, the read-only memory stores subroutines that calculate roots, powers, and logarithms, for example. These are faster than subroutines in core storage, and cheaper than wired-in routines. The memories can also convert codes—Teletype to Flexowriter, for instance. The incoming code word is the memory address, and the address produces the corresponding output code word.

In experiments with read-only memories in their new role, each bit stored corresponds to the product of several logic variables—what logic designers call a minterm. The 1's in the memory indicate the presence of a minterm, and 0's its absence. Thus, the address 1010 would be interpreted as a minterm AB'CD', and in the word stored in location 1010, the 1's correspond to functions containing that minterm and the 0's to functions that don't.

Output is the same as it is in the memory's conventional applications except that here it's used as a logic expression rather than as a sequence control or instruction. Furthermore, by connecting the outputs back to the address inputs, the memory can be made into a sequential logic device—one whose output at any moment depends upon its past history as well as its immediate inputs.

This approach can result in improved performance and easier fabrication. Fast memories can manipulate logic at greater speeds than can conventional logic circuits. And the read-only memory is made with a much simpler mask layout than the one used to produce the flip-flops and gates of present logic configurations. Also, the memory can be tested before establishment of the internal connections that define the sequence of operations.

Sum of minterms

Any logic function can be represented in Boolean algebra as a sum of minterms. For example:

\[ R = \overline{J}K'L'M + \overline{J}K'LM' + JK'L'M + JK'L'M' + JKL'M + JKL'M' + JKL'M + JKL'M' + JKL'M + JKLM' + JKLM' + JKLM + JKLM' + JKLM' + JKLM + JKLM' + JKLM' + JKLM + JKLM' + JKLM' + JKLM' + JKLM' + JKLM' + JKLM' + JKLM' + JKLM' + JKLM' + JKLM' + JKLM' + JKLM' \]

Standard techniques of Boolean algebra can reduce this redundant expression to the minimized form:

\[ R = JK + K'L + J'L'M. \]

Classic logic design demands this reduction to minimize the number of relay points or transistors. With the advent of large-scale integration, however, logic designers often find it convenient to work directly with a sum of minterms.

Suppose the function \( R \) is stored in a read-only memory that contains 16 words and that therefore
Feedback connections from output to input (color) enable read-only memory to perform sequential logic operations.

Feedback connections from output to input (color) enable read-only memory to perform sequential logic operations.

requires four-bit addresses. An address corresponding to one of the 10 minterms in R will generate a 1 on the output line corresponding to R. Other output lines corresponding to other functions containing the same minterm will also show a 1; lines for functions of other minterms will carry a 0.

In addition, read-only memories with the proper electrical characteristics can provide complex sequential circuits by the routing of some of the output lines back to the address inputs, as shown above. A sequential circuit can be created in a conventional logic design by connecting several combinational circuits—circuits whose outputs depend only on their inputs—and introducing feedback. The electrical characteristics needed to make a sequential circuit out of a read-only memory include an output signal of sufficient amplitude and free of glitches—transients of short duration that can affect other logic circuits.

Feedback connections from output to input (color) enable read-only memory to perform sequential logic operations.

Feedback connections from output to input (color) enable read-only memory to perform sequential logic operations.

The operation of such a sequential circuit depends on the relation between the number of bits in the words of the memory and the number of bits in the address, which in general equals the logarithm, base 2, of the number of words in the memory. If the word length is less than the address length, the additional address bits can provide the conditions for the operation of the sequential circuits. If the word length is greater than the address length, the output bits that aren’t fed back to the input can provide additional outputs related to the various states of the sequential circuits.

Two-way counter

An example of a sequential circuit that can be based on a read-only memory is a dead-ending two-way counter. Such a device counts either up or down, depending on which of two inputs is pulsed, and counts only to a specific value in either direction, even if the corresponding input continues to pulse.

In the first step in designing the counter, the memory outputs are considered as arbitrary logic expressions that don’t feed back to the inputs. Feedback is necessary in any sequential circuit, but it will be considered in the second design step.

In a read-only memory containing 64 words of four bits each, the address must contain at least \( \log_2 64 = 6 \) bits. In the diagram above left, the address bits are labeled A,B,C,D,E,F; the output bits are J,K,L,M. When all the address bits are 0, all the output bits are also 0; this combination is one of the 64 stored words. If address bit A becomes 1, the output from the word corresponding to address 100000 might be 0010. Likewise, for

Feedback connections from output to input (color) enable read-only memory to perform sequential logic operations.

Feedback connections from output to input (color) enable read-only memory to perform sequential logic operations.

Flow chart shows contents of read-only memory connected to operate as a two-way dead-ending counter. The colored arrows show some of the steps in the counting sequence.

Free-running counter results when words in last column of the memory are chosen so that every location addresses the adjacent location.

Feedback connections from output to input (color) enable read-only memory to perform sequential logic operations.

Feedback connections from output to input (color) enable read-only memory to perform sequential logic operations.
the address 011001, the output might be 1001.

Thus, an address can generate a binary number that can be interpreted as an expression in Boolean algebra. The output can also be interpreted as a signal for routing data through a computer, or as an instruction in a subroutine.

Feedback connection

The dead-ending two-way counter is completed when feedback is provided by connecting the output lines to some of the input lines. For this example, output line J is connected to address input C, and K is connected to D, L to E, and M to F, as shown in color in the diagram. Address lines A and B are controlled externally, as before. As long as both A and B are 0's, the output of the memory is 0, and the remaining four address bits are therefore also 0. But, as before, if address bit A is made 1, the output becomes 0010, and feedback suddenly changes the address from 100000 to 100010. If the word in this location is also 0010, the output will remain stable.

If A and B are both 0 and the remaining address inputs are 1100, the memory location selected contains 1100. This output is fed back to the address inputs and maintains the selection of its own location. Now if B becomes 1, another location, containing 0100, is selected. The address becomes 010100 and selects a third location, which also contains 0100. The output feeds back to the input and maintains the selection of its own location. The locations that maintain themselves through the feedback to the address inputs are referred to as stable, the others as unstable.

The sequence of states taken by the memory depends on the way the outputs feed back to the inputs, and on the data stored in the memory. The table at far left is an example of what logic designers call a flow chart. It shows what the contents would be of all 64 words of the memory, which is connected in this example to create a dead-ending two-way counter. If the initial address is 000000, of which the last four bits are fed back from the output, and if address bit A is alternately set to 1 and to 0, the output states will advance, or count, through seven states until 1001 is reached. Further alternation of address bit A will cause no further changes. But if address bit B is alternated, the output states will count back to 0000 and then stop.

The table uses the standard logic-design convention of circled entries representing stable states of the sequential circuits. Whenever an address applied to the input causes the circuit to enter an unstable state, the feedback lines change the address to cause the circuit to go to another stable state, where it awaits a new input change.

In the design shown in the table, all address bits are initially 0 and all output bits are 0. As described earlier, the output becomes 0010 if address bit A becomes 1; this forces the address to 100010, for which the output is 0010—a stable state. When A returns to 0, the address becomes 000010, for which the output is 0011; this forces the address to 000011, another stable state. As A continues to alternate between 0 and 1, the sequential circuit continues to step through stable states. The colored arrows at the top of the flow chart indicate the pattern followed. In the second row from the bottom, alternating input A causes the circuit to oscillate between the same pair of stable states; it dead-ends. The complete sequence of stable states is shown in the diagram above.

Likewise, as address bit B alternates, the sequential circuit steps through stable states that culminate in output 0000. Colored arrows at the bottom of the flow chart indicate the beginning of this sequence; in the first row they show how the sequence dead-ends. If the alternation of a single address bit stops during the progression and the other bit begins to alternate, the progression is reversed. If both A and B become 1 at the same time, the outputs go to 0000 and the sequence jumps back to the starting point, regardless of the circuit's prior state and regardless of which of the two bits returns to 0 first.

Variations

A slight change in the contents of the read-only memory can turn the circuit into a two-way modulo-8 counter. If the word in location 101001 were 0001 instead of the 1001 shown in the flow-chart, and the word in location 010000 were 1000 instead of 0000, both locations would be unstable. The circuit would retain its two-way operation but wouldn't dead-end. It would have eight stable states when both inputs were 0, and it would cycle indefinitely through all eight states. The rotation would go in one direction as one address bit was alternated, and in reverse order with the other bit.

A free-running counter is represented by the flow chart at right on the opposite page, which differs from the first flow-chart only in the last column. The chart represents a read-only memory with the same feedback connections as before, but with different data in the 16 words addressed 110000 through 111111. When both externally controlled address inputs are 1, the memory counts forward continuously at a speed determined by the circuit delays within the memory. It keeps going until one or both bits return to 0, at which point it stops at the nearest stable state.

Reference

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<table>
<thead>
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<th>TYPE</th>
<th>POWER</th>
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<td>2N1769</td>
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<td>TO-57</td>
</tr>
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</table>

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There must be an easier way to buy silicon power transistors.
A maser that works in radar by avoiding saturation

Frequency-shifting technique that uses an auxiliary coil to produce a magnetic field makes maser transmitter more attractive for applications in high-power radar

By Simpson B. Adler
Missile and Surface Radar Division, Radio Corp. of America, Moorestown, N.J.

Although masers—low-noise microwave amplifiers—could extend the range capabilities of high-power radars, they aren’t used frequently. The reason: high-energy radar pulses leaking into the receiver can either damage the maser or cause it to saturate, blocking the reception of return pulses. Once saturated, the receiver can be ineffective for some 2 to 6 milliseconds, blocking the detection of targets up to 400 miles away.

Shifting the maser’s frequency response while the radar pulse is transmitted overcomes the saturation problem and makes the maser considerably more attractive for applications in high-power radars. Interest in the amplifier, which operates on quantum-mechanical principles, is also increasing because of improved maser crystals and circuits. In addition, newly available superconducting magnets in small sizes can produce the large magnetic fields needed for maser operation, while reliable closed-cycle liquid helium cryogenic systems are available for the necessary cooling.

Magnetic pulsing

In the frequency-shifting technique, an auxiliary coil is pulsed to produce a magnetic field that adds to or subtracts from the maser’s main d-c magnetic field, causing a shift in the maser’s frequency response. Input signals at the transmitter frequency can’t couple to the maser during this period, thus a high degree of isolation is achieved, reducing the possibility of saturation. After the transmitted pulse ends, the auxiliary coil is deenergized and the maser can receive return pulses. The technique allows signals to be detected at ranges as close as from 3 to 5 miles.

In effect, the maser acts as an attenuator as in the oscilloscope pattern in the photo at the top of page 119. It is possible to get about 70 decibels of isolation in this manner. If, in addition, a low insertion loss isolator is included in the system, it is possible to attain 130-db isolation, enabling the maser to operate despite the presence of pulses with megawatt peak powers. A 60-db isolator having an insertion loss of about 0.5 db would degrade the system’s noise temperature by only 35° Kelvin. Practically, a radar employing a maser and the frequency-shifting technique could be designed to have a system noise temperature of less than 100°K, rather than the 1,500°K that presently exists in mixer type receivers or the 900°K that exists with parametric amplifiers.

In monopulse radars, requiring three receivers, three traveling-wave masers can be packaged in one unit to achieve the desired frequency and phase stability, and maintain equal gains among the various receivers.1 If the main d-c field is uniform, tuning can be accomplished with the main magnet. If not, separate trimmer coils may be needed to adjust the field for each channel.

The frequency-shifting technique also has possible applications in electronic countermeasure systems. When the maser’s response is shifted, the

The author
Simpson B. Adler, a physicist at RCA, has been involved in radar and ballistic missile programs, and studies of electromagnetic scattering. Holder of a doctorate degree from Temple University, he headed development of the AN/FPS-16 precision monopulse radar.

Electronics | June 12, 1967


**A short course in maser operation**

The maser referred to in the accompanying article is a solid state amplifier that finds wide use in satellite communications and radio astronomy. The reasons for interest in masers is their extremely low-noise operation. System-noise temperature — a measure of the noise power produced by amplifiers and transmission lines — can be less than 50° K compared to a few hundred degrees or thousands of degrees in systems employing conventional amplifiers as microwave frequencies.

In a solid state maser, radio frequency signals interact with a crystalline material that can absorb and release microwave energy. Energy pumped into the atomic structure of the crystal by a very high frequency source is released in such a way as to amplify a desired microwave signal that has a frequency lower than the pump source.

The crystal must be subjected to a high d-c magnetic field to produce paramagnetic energy levels — the so-called Zeeman levels. Maser operation depends on the transition of electrons (spins) between those energy levels. Energy is absorbed from the pump source when electrons are stimulated, or made to jump, from a low energy level to a higher level. In order for sufficient energy to be absorbed, the maser must operate at liquid helium temperatures. The energy for amplification is released when the stimulated electrons drop back to a lower level.

This process accounts for the acronym maser, standing for microwave amplification by stimulated emission of radiation.

Three energy levels for iron-doped rutile crystal, TiO₂, are in the diagram at the left. The difference between the energy levels determines the frequencies of operation. For example, at a specified magnetic field, the frequency of the emitted energy caused by electrons dropping from level 3 to level 2 is given by

$$ f_{32} = \frac{E_3 - E_2}{h} $$

where $f_{32}$ = frequency of the energy

$E_3$ = the energy of level 3 at the specified magnetic field

$E_2$ = the energy of level 2 at the specified magnetic field

$h$ = Planck's constant

The magnetic field is chosen so that $f_{32}$ is the frequency at which amplification is desired. The pump source, which supplies energy to the crystal, would be at a higher frequency $f_{13}$, given by

$$ f_{13} = \frac{E_1 - E_3}{h} $$

Without a pump source and with the crystal at thermal equilibrium, the number of electrons — the population — in each level decreases as the energy goes up. For example, the ratio of the population at level 3 to the population at level 2 is

$$ \frac{N_3}{N_2} = e^{-(E_3 - E_2)/(kT)} = e^{-f_{32}/kT} $$

Amplification occurs when electrons in energy level 3 drop back to energy level 2 (curves in color).

**Saturation and recovery**

Masers saturate because high energy pulses tend to equalize the difference in the number of electrons in the various energy levels needed to produce gains. In the maser discussed here, the population difference $n_3 - n_2$ between energy levels 2 and 3 approaches 0 [see "A short course in maser operation," above].

Saturation and recovery may be analyzed by first considering the rate-of-change of populations, given by

$$ \frac{d(n_j)}{dt} = - \left( \frac{\Delta n_{12}}{2 T_{12}} \right) \left( \frac{\Delta n_{23}}{2 T_{23}} \right) + \left( W_p \Delta n_{12} \right) $$

$$ \frac{d(n_i)}{dt} = - \left( \frac{\Delta n_{12}}{2 T_{12}} \right) \left( \frac{\Delta n_{13}}{2 T_{13}} \right) - \left( W_s \Delta n_{13} \right) $$

where

$$ \Delta n_{1i} = n_i - n_i $$

$N_i$ = instantaneous population of level $i$

$\Delta N_{ij}$ = $N_i - N_j$

$N_i$ = population of level $i$ at equilibrium

$T_{ij}$ = spin-lattice relaxation time between levels $i$ and $j$ — the time in which the normal relaxation process in the atom will destroy population inversion between two levels

$W_p$ = stimulated transition probability due to pump power

$W_s$ = stimulated transition probability due to signal power.

Although the $\Delta n_{ij}$ are interrelated by the rate...
Maser's population—the number of electrons in each energy level—has an exponential distribution (in color) when the crystal is at equilibrium.

\[ N_3 = \text{the population (number of atoms) in level 3 during equilibrium} \]
\[ N_2 = \text{the population in level 2} \]
\[ k = \text{Boltzmann's constant} \]
\[ T = \text{temperature in degrees K.} \]

The relative size of the populations are indicated by the graph directly above. Equation 3 also indicates the reason for cooling the maser. If \( f_{12} \) is in the microwave region and \( T \) is at room temperature, the ratio \( N_3/N_2 \) is almost unity, indicating small population difference. This is indicative of low gain. At a lower temperature, the population difference will increase and provide the basis for higher gain in the maser.

When the pump source is applied, it excites the atoms reducing the population in level 1 and increases the population in level 3. This process results in higher population in level 3 than in level 2, as in the bar graph above at the right. In this condition the populations are said to be inverted.

The power absorbed by the crystal is

\[ P_p = h f_{13} (W_{13} n_1 - W_{31} n_3) \quad (4) \]

Population inversion occurs after crystal is pumped by an external source. Thus the input signal can be amplified by the difference in levels 2 and 3.

\[ \Delta n_{32} = \left( \frac{Z}{2W_s + \frac{1}{T_{23}}} \right) + \left( \Delta n_{23} \right) \left( \frac{Z}{2W_s + \frac{1}{T_{23}}} \right) e^{-\left( \frac{2W_s + \frac{1}{T_{23}}} {W_s + \frac{1}{T_{23}}} \right) t} \quad (4) \]

where

\[ Z = -W_p \Delta N_{31} + \frac{\Delta N_{32}}{T_{23}} - \frac{\Delta n_{31} - \Delta N_{31}}{2T_{13}} + \]
\[ + \frac{\Delta n_{21} - \Delta N_{21}}{2T_{12}} \]

\( (\Delta n_{23})_0 \) is the initial condition at \( t = 0 \).

The power gain of the maser is proportional to \( \Delta n_{32} \). Because \( W_s \) in equation 4 is proportional to power, any large increase in signal power—a pulse leaking into the receiver—will cause an exponential decrease in \( \Delta n_{32} \), reducing the maser’s gain.

**Saturation**

The saturation time constant \( \tau_s \) in the exponential of equation 4 is

\[ \tau_s = \frac{1}{2W_s + \frac{1}{T_{23}}} \quad (5) \]

The larger \( W_s \), the shorter the time constant, and the faster the system saturates.

For high-level input signals, \( W_s >> T_{23} \), the maser saturates at a rate governed by the stimulated transition probability \( W_s \). For a given peak power, the wider the pulse the greater the saturation.

At small input levels, \( W_s << 1/T_{23} \), the response is determined by the spin-lattice relaxation time, usually greater than a few milliseconds. At typical radar pulse widths in the order of a few microseconds, the maser’s response to a low-level
Amplifier operating at 5,528 Mhz was used in tests that verified frequency shifting by magnetic pulsing. Crystal is placed within the superconducting magnet, thus establishing proper magnetic field for gain at microwave frequencies.

Auxiliary coil that shifts frequency is wound around maser structure so coil's field will add or subtract from the field produced by superconducting magnet. Two parallel coils form auxiliary coil.

Pulse is essentially constant over the duration of the pulse.

**Recovery**

To determine how the maser recovers from a pulse, the value of $W_s$ is set equal to 0. Thus

$$\Delta n_{\text{R}} = T_{23} Z + [ (\Delta n_{32})'_{0} - T_{23} Z ] e^{-T_{23}/T_{23}}$$  \hspace{1cm} (6)

where $\Delta n_{\text{R}}$ = population difference during recovery and $(\Delta n_{32})'_{0}$ is difference $n_3 - n_2$ at the instant the pulse is removed.

Since $(\Delta n_{32})'_{0}$ is always smaller than $T_{23}Z$, the equation is written

$$\Delta n_{\text{R}} = T_{23} Z - [ T_{23} Z - (\Delta n_{32})'_{0} ] e^{-T_{23}/T_{23}}$$

After the pulse is removed, the population difference increases exponentially to a finite positive value. The recovery time constant, $T_{R}$, is equal to the spin relaxation time, $T_{23}$, generally a few milliseconds.

A maser's saturation and recovery is indicated by the curves in the graph at the bottom of the next page. When the pulse is present, the population difference drops exponentially with the time constant, $T_{R}$. After the pulse is removed, the gain increases with the time constant, $T_{R}$, until it reaches the presaturation level.

Another way of showing the effects of saturation is a plot of peak output power as a function of peak input power for pulses of different widths. A graph plotting these effects for a maser with a 30-db gain at 5,600 megahertz is shown on page 120. The output power increases linearly until saturation starts. With the wider pulses, saturation begins at a lower input level. For radar pulses with widths up to
about 10 microseconds, the response is linear as long as the input level is less than —40 db referenced to a milliwatt.

**Preventing saturation**

To show that saturation could be prevented, laboratory tests were conducted with the traveling-wave maser in the top photo on the opposite page. The maser operates with a pump frequency of 60 gigahertz and amplifies signals at about 5.6 Ghz. A superconducting magnet used in the test produced a d-c magnetic field of about 2 kilogauss.

The iron-doped rutile crystal was placed along a meander line, a slow-wave circuit that increases the maser's gain per unit length and serves as the transmission line for the signal. The meander line-crystal unit was inserted within the superconducting magnet shown in the bottom photo on page 118.

Two parallel coils with about 10 turns produced frequency deviations of 25 Mhz in the maser's response. Since the maser's bandwidth, measured to the skirts of the frequency response curve, was 25 Mhz, the auxiliary coils were able to shift the maser almost completely out of the normal response band.

The shift occurs because the magnetic field produced by the auxiliary coil establishes a new set of energy levels within the crystal, affecting the maser's interaction with external signals. Under the shifted condition, the transmitter pulse can't interact with the crystal because the transmitter energy is decoupled from the crystal's electron spin system. When the auxiliary field is removed, the original energy levels are reestablished, allowing the maser to receive the radar pulses reflected from the target.

These effects can be demonstrated with an experimental apparatus. Two pulse generators—a transmitter pulse and a received signal pulse—are utilized. A transistor switch, actuated by a d-c pulse, allows current to pass through the auxiliary coils at the same time that a saturating transmit pulse is applied to the maser. The saturating transmitter pulse is delayed so that it arrives at the maser when the auxiliary field is maximum. This results in maximum isolation between the maser and the transmit pulse.

When the auxiliary coil is pulsed, it detunes the maser. The magnetic field around the auxiliary magnet increases, thus shifting the maser's frequency response. This results in the maser's power output dropping about 40 db—the gain of this maser. Exponential curves in the photos above are due to the coil's time constant.

The exponential decay in the top photo can last 100 microseconds. However, in a radar the decay period would be at the end of the receiver's listening period, merely reducing the maximum range by about 8 nautical miles. The radar's pulse-repetition rate could be adjusted to compensate for this.

After the auxiliary coil is deenergized, the maser returns to its full gain in about 35 microseconds—a delay corresponding to a minimum radar range.
Pulse width 0.5 microseconds

-4 -0.5 12 100 microseconds

-8 -12 -16 -20 -24 -28 -32 -36 -40 -44 -48 -52 -56 -60 -64 -68

Peak input power - dbm

Higher input-power levels and longer pulse widths increase maser's tendency to saturate as shown by leveling off of the curves. For reference, most radar pulses are less than 10 microseconds in width. When pulse compression techniques are utilized at the receiver, transmitted pulses are as wide as 30 microseconds.

of about 3 nautical miles. Again, the delay is due to the coil's time constant and is independent of the maser's longer spin-lattice relaxation time.

Receiving at the shift

While this pulsing scheme protects the receiver from saturation, it also allows the maser to respond to signals at the new frequency to which the auxiliary coil has shifted operation. Thus, the maser can be electronically tuned to receive signals at different frequencies on a pulse-to-pulse basis—a useful technique for electronic countermeasure systems such as frequency-jumping radars.

Changing the pump frequency isn't necessary in this process. The function of the pump is to produce a population inversion in the maser spin system. Once the inversion has been accomplished, it will last for a few milliseconds corresponding to the maser's spin-lattice relaxation time. Therefore, if the magnetic field changes within microseconds, the inversion is still effective and the maser can amplify signals at the new frequency.

This operation is shown in the lower scope trace on page 119. The resonant frequency of the maser in the absence of auxiliary pulsing is 5,528 MHz. If the maser's input frequency is decreased 23 MHz while the auxiliary pulse is present the input signal falls within the maser's new passband and the signal is amplified.

When the maser's frequency response is shifted, part of the incoming power is dissipated in the maser's cryogenic system and some stray power may affect low-level circuits. Isolation is therefore needed for protection.

As an example, consider a radar with a 1 megawatt peak power. Ordinarily, 130 dB of external isolation would be required to hold the power input to the maser below -40 dbm, the maser's saturation level. When the frequency-shifting technique is employed, the maser can supply 70 db of the needed isolation.

The major limitation is the amount of heat that must be dissipated in the liquid helium cooling system. Excessive power dissipation would require a larger cooling system and additional weight. With 60-db external isolation, the dissipated power would be limited to 1 watt. The full 130-db isolation prevents burning out the maser.

References

New *Linde* welding techniques solve most assembly problems.

**Laser Welding:** *Linde* LWM-1—industry’s first laser welder that makes precise reproducible welds on a production basis. Use it where the weld area may be smaller than a mil. The LWM-1 features low total heat input but high energy density. Since all this energy comes from the laser light beam, there is no physical contact with the work itself. All that is needed is a line of sight. The welder joins metals like copper, nickel, tantalum, stainless steel, molybdenum, titanium and others. It will join dissimilar metals of widely varying mass and thermal conductivity.

**Plasma Needle Arc Welding:** *Linde* PWM-4—the practical, economical way to make high quality fusion welds on thin metals and miniature components. Plasma needle arc welding uses a constricted arc jet which extends more than ½ inch beyond the torch nozzle. The needle-like arc is extremely stable and easy to use: melting action remains constant despite great changes in arc length. Current values can be set so that burn-through is impossible. The angle of the torch and the long arc permit an unobstructed view while welding.

Plasma needle arc welding eliminates electrode contact and corrosive fluxes in the weld area; and these, combined with inert gas shielding and the highly stable arc, produce high quality welds without the limitations imposed by other commonly used processes.

---

The *Linde* LWM-1 is easy to use. The 25:1 ratio micro-manipulator makes precise positioning a simple operation. The binocular viewer in combination with a turret arrangement of three objective lenses gives a continuous view of the weld area at 20, 40 and 100 power of magnification. A shutter protects the operator at the moment the weld is made. LWM-1 adapts readily to automated welding and digital tape controls.

Cross weld between 0.005-in. diameter tungsten and 0.020-in. diameter nickel wires.

LWM-1 plasma needle arc welder—a complete package, including power supply/control unit designed for bench mounting. Uses conventional power and water supplies. Foot switch provides on-off arc control; 10-ft. service line connects torch to control unit.

PWM-4 plasma needle arc torch.

Repair welding of hermetically sealed relay case, using *Linde* plasma needle arc torch.

For more information write *Union Carbide Corporation*, Linde Division, 270 Park Ave., New York, N.Y. 10017.
EIMAC's new line of miniature planar triodes is specifically designed for use in advanced airborne and space applications. They are rugged and reliable, and feature larger contact areas for improved electrical paths. EIMAC 8755, 8756, and 8757 triodes are miniaturized versions of the well-known 8533, 7815, and 7698 tubes. You're assured of excellent tube-to-tube uniformity because of our more than 20 years experience with planar triode design and manufacture. Cooling is by forced air or heat sink. All tubes have arc-resistant cathodes, and provide good high-frequency efficiency through S-band. Write Power Grid Tube Marketing for more details, or contact your nearest EIMAC distributor.

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<tr>
<th>TUBE TYPE</th>
<th>DESCRIPTION</th>
<th>CHARACTERISTICS</th>
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<td>Miniature, high voltage, high current, stable anode</td>
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<td>Miniature, high current, stable anode</td>
<td>3000</td>
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<tr>
<td>8757</td>
<td>Miniature, high current, stable anode</td>
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**TYPICAL OPERATION**

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<td>AMP OSC</td>
<td>65 25</td>
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</tbody>
</table>

EIMAC Division of Varian
San Carlos, California 94070

Circle 122 on reader service card

Circle 123 on reader service card
FACTS MAKE FEATURES:

1. Comprehensive overload protection.
2. One selector switch minimizes chance of incorrect settings.
3. Polarity reversing switch.

Additional protection is provided by Model 630-PLK's new transistorized relay circuit. Transistorized overload sensing device does not load circuit under test, eliminating the possibility of damaging circuit components. A special meter shorting feature on "off" position offers high damping when moving tester. The exclusive patented Bar Ring Movement provides self-shielding and is not affected by stray magnetic fields. Wider spread scales, and unbreakable clear plastic window assure maximum readability. Diode network across meter protects against instantaneous transient voltage.

TRIPLETT ELECTRICAL INSTRUMENT COMPANY, BLUFFTON, OHIO
We're honored! Not that we've won our crusade yet...just another battle ribbon. A while back we scored a military victory with our Model 880, the first solid state Mil Spec counter. This time it's a fully-militarized 5MHz all-silicon solid state universal counter-timer. Call it AN/USM-245, sir.

There's a good reason you should be interested. You see, the military model had its basic reliability well proved by our original commercial version, Model 607A. Now there's the one for you! It offers more features and capabilities than even the Admirals asked for. And it's available on-the-double.

Now hear this: Our lowest-bidder-type price is only $1,575. (Check that saving against our competitor.) Then check these features: Model 607A is ideal for wide-range frequency measurements, frequency ratio determination, period and multiple period or time interval measurements, and pulse count totalizing. Time base is a 1 MHz crystal oscillator (for 1 microsec resolution). Display is six decade inline with display storage. BCD output transfers directly to CMC Model 410 tape printer, computer systems, etc. Automatically positioned illuminated decimal. Either ac or dc coupling of input signal. Front and rear A and B channel inputs. Rugged, compact (approx. 3½" high). Available for bench or rack.

THANKS

With all our pride and excitement over our AN/USM-245 award, and other new products, we haven't forgotten our fellow Crusaders who've made this success possible...YOU. A FREE Crusading Engineers medal is our fun-loving way of saying thanks. Get yours by writing for data so you can "Check the Specs" of our 607A. Your "chief" will be so proud of you at mail call!

12981 Bradley/San Fernando, California
Phone (213) 367-2161 / TWX 910-496-1487
The fire fighter is rarely on the air for as long as 60 seconds and he is "otherwise occupied" for at least five minutes between calls. The same goes for most radio-dispatched vehicles.

PTTS* (Push-To-Talk-Service), with its duty cycle of ONE MINUTE ON and FOUR MINUTES OFF has been shown to be the most realistic, economical and practical rating system for vehicular communications systems.

For this reason, Amperex developed the 8637, the only twin tetrode ever designed and rated for PTTS. Featuring high thermal inertia anodes and incorporating a wealth of twin-tetrode manufacturing experience, the 8637 offers the designer a new approach in creating a better vehicular radio. Fewer, and less costly components may be used. Some typical operating conditions which bear this out are shown on the chart at right. Lower plate voltage, lower drive and higher efficiency at the VHF frequencies.

The 8637 is a "small tube", (only 3½" seated height), perfectly suited for today's low-profile designs. Its cost is lower than ICAS and CCS rated tube types of the same power.

For data, applications reports and engineering assistance, write: Amperex Electronic Corporation, Tube Division, Hicksville, L. I., N. Y. 11802.

Circle 125 on reader service card

111,331 radio-dispatched fire-engines and only one tetrode rated for PTTS*
If your work has anything to do with visual readout, there's something in this IEE Catalog for you. It contains the most complete, up-to-date information available on rear projection readouts. If you design, manufacture, market or use products requiring visual display, you should become familiar with current developments in rear projection display. It's in this catalog. The catalog explains the operating principles of rear projection readouts. It also describes the unique results you get with this product.

You will easily see why it is specified for applications requiring readability, appearance and versatility. One of these applications could be yours. In addition to specifications on the complete line of IEE projection readouts, the catalog includes information on displays, assemblies, accessories, lamps and prices. It's complete.

Ask us for a copy now.

The Rear Projection Readout: When one of the 12 lamps at the rear of the readout is lighted, it illuminates one of 12 film messages, focuses it through a lens system, and projects it onto the non-glare viewing screen at the front. The displayed message is clearly and distinctly projected on a single plane, with no obstruction from unlighted filaments. There is a wide viewing angle and a minimum of interference from ambient light. It is extremely versatile, since anything that can be put on film can be displayed on an IEE readout. That includes any combination of colors, symbols, numbers, letters and words. A total of five different models offering character sizes ranging from \( \frac{1}{8}'' \) to \( \frac{3}{8}'' \).

"I double-E," the world's largest manufacturer of rear projection readouts.

We're First in Thin Film Microwave Components

LEL can deliver them off-the-shelf. Just take a look at what LEL-LINE TF gives you: ultra small size . . . light weight . . . module interconnections (OSSM) . . . ceramic substrates for high temperature operations . . . over 37 standard module designs. How does LEL do it? It's the result of a complete in-house capability which makes for rapid delivery . . . uniformity of design permits low cost manufacture. If you're in any microwave endeavor involving sub-miniature systems, investigate LEL-LINE TF components. They measure 1 3/8" x 1 3/8" x 1 3/82" and weigh less than an ounce each. Now ready are: Balanced Mixers, (1-6 GHz) Quadrature Hybrids (1-4 GHz) and Magic-T Hybrids (2-6 GHz) reactive Power Dividers (1.5-6 GHz) and Directional Couplers (1.5-6 GHz). Naturally, they feature utmost economy and reliability . . . they're created by LEL.
for Instant Analog Systems

Burr-Brown Encapsulated Function Modules

Cut costs, simplify design, and achieve maximum performance from your analog and hybrid circuits by utilizing Burr-Brown encapsulated function modules. These compatible sub-systems are designed to mount and work side by side with operational amplifiers. You save money on component and assembly costs, design time is reduced to an absolute minimum, and you gain the performance advantage of Burr-Brown's specialized experience in analog applications.

Currently, Burr-Brown is supplying thirteen 10V, encapsulated function modules from stock. Each one provides the type of performance you'd expect from the company that "wrote the book" on operational amplifier applications. Available units include: □ Quarter Square Multiplier — Fast, E, = —E.E./10. □ Squaring Modules —


Rack Mounting Units — For your rack-mounting applications, Burr-Brown offers thirteen modules. These pre-engineered circuits are ready for you to plug in, wire together, and put to use immediately.

FOR COMPLETE INFORMATION on these maximum value units, contact your nearest Burr-Brown Engineering Representative and ask him for a copy of the new 16-page Burr-Brown catalog. He also has demonstrator units available for your immediate evaluation.
The way new uses for printed circuits are being found, it stands to reason that there should be enough different PC connectors available to insure that your application requirements are met squarely. Burndy gives you that choice.

In fact, we have more than 200 different PC connectors to choose from. And it's likely you'll find a connector that will meet the requirements of several projects. Individually, and as a group, the application potential is enormous. Call it choice . . . call it versatility. You're right on both counts.

This is part of what you have to choose from:

**Card Receptacles**
- Crimp removable contacts per MIL-C-21097/B .156" spacing. Non-specified types for .078" .100" and .156" spacing. (The flexibility and convenience of crimp removable contacts often indicate new applications.)
- Solder or weld termination in spacings down to .050".
- Solderless wrap termination on .150" and .200" spacing.

**Two-Piece Connectors**
- Crimp removable contacts on .100" and .150" centers meet the requirements of the most rugged environments. Round socket contacts support wires against severe vibration and shock.
- Solder dip types on .100" and .150" spacing. 11 sizes from 13 to 92 contacts conform to several NASA drawings and

**Signal Corps specifications**
SCL6250B (MIL-C-55302). Are they reliable? Today, Burndy PC connectors are being used in everything from business machines and computers to telemetry systems. They wouldn't be if they weren't exactly that . . . reliable.

If you're involved with printed circuitry you'll want a copy of our PC connector catalog. Write now for catalog PC.

**INTERNATIONAL SALES HEADQUARTERS AND MANUFACTURING FACILITIES:**
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**BURLNDY**
Norwalk, Connecticut
Chapter VI.

NICE TRY, GUYS

Man's first aerospace project, Babel I, utilized a straight-forward design concept: Travel into outer space would be effected by climbing a tower. However, it did not meet noise specifications, and the mission was aborted.

Now that Genisco offers a complete selection of power line filters and shielded enclosures you can avoid analogous difficulties.

Rated from 30 amps to 200 amps, 120 V to 250 V, single or three-phase power lines, the three series are designed for typical circuit breaker panelboards with or without requirements for power line filtering, and for use in shielded rooms and for installations requiring electrical distribution.

Although these power line filter assemblies meet MIL-F-15733, we do not recommend their use in towers extending beyond terrestrial limits. This application is not approved by The Chief Design Engineer.

Circle 308 Readers Service Card

DIDJA HEAR THE ONE ABOUT THE BI-PLANAR NAB 14" REELS?

Seems like there's this Model 10-276 magnetic tape recorder for aircraft, shipboard, or field portable use. Now, it has this low inertia capstan drive motor, and 6 speed selectable servo to eliminate belts, pulleys, and like that. And get this: no pinch rollers and solenoids to create flutter and skew! Well, these Genisco guys are making a mint on the thing, but they figure they'll come out with a Model 10-286 with 14" instead of 8.5" reels for customers who need longer record time! Then they go and stack the reels in a bi-planar configuration to save space. The funny thing is it works great. Not much of a story maybe, but they sure are nice tape recorders.

Circle 309 Readers Service Card

EARN BIG $$$$ AS A TELEMETRY PERSON !!!!

Now you can learn telemetry in the privacy of your own home! Take this free aptitude test NOW!

1. (T) (F) A telemetering checkout station is where you sign out for a telemetering.

Congratulations! You've just won our free correspondence course! Naturally you'll now want a Model A-180 or A-186 completely portable ground station. The A-180 completely de-multiplexes any standard FM/FM Signal. Ideal for checkout of airborne or sledborne applications. The A-186 has fourteen stunning channels. Its receiver is continuously tunable over the 215MC to 260MC band. So get on the road to success! Buy some of our telemetry stuff.

Circle 310 Readers Service Card

WHEEP! WHEEP! WHEEP!

As your missile speeds downrange you are secure in the knowledge that its electro-explosive device can be armed only by the precise signal you alone can send.

Or, horror of horrors, by an unfiltered random burst of identical frequency and duration.

As perspiration beads your brow you feel a sudden fondness for Genisco, renowned experts in RF hazard testing. How nice of them, you think, to have in stock or to design just the filters for the RFI and EMI protection my firing circuits need.

By golly, you conclude, next one of their ads I see I think I'll just

Circle 311 Readers Service Card

IT JUST KEEPS ROLLIN', KEEPS ON ROLLIN' AROUND.

Going round and round is our new Model 1147 rate-of-turn table's main trick. It keeps at it no matter how much you abuse it.

Hydrostatic bearings give precise dimensional stability, excellent alignment, low runout and eccentricity, low mechanical noise, and long happy life. It rotates smoothly at less than sidereal rates (0.004°/sec.). And it's just as smooth up to 1500°/sec. Which is why particularly brilliant (and handsome) engineers picked it as the AGE gyro test table for the F-111 Aircraft System.

Great for the lab or just to tote around de field.

Circle 312 Readers Service Card

GENISCO TECHNOLOGY CORPORATION
18435 SUSANA ROAD
COMPTON, CALIFORNIA 90221

130

Electronics | June 12, 1967
Control Switch announces

First and only pushbutton switches certifiable to MIL-S-8805
All 110 Versions of MIL-S-8805/3 – MS25089

- 7 mounting styles
- 5 circuit arrangements
- 2 button colors.
- 2 button styles.
- Momentary or push-pull actions.
- Temperature range: -55°C to 85°C.
- Life: 25,000 operations minimum at rated load.
- Shock: High Impact, momentary types. 50G, all types.
- Vibration: 10 to 500 cps.

This new Series may include the pushbutton switch you need right now for extreme dependability in military or other equipment. Or the switch that breaks a design block, or sparks a new design idea. The specifications speak for themselves!

Series W190 pushbutton switches are another in a spectacular series of firsts from Control Switch... source of the widest selection of high-reliability switches and indicator lights available anywhere. More firsts are coming. Soon! Order Series W190 from your Control Switch distributor, or direct from us.

DETAILED BULLETIN!
Check Number on Reader Service Card corresponding to number at left below for our Bulletin on new Series W190 pushbutton switches. While you're at it, get all the items listed below:

- #483 MIL-S-8805 Bulletin 64
- #484 Condensed Switch Catalog 100
- #485 Basic Snap-Action Switch Catalog 110
- #486 Toggle Catalog 160
- #487 Indicator Light Catalog 120
- #488 Hermetic Switch Catalog 130
- #489 Switchlite Catalog 220
- #490 Pushbutton Catalog 190
New CEC Accelerometers up to 30 times more resistant to base strain

Thanks to a unique application for CEC’s Ceramicite®, the compliant rod/mass assembly of CEC’s new 4-250 Series Accelerometers is virtually isolated from distortion of the base. This means that unwanted inputs from deformation of the accelerometer base are effectively eliminated. And—users are no longer plagued by temperature transients and acoustic loading.

As a result, CEC specifies a maximum base strain sensitivity guaranteed to 0.01 g/10⁻⁶ in/in. on each accelerometer.

The new series consists of four piezoelectric accelerometers—the 4-250, 4-251, 4-252 and 4-253. The extreme flexibility of these instruments is evidenced by the fact that only one is needed for a given measurement requirement: whereas before, multiple units were used for various environmental conditions.

Price and Prospects

In spite of their advantages, these piezoelectrics sell for less than competitive accelerometers. Reason: more efficient construction techniques—something you might expect from the world’s leading transducer manufacturer.

We predict that these units will soon be a “must” for aerospace, airlines and engine test stand applications.

The advent of the 4-250 Series Accelerometers provides the user with the ability to replace existing accelerometers and obtain much more accurate data. And the series also offers those interested in new vibration measurement applications the same advantages.

For complete information on CEC’s new piezoelectric line, call your nearest CEC Field Office. Or write Consolidated Electrodynamics, Pasadena, California 91109. A subsidiary of Bell & Howell. Bulletin Kit 326-XI.

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<td>22 mv/g nom.</td>
<td>20 pcm/g</td>
<td>500 Hz ±5%</td>
<td>2000 pk-g 2000 pk-g</td>
<td>3% max.</td>
<td>-100°F to +500°F</td>
<td>Charge ±8% max. O°F to +500°F</td>
<td>920 pf ±10%</td>
<td>32 grams</td>
<td>High charge output and flat charge vs. temperature sensitivity.</td>
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<td>3% max.</td>
<td>-320°F to +50°F</td>
<td>Voltage ±0% to ±5°F Typical</td>
<td>760 pf ±10%</td>
<td>32 grams</td>
<td>Flat voltage response over wide temperature range.</td>
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<td>8 pcm/g</td>
<td>5000 Hz ±5%</td>
<td>2000 pk-g 2000 pk-g</td>
<td>3% max.</td>
<td>-320°F to +300°F</td>
<td>Charge ±5% max.</td>
<td>640 pf ±10%</td>
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<td>1000 pk-g 1000 pk-g</td>
<td>3% max.</td>
<td>-320°F to +700°F</td>
<td>Charge or Voltage ±5% max. -320°F to +500°F</td>
<td>100 pf nom. 90 pf min.</td>
<td>35 grams</td>
<td>Flat charge or voltage response at cryogenic and very high temperatures.</td>
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1. With a 500 megohm load
2. When shunted with 750 pf capacitance
3. With a 500 megohm load and 100 pf capacitance
Our I.C. digital modules reject more noise than anybody's.

Integrated flip-flops, inverters and buffer amplifiers in T Series modules are made to our proprietary design and hermetically sealed in TO-5 cans.

Full-width copper ground plane sandwiched between epoxy-glass boards minimizes circuit inductances and discourages noise spikes. Mounting cases also have full-width shield planes to retard noise coupling between logic wiring.

The payoff.

T Series logic levels are 0 and +4 volts, and noise rejection is 1.5 volts minimum, leaving a maximum uncertainty band only one volt wide within which noise can trigger the circuit output. This uncertainty band of 25% is far narrower than those of other I.C. modules on the market.

T Series input and load resistors, made to much tighter tolerances than can be attained with integrated components, are mounted outside the integrated circuit containers, eliminating power dissipation problems.

Discrete input diodes enable us to place the switchin threshold right in the middle of the logic swing.
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Reception is loud and cool for subminiature antennas

While developers test new versions and compile additional data, critics question whether such integrated devices can make it in TV.

By Leonard Weller
Communications editor

and John Gosch
Electronics Bonn Bureau

When he announced his mighty mites this April and received national publicity, Turner said such SIA's could be built into TV sets, and would outperform antennas many times their size. Not too surprisingly, a number of antenna experts—particularly those in the business of vending TV apparatus—took vigorous exception to the headline claims made for SIA's. "We're convinced that the subminiature integrated antenna is of no value for television reception," says Henry Grunberg, chief electronics engineer at the Channel Master Corp., Ellenville, N.Y., a leading producer of outdoor TV antennas. "In our opinion, it wouldn't even perform as well as the ordinary rabbit-ear type of antennas, let alone replace outdoor rooftop antennas."

Some observers dismiss the SIA development as essentially a technique for increasing bandwidth. Others question the SIA's ability to deal with problems of signal-to-noise ratio, intermodulation distortion, and directivity.

In the eye of this storm are Turner and Hans Meinke of the Institute for High-Frequency Research at the Technical University, Munich. Turner is contract manager for the development of small integrated antennas for military applications at Wright-Patterson; most of the actual work on the new SIA is being done in Munich under Meinke's direction.

Solo flyer. Apparently, Turner released his claims about the tiny antennas' potential commercial applications on the basis of a report from Meinke—without consulting his colleague. Shortly after the announcement, TV-antenna manufac-
Short course on short antennas

A short antenna has a length of less than 1/8 of a wavelength at the frequency it is designed to receive. Such antennas act like a very large reactance—usually capacitive—in series with a very low radiation resistance. Radiation resistance, which accounts for the power received or radiated by the antenna, can't be measured with a d-c resistance meter but can be calculated from antenna dimensions or experimentally determined by measurements.

To get maximum power from the antenna it's necessary to match its impedance to that of the cable or receiver connected to it. The capacitive reactance has to be tuned out with a coil, and the usually low radiation resistance has to be raised to match the input resistance of the desired circuit. A great deal of the power can then be dissipated in the matching circuit, and efficiency declines.

For an antenna of a given length, efficiency and bandwidth are interrelated: the wider the bandwidth the lower the efficiency of the antenna.

In general, the smaller the antenna the lower the signal that can be picked up; thus the signal-to-noise ratio tends to go down as the antenna gets shorter. However, below 30 to 100 Mhz, atmospheric noise is so great that the signal-to-noise ratio is generally independent of the antenna-receiver combination. A smaller antenna still implies smaller received signal, but not necessarily a smaller signal-to-noise ratio.

According to Turner and Meinke, the controversy over subminiature integrated antennas provide a wide-band impedance match at the antenna terminals without the use of tuning coils or transformers. Their six units have two or three small rods or coaxial cables built around a transistor circuit. One or more of the rods picks up the signal as in a conventional antenna. However, the characteristics of the antenna, as viewed by the load, depend on the manner in which the transistor is connected to the circuit as well as whether the sections of the antenna are operating like a vertical antenna, a loop, or both.

Turner and Meinke have analyzed several versions of the six.

- turers in both the U.S. and Germany began a concerted debunking campaign.
- Meinke has also been under fire in Germany. To put the problems and potential of the antenna in perspective, he has prepared a special article and submitted it to the Association of German Engineers for publication.
- Meinke shrugs off criticism of the antenna, saying that most of it is perfectly valid at this time. He contends he would probably have made the same kind of comments if someone had talked to him about such a device at this stage of its development. He says his report is not a description of an immediately practical device but simply a compendium of his findings.

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SIA, which is supposed to have TV applications, can operate only over a 2-to-1 band, but produces a directive beam. It can be grouped in arrays to electronically rotate the beam.

II. Turn off

Although Turner says Meinkne has provided experimental evidence to back the claims made for these three SIA's, there is still considerable doubt as to whether the antennas in general and the TV unit in particular are ready for practical applications.

Harold Wheeler, an expert in the design of short antennas and president of Wheeler Laboratories, Inc., a subsidiary of the Hazeltine Corp., says: "Based on reports I've seen, a more objective evaluation is needed before we assume that the antenna is ready for useful applications in any frequency range."

Wheeler contends the transistor doesn't have to be integrated into the antenna at all. "You could get the same results with some type of active circuit at the output of the antenna," he says, citing the example of short antenna with wide bandwidth. In this case, a high resistance would be connected to the antenna to increase bandwidth — a procedure akin to adding a resistance to a tuned circuit to broaden response. Adding a transformer to the circuit matches the high resistance to the cable; finally, an amplifier is installed to compensate for the losses.

Out of focus. One of the faults of Meinkne's initial report, Wheeler says, was that it never made a comparison between the bandwidth performance of the SIA and that of a comparable passive antenna with an active network at the output. He also considers the report hazy: "I'm sorry that it wasn't presented in a simpler way so we could see what it (the SIA) can or can't do. At no time have they presented their basic ideas stripped of all confusions."

He feels there isn't enough information about the noise level of the transistor, and he questions how easy it would be to operate the antenna at higher frequencies. The tests reported by Meinkne were run at 2 to 32 Mhz. If used for TV, the antennas would have to operate from 54 to 174 Mhz for chan-

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nals 2 through 13 and from 470 to 890 MHz for channels 14 through 83. "Transistors aren't so good that you can take low-frequency behavior and scale to high frequencies," Wheeler declares.

### III. Put down

Donald D. King, director of the electronics research laboratory at the Aerospace Corp., considers the antenna an interesting but not major development—essentially an improvement in the use of what is available. He describes the SIA as an extension of the work Turner did earlier with Ohio State University's solid-state antenna in which amplifiers were combined with antennas [Electronics, Oct. 6, 1961, p. 68].

King believes the device's biggest problem is cross modulation. He doesn't believe a quantitative study has been made of how the SIA behaves in the high cross-modulation environment of television reception. "There's no simple way to filter it out with a device at the terminal itself," he asserts.

Turner says one answer to this difficulty is to use the omnidirectional-beam version of the SIA and reduce the bandwidth to the level needed to receive the signal. This version has a bandwidth of 10% to 20%, but it could be made narrower. It could then be electronically shifted to pick up signals at other frequencies.

**Aye votes.** There are observers who consider the antenna worthwhile, but they suggest that definitive tests be run. Raj Mittra, a professor of electrical engineering at the antenna laboratory of the University of Illinois, says: "The chief merit of the antenna seems to be the achievement of a match over a fairly wide bandwidth. I do feel that there should be more tests and evaluations made. The idea has potential and should be developed further."

Carlyle Slettten, chief of the electromagnetic radiation laboratory at the Air Force's Cambridge Research Laboratories, cautions that critical measurements haven't been made. The same kind of fanfare happened two or three years ago when the 'hula hoop' antenna [Electronics, Jan. 11, 1963, p. 44] was hailed as a panacea for antenna problems," he notes. "It was learned later that the device's efficiency was very low. Here, of course, there are compensating reactances. But still, the necessary measurements of efficiency and signal-to-noise ratios must be made."

However, Turner claims that the SIA's efficiency is high, arguing that the transistor raises the device's radiation resistance and thus prevents the resistance of the transistor and antenna leads from dissipating the bulk of the power. In a conventional antenna—one that doesn't have an amplifier—efficiency is the ratio of the radiation resistance to the sum of the radiation resistance and resistive losses. The higher the radiation resistance compared to the resistive losses, the higher the efficiency.

**Neat trick.** Turner alludes to high radiation resistance in a story in the May 19 issue of Time magazine in which he is quoted as saying: "We have in effect substituted a short antenna carrying a large current for a long antenna carrying a small current." A high radiation resistance often implies a higher current distribution.

Most sources agree that the transistor doesn't increase the SIA's efficiency. They characterize the transistor as an amplifier that boosts output signal level but not efficiency. Mittra says that there might be a slight increase in radiation resistance due to the transistor, but he attributes the big increase to the top-hat structure on the integrated antennas that have been built.

Lucio Vallese, a senior scientist at the ITT Federal Laboratories of the International Telephone & Telegraph Corp., says: "For a given antenna and a given ground plane, the losses are fixed. The transistor is only good for matching. As far as the efficiency is concerned, you don't gain anything."

Wheeler says, "You don't increase efficiency with an amplifier." Neither King nor Wheeler believe that radiation resistance is really defined for an antenna with a built-in transistor circuit. However, Wheeler's main point is that high radiation resistance is inherently good or bad: "It's where the power goes and the signal-to-noise ratio that is important."

### IV. Snow job

Television set manufacturers make much of the SIA's assumed problems with signal-to-noise ratios. They claim that with the tiny antenna described by Turner, the signal to the receiver would be very low. At the same time, the transistor would be adding noise—a situation that would lower the signal-to-noise ratio and produce "snow" on the picture.

In an interview in Munich, Meinke agrees that this is a problem. "If the antenna is made smaller, the received power is decreased while noise is added by the transistor. In principle then, miniaturization of the antennas is only possible for areas where high levels..."
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of field strength prevail.”

Backing off. Turner willingly concedes this point. He says that he never meant to imply that integrated antennas only 2 inches long would be used for tv. “There’s no percentage in making an antenna 2 inches long when you can use antenna, say, 18 inches long and improve the signal-to-noise ratio. You don’t make an antenna shorter than you have to. You make it big as the television cabinet permits.”

Tests on the 2-inch unit that got everyone excited in the first place have already been abandoned. “We ran a check at 400 Mhz,” says Turner, “but it was inconclusive one way or the other. I don’t even consider it a test.” Turner’s group is now working on 4-inch omnidirectional SIA’s at 30 to 150 Mhz.

Turner points out that in military applications there are many cases where only very small antennas are practical. Mounting such miniature assemblies on an aircraft could save many thousands of dollars in installation costs, he says. “The installation of conventional flush-mounted very high frequency antennas on a fighter aircraft can cost several thousand dollars—especially when structural members or fuel lines have to be rerouted.”

But signal-to-noise ratio isn’t the only problem involved in television reception. Antennas must be directive to avoid interference from other stations and to eliminate ghosts caused by reflections. The antenna on which Meinko reports has only limited directivity, definitely no more than simple yagis.

V. Put to the test

On the basis of this drawback alone many manufacturers have decided against the SIA. Robert Leitner, chief engineer of the Jerrold Corp.’s Technical Appliance Division, Sherburne, N.Y., says: “This device, I am sure, is limited for what we know is required for tv reception. It won’t meet the need in fringe areas from the standpoint of interference-free and snow-free operation.” Leitner also believes the SIA would be relatively useless as a replacement for rabbit ears.

The JFD Electronics Co. has actually tested the antenna at its research and development labora-

atory in Champaign, Ill. The company’s conclusion is that the very tiny antenna won’t do the job. According to one company representative, the work has been going on since before mid-April when the antenna began receiving widespread publicity.

Loop capability. Both Wheeler and King question the SIA’s ability to operate as a loop—a capacity essential for directivity. “Every antenna has some directivity accidentally,” Wheeler says. “The question is: is it a useful amount? In a small antenna, if you can’t change the pattern appreciably, you gain nothing. The cardioid pattern that Meinko is talking about represents only a 3-db change over an omnidirectional version.”

Wheeler also observes that the close spacings of the loop would produce a very low signal level in the receiver. Explaining the frequency dependence of this antenna, he says that the signal level depends on the width of the loop in wavelengths. For a given loop, the signal level drops off as the wavelength increases or as the frequency decreases. “The vertical arms should be one-sixth of a wavelength apart for optimum performance,” he says. This would provide a phase relationship in the arms that would produce maximum voltage difference across the transistor.

VI. What’s ahead

Applications for SIA’s in television aren’t the dead issue some contend they are, says Meinko. Tests were run on the television version SIA early this year at frequencies from 40 to 100 Mhz. The antenna was an eight-wavelength assembly with omnidirectional pattern. In a few months, Meinko says,
the directive-type antennas will be checked out. He concedes that results to date have been poor, but points out that it's difficult to develop a high-performance device after only a few months of experimentation.

"The best opportunities for success are probably in the areas of indoor antennas and portable equipment," Meinke says, explaining that neither field enjoys optimum performance and progress could be made quite easily.

**Nullifying echoes.** One possibility is to develop six's with null points patterned to eliminate echoes. The design would have a simple control that could electronically adjust the null at any time.

Meinke says his institute has just designed a device that combines the function of a transmitter and receiver in a single antenna structure. The assembly, an antenna 1/16-wavelength long coiled inside a plastic tube, employs one transistor for receive functions and another for transmit. A button on the handle just below the tube is used for switching. Meinke says two companies are already considering it for walkie-talkie radios.

For the present, six's will be used only in systems operating at frequencies between 10 and 20 Mhz. For all practical purposes, such devices can be no smaller than 1/16 of a wavelength, says Meinke.

**Happy warrior.** Turner takes a philosophical view of the controversy surrounding his work. "I've gone through this four times already where almost the entire scientific community took exception to the work we've been doing," he says. "It will take three or four years for people to accept it. I've won my battles so far and I think I'll win this. I discovered the spiral antenna around 1953, and had a violent argument about what it could do. But it didn't matter what people said, the data stood on its own. I am now in a crash program to get experimental data on what he [Meinke] has done."

The acerbic controversy surrounding six's is clear proof that the antenna establishment has been shaken by their debut. Vindication of Turner's and Meinke's claims would cost it dearly in dollars and prestige.

---

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Electronics | June 12, 1967
A tall, bearded student strolls out of the electronics laboratories at Stanford University's campus in Palo Alto, Calif., chats with several classmates, turns and heads for the men's dormitory. In his wash-and-wear trousers and sports shirt, he looks like any other American graduate student—except that he isn't. He is Ants Koort, a 36-year-old exchange student from the Soviet Union.

Softspoken and easygoing, Koort is also a good-will ambassador to the U.S. "There are big differences between the two countries," he says, "I don't see anything wrong with differences."

While he doesn't fit into any convenient stereotype—"I'm Estonian, not Russian"—Koort's presence on an American campus belies a number of misconceptions about the Soviet Union. For one thing, it indicates that Russians may enjoy more freedom than most Americans give them credit for having. Although Soviet citizens can't study abroad without state approval, Koort maintains that the selection of Stanford was his own. He chose the West Coast school after reading an article in Time magazine last summer that gave it high marks in electrical engineering. And he says he was given the widest possible latitude in regard to his academic pursuits. "The only recommendation I received before leaving the Soviet Union was to work. How I do it is my option," he says.

The latitude given him by his government may have been wide, but the subject matter he studied was, at least compared to American standards, narrow: statistically optimizing the reliability of ohmmeter and voltmeter circuits. Koort is considered a good student by his professors. His year in this country will be credited toward his technical science degree—equivalent to an American Ph.D.—at Tallinn Polytechnic Institute in Estonia.

Bruce B. Lusignan, Koort's faculty adviser at Stanford, says: "Specialized study in voltmeter reliability problems is a subject one level below that which is taught in the U.S. We teach students how to use them, but our students will have the same experience after two years in industry." He points out that while American universities have five basic engineering majors, Russian colleges have 140. However, U.S. schools do have 200 fields of concentration within this framework.

Koort's other special study at Stanford was comparative American education. "He's bucking for professor back there," Lusignan says.

Soviet vs. U.S. When he leaves for home later this month, he will take with him some opinions of American higher education, which he found somewhat lacking. "Soviet undergraduate departments are better because we are more specialized," he says. Unlike the U.S., freshmen in Russia are required to choose a major at once. "Early specialization is good," says Koorts. "It allows you to go deeper into your field."

After a Russian student completes his engineering program—usually a five-year curriculum—he generally goes on to graduate school where he is expected to publish several papers and take three or four exams designed to aid his research project.

Like most of his Soviet engineering colleagues Koort was dismayed by the number of students in the humanities. "Here, there is less emphasis on science and engineering," says the Russian. "In my country, young men prefer the engineering and scientific fields. In every university there are more students in science and mathematics than in the so-called 'social sciences' and humanities." Perhaps most startling to him is the fact that in the U.S. a great number of college students actually do prefer the humanities.

Freedom of choice. Admitting that the state places a newly graduated technocrat in a factory job for three years—"to repay the state for his tuition-free education"—Koort contends that rigid control over engineers has been relaxed. "They are free to change jobs and do so often," he says. But job-hopping Russian style isn't quite the same as in the U.S. Soviet engineers have one employer, the state, so the issue is purely academic.

Most Russian engineers are able to keep up with American technology. The large factories have libraries stocked with the latest Free World technical and popular periodicals—read and understood because Soviet engineering students are required to learn at least one Western language. At least in this respect, the Russians have a definite advantage over their free world counterparts.
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Lending a hand to the Pentagon

Nonprofit Institute for Defense Analyses furnishes technological and scientific services on strategic matters; Strat X report, due this summer, assesses U.S. missile posture into mid-1970's

By James Canan
Washington News Bureau

At the end of this summer, John S. Foster Jr., the Pentagon's director of defense research and engineering, will receive a classified document projecting the ballistic missile posture of the United States and that of its potential adversaries into the mid-1970's. Called Strat X, the report will culminate a nine-month study by the Institute for Defense Analyses (IDA), a systems-oriented, nonprofit consortium of 12 universities created 11 years ago as a Federal contract research center to furnish scientific and technological services beyond the reach of Department of Defense personnel. Similar IDA studies preceded development of the Polaris and Minuteman missile systems.

Among other matters, Strat X will recommend whether the missiles of the future should be based on railroad cars, in silos, on ships, or at other sites. The Pentagon may or may not accept IDA's conclusions completely, but the advice will certainly influence the military's final decisions on deploying the next generation of nuclear, intercontinental missiles.

Strat X illustrates the significance of the defense subjects handled by IDA. It does not, however, illuminate the scope of IDA's involvement in critical affairs over the years. An idea of IDA's wide-ranging mandate is apparent in the language of its contract with DoD, which specifies that the institute provide: "... personnel, facilities, and material required for surveys and analyses of the effectiveness of various weapons systems; evaluation of new equipment in the light of military requirements; evaluation and analyses of military problems to predict the operational behavior of new material and equipment; development of new tactical doctrines to meet changing military requirements; studies and reports on the technical aspects of strategic planning; and analysis of combat reports, tactical and strategic plans, and field exercises in both the continental U.S. and elsewhere, with a view to determining how existing weapons and weapons systems could be more effectively employed."

In view of its responsibilities, it is no surprise that IDA's work is highly classified. Security is tight at the modern 10-story building which IDA occupies in Arlington, Va. near the Pentagon. Visitors make every step under escort, and in such an environment, details on specific projects are hard to come by as is an assessment of their impact on the electronics industry.

However, that impact is tersely described by Norman L. Christeller, IDA's vice president and general manager, as "considerable."

I. Rocky road

It hasn't all been clear sailing for IDA. Last year, the House Defense Appropriations Subcommittee accused it of sloppy administrative practices and of being over generous with its funds, particularly in the area of employee salaries and fringe benefits. And one of IDA's five divisions has been embroiled with a Pentagon weapons group. Throughout its existence, IDA has been criticized along with the other "think tanks," like the Air Force's Rand Corp., by those who question the wisdom of having tax-exempt, nonprofit corporations use public funds on public-policy matters in a decidedly nonpublic atmosphere.

But IDA seems to have weathered the storms. A spokesman for the House subcommittee says that IDA's administrative deficiencies have been corrected under the direction of retired Army Gen. Maxwell D. Taylor. The value of IDA's studies keeps its other critics mollified.

Champion. Taylor, chairman of the Joint Chiefs of Staff and ambassador to South Vietnam before taking over as IDA's president last September, says he has "a deep feeling of the essentiality" of IDA and the other nonprofit groups which serve the military services.

"I felt it as a military man, watching the development of weapons systems over the years," he says. "I've seen our weapons arsenal grow in both quality and quantity. We've gone down a long and difficult road since World War II. What has happened shows that the work of the study groups—not just..."
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Sometimes we feel like we're five different companies. We often have that many telling us what to do and how to do it. Because we set up our customers' own departments right here in our plant. We run the departments for them, or let them come down and establish priorities and schedule production personally.

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...over the years, IDA has ranged into broadening areas of study...

IDA—has been fruitful.

In 11 years, IDA's staff has grown from about 50, including 30 scientists and engineers, to 637, including 320 professionals in the scientific and engineering disciplines as well as in systems analysis. There are 31 electronics and electrical engineers in this group. The institute also uses consultants from universities and industries, and the Strat X study provides a case in point.

Requisition. Officials at IDA told the Pentagon they would undertake the study if they could get a particularly qualified man like Fred Payne, the Marquardt Corp.'s vice president of corporate development, to take charge of organizing the project. Among other credentials, Payne was deputy director of defense research on strategic weapons from 1961 to 1965, so Strat X was right up his alley. The Pentagon went to bat for IDA and landed Payne, persuading Marquardt to give him a leave of absence.

But assembling the Strat X team posed another problem. The study required a thorough knowledge of missile design. The institute has staffers who are knowledgeable in the design of fuel and control subsystems, but no experts in over-all design. Consequently, IDA turned to industry, picking off 20 men to work with 20 of its own.

II. Pedigree

IDA traces its history to the weapons systems evaluation group (WSEG) at the Pentagon, which was formed in 1949 at the behest of James L. Forrestal, the first secretary of defense. The group had both military men and civil-servant scientists. Six years later, Defense Secretary Charles Wilson asked for organized university support to back up WSEG in weapons development. Five universities—the Massachusetts Institute of Technology; the California Institute of Technology; Stanford University; Case Institute; and Tulane University—promptly set up IDA with the idea that they could, through cross-fertilization, serve themselves along with the defense establishment.

During its first two years, IDA had only a weapons systems evalua-

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... communications research work is kept under tight security...

President's Commission on Law Enforcement and Administration of Criminal Justice on the use of science and technology in combating crime. If acted upon, its recommendations in this area should open up a substantial electronics market [Electronics, May 1, p. 105].

Meat-and-potatoes electronics studies undertaken by IDA include several by RSP, focusing on sonar technology and sonar signal processing, as well as on the potential of airborne low level television for night reconnaissance.

Of all IDA's divisions, communications research keeps the tightest lid on information. That its work is largely theoretical is indicated by the fact that nearly all of its 30 professionals are mathematicians.

IDA also had a hand in Defense Secretary Robert S. McNamara's decision to ask Congress for money for fast deployment logistic ships—a project designed to interest aerospace companies in building automated shipyards. To gather material for reports on that subject, IDA men visited automated shipyards in Sweden and Japan.

Last year, IDA set up the defense systems analysis educational program, in cooperation with the University of Maryland, to inform military officers and civilian officials of the knowledge being gained about analyzing defense problems.

III. New home

Two years ago, IDA moved from two locations in downtown Washington to a new building in Arlington, Va. The House subcommittee that probed IDA reported that it was paying $991,000 a year, on a 10-year lease, for its 190,000 square feet of space in the building. The property is valued by Arlington County for tax purposes at $7,342,780. It is owned by an organization called 400 Army-Navy Drive Associates, described as a group of local businessmen.

The House subcommittee wondered if the rental wasn't a little high. IDA countered by saying that it was less, per square foot, than the cost of quarters IDA had vacated downtown.

The subcommittee had much to say about such items as apparently inflated expense accounts and it noted, pointedly, that IDA, as a non-profit organization, was not required to pay taxes on income from Government contracts.

New deal. The upshot was that the Pentagon cut by 20% the level of management fees which it pays IDA for performance of negotiated contracts, in which fees (or profits) are predetermined.

In its first decade, IDA received $3.6 million in fees—a range of 5% to 6% of the total value of contracts. At the moment, it gets an average fee of only 4.5% on contracts valued at some $14.9 million.

Where the fee reduction hurts IDA most is in its inability to build up financial reserves to help maintain the backlog of personnel and flexibility of purpose that are the main reasons for its existence. Financial reserves are now growing at a significantly slower rate.

IDA and Pentagon officials contend that turning IDA's presidency over to Gen. Taylor was not related to the congressional investigation. Taylor succeeded J.P. Ruina, the only scientist ever to head the science-oriented institute. Ruina returned to MIT.

Before Ruina, Richard M. Bissell Jr., formerly deputy director of the Central Intelligence Agency, was IDA's chief executive. At IDA, Bissell brought to a head the long-smoldering antagonism between IDA's WSED and the Pentagon's WSEG over prerogatives.

For nearly two years, the two groups had been at odds over whether WSEG could shape the contents of reports which IDA's WSED prepared for it under Pentagon contract. The flag and general officers overseeing WSEG wanted to exert more influence than suited IDA's taste. Exactly what happened is a well-kept secret, but Bissell and the general in charge of WSEG left the scene at about the same time.

The issue seems to have been resolved in IDA's favor, and Taylor, when he took over, made it clear that he would not be a rubber stamp for the military. By all accounts, he has made this decision stick.
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The model 441 amplifier holds the average output to a dynamic range adjustable from 10 to 20 decibels. Inputs that can swing between -10 db and 80 db are brought into range by gain switching in 10-db steps. The manufacturer claims that's seven more steps than other automatic gain-switching amplifiers provide.

Combinations of the amplifiers can eliminate the task of manually controlling gain when many channels are operating in a system. Each amplifier monitors and displays its gain status. The operator can also manually control gain.

The output is fed back through a gain-control loop as shown in the block diagram so the control amplifier will boost or attenuate the input signal. Low-frequency roll-off is manually set between 1 hertz and 10 kHz; high-frequency roll-off is fixed at 100 kHz. The frequency response is therefore compatible with very low frequency acoustic and vibration test systems. The averaging detector's time constant can be set up to 30 seconds to handle the lowest frequencies.

If the output signal level is too low, a threshold trigger produces gain-incrementing command pulses that tell the control amplifier to raise the gain in 10-db steps. If the output signal level is too high, the gain-decrement trigger reverses the process. The process ceases when the output reaches an adjustable threshold level, typically between 0.25 and 1.0 volt rms, or when the -10- or 80-db gain limits are reached.

Gain switching may be controlled externally with a gain-change enable signal from a multiplexer or programmer. If enabling is sequential, up to 32 channels of gain-status information can be serially multiplexed on a single channel of an instrumentation tape recorder operating at d-c to 300 hz.

For manual adjustment, gain rises 10 db each time a toggle switch is pushed up; each time it is pushed down, gain falls 10 db. The gain-control logic continues operating automatically.

In either automatic or manual mode, gain status is monitored with solid state switches and panel lamps, and can be multiplexed with a standard nucl time code and recorded on one channel of magnetic tape. Or, it can be fed directly into analysis equipment.

Ithaco sells the model 441 for $960. A rack adapter for eight amplifiers costs $350. The amplifiers operate with line power and contain a 60- to 400- hz power supply that is fully shielded.

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Electronics | June 12, 1967
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Dial-an-airport computer

Pilots and navigators will soon be able to simply dial their destination on a digital differential analyzer—and leave the navigating to the computer. A wired-in program actuated by a punched card will enable the computer to utilize data from other navigation subsystems to guide the plane.

Made by Britain’s Marconi Co., the computer is designed to be a part of an avionics, air data analyzer or weapons fire-control system. In a navigation system, the computer—called the AD 670—would accept data from such inputs as very-high-frequency omnirange and distance—measuring equipment, doppler and inertial navigational aids, and altimeters.

A destination selector, at left in the photo, holds 12 cards on which the latitudes and longitudes of airports as well as flight data are represented by coded punched holes. The pilot dials the airport he wants by rotating the knob on the selector unit’s front panel. Contacts inside the unit engage the holes and flight orders are relayed to the computer. An optical system built into the selector projects the information onto the front panel so the pilot sees the orders the computer receives. The letters on the dial, A to M, correspond to a list on the panel that indicates the latitude and longitude of the aircraft’s destination and way points.

The computer has several outputs. One is used to drive the panel indicator, at right in photo, which continually displays either the aircraft’s position or its distance from the correct ground track. Other outputs drive cockpit displays that indicate wind velocity, heading, drift, ground speed, and time between direction changes.

The computer’s output can also be fed to an autopilot to guide the aircraft automatically. Another output is available for pictorial and tactical displays.

The complete AD 670 system consists of a computer, an analog-to-digital converter, control units, and displays. Because of the specialized design, the computer requires only 50% of the logic circuits and 18% of the memory capacity of a general-purpose machine. However, its arithmetic unit and ferrite memory are equal to those of most such machines. The memory has 1,536 15-bit words.

Power is provided internally for the computer’s logic circuits, read-write amplifiers, and ferrite memory. If external power fails, the internal power initiates an automatic shut-down procedure that enables the computer to complete its iteration cycle. Restarting can be achieved automatically or manually, because the memory isn’t destroyed. Built-in test equipment warns the pilot of computer failure. According to Marconi, production models of the AD 670 navigation system will be available next year. The Marconi Co., Essex, England [350]

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In Making Masks for Electronic Components... there’s no Margin for Error!

With sharp blade, outline the areas to be masked. Do not cut through the backing sheet. The Ulano Swivel Knife does the job quickly, easily.

Now carefully peel off the film as outlined leaving a completed photo mask, positive or negative, that corresponds exactly to the desired pattern.

THAT’S WHY EXPERIENCED DESIGNERS AND ENGINEERS ALWAYS INSIST ON...

THE KNIFE-CUT, LIGHT-SAFE MASKING FILM LAMINATED TO A STABLE POLYESTER BASE

The most versatile line of hand-cut masking films, including

.0075—RUBYLITH 75 DR* .005 RUBYLITH 5 DR
.005 AMBERLITH 5 DA

These new, thick Ulano films provide the positive answers where exact register assumes a critical importance.

*Available in sheets only, cut to your specifications.

In Europe: ULANO A. G., Untere Heslibachstrasse 22, Kusnacht 8700, Switzerland

Write on your letterhead for special electronic test kit (no charge) No. 4148
Bulova forks solve low frequency problems

Let the experience behind 300,000 forks per year help you!

American Time Products forks are now available up to 25 kc, thanks to years of experience plus new design techniques developed by Bulova. (Including the tiny forks for Accutron® electronic timepieces, Bulova made 300,000 last year alone!

Result: ATP units provide lower cost, smaller size, lighter weight and greater long term stability in such applications as Computers, Navigation Systems, Doppler Radar, Motor Drives, Encoders and Timers. Accuracies of up to 0.001% are available. Bulova fork oscillators offer the added advantage of simplicity of design and circuitry. Fewer components mean greater reliability. Finally, Bulova fork products are uniquely capable of withstanding severe shock and vibration environments.

No wonder Bulova sold 300,000 last year!

FS-11 FORK FREQUENCY STANDARD

Standard Frequencies: Up to 10,000 cps
Accuracy: Up to ±.001%
Input: 28V DC (others on request)
Output: 5 volts p-p min. into 10K ohms
Temperature Range: As low as −55°C to as high as +85°C
Size: 1½ in. sq. x ¾”

SUB-MINIATURE TF-500 TUNING FORK

Standard Frequencies: Up to 2400 cps
Accuracy: Up to ±.001% at 25°C
Input: 28V DC (others on request)
Output: Up to 5V rms into 20K ohms
Temperature Range: As low as −55°C to as high as +85°C
Size: ⅜” x ⅜” x ⅜” max.

Write or call for specifications on Bulova’s complete line of tuning fork products. Address: Dept. E-16.

New Components and Hardware

Transistorized indicator is driven by IC’s

Conventional integrated circuits can operate a subminiature indicator light. All the circuitry needed to drive the lamp is contained in the indicator housing. Power-supply and logic requirements are compatible with IC’s, eliminating the need for interface circuitry.

Indicator loading is minimal, and practically the full drive capability of the IC is available for other loads. Each indicator requires one load of a typical diode-transistor-logic module, two loads of a transistor-transistor-logic module, or 10 loads of a resistor-transistor logic module.

The incandescent lamp is driven by a high-gain transistor with a diode AND gate input. The lamp operates from a 4.5 ±1 volt d-c supply. When a logical 1 level input between 1 and 15 volts turns the lamp on, open-circuit current is less than 10 microamperes. When the lamp is off (logical 0 input, between 0 and 0.6 volt), the indicator represents a sink load of 2.8 milliampere.

Specifications

<table>
<thead>
<tr>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>903-1458</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mounting</th>
</tr>
</thead>
<tbody>
<tr>
<td>15/32-in. hole in ¼ in. or 3/16-in-thick panel</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Bulb</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1½ incandescent bulb with midget flanged base (GE 377)</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Temperature range</th>
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<tbody>
<tr>
<td>−20°C to +70°C</td>
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<table>
<thead>
<tr>
<th>Lamp life</th>
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<tr>
<td>20,000 hours min. at 3.6 volts</td>
</tr>
<tr>
<td>5,000 hours min. at 5.0 volts</td>
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</table>

<table>
<thead>
<tr>
<th>Off load</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.8 ma at 0 to 0.6 V</td>
</tr>
<tr>
<td>less than 10 microamperes at 1 to 15 V</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>On current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
</tr>
<tr>
<td>$5.63 in lots of 1,000</td>
</tr>
</tbody>
</table>

Dialight Corp., 60 Stewart Ave., Brooklyn, N.Y. [351]

Fiber-optic faceplate for line-scan crt’s

Parallax is eliminated by a fiber-optic faceplate that brings the intensity-modulated line display of a cathode-ray tube to the front surface. By moving photosensitive paper past the line scan, contact prints of photos, charts or other information can be generated. Applications for the tube include copying equipment, automatic printing equipment, telemetering systems, and computer communications and read-out systems.

The faceplate is available up to 10½ in. long x 2 in. wide. Any thickness can be supplied to meet voltage standoff or three-atmosphere pressure test requirements. The faceplate can be sealed to glass like KG-12, 0120, and others having equivalent coefficients of expansion. It can also be supplied sealed to a crt bottle.

The faceplate may have a numerical aperture from 0.3 to greater than 1.0; fiber size is available from 5 to 30 microns. Extramural-absorbing material may be incorporated within the matrix for contrast enhancement. The plate is
From RCA “overlay”... 8 great RF-Power transistor advances!

new:

Industry’s Best Performing RF-Power Plastic Transistor

RCA
2N5017

\( P_{\text{out}} = 15 \text{ W (Min.) @ 400 MHz} \)

Low emitter and base inductances (0.1 nH and 0.2 nH respectively). . . . rugged “terminal block” structure permits choice of stripline, printed circuit, or lumped circuit mounting.

Circle 472 Reader Service Card

new:

Microwave Coaxial Package!

RCA
TA7003

\( P_{\text{out}} = 1 \text{ W (Min.), 5 dB Gain @ 2 GHz} \)
\( P_{\text{out}} = 2 \text{ W (Min.), 10 dB Gain @ 1 GHz} \)

New low-inductance package for UHF and microwave oscillator, frequency-multiplier, and rf-amplifier service.

Circle 476 Reader Service Card

new:

Industry’s Best Performing RF-Power Plastic Transistor

RCA
2N5016

\( P_{\text{out}} = 15 \text{ W (Min.) @ 400 MHz} \)

Formerly TA2675, this type uses the same chip as in RCA’s new 2N5017 plastic-stud package, but in the popular hermetically sealed TO-60 case.

Circle 473 Reader Service Card

new:

High power version of RCA’s new 2N5016 transistor!

RCA
TA7036

\( P_{\text{out}} = 20 \text{ W (Min.) @ 400 MHz} \)

For Class B or C VHF-UHF Military & Industrial Communications.

Circle 477 Reader Service Card

new:

For Class-A Wideband applications in VHF Equipment!

RCA
TA2800

\( f_{\text{c}} = 1200 \text{ MHz (Min.) @ } I_c = 50 \text{ mA} \)

Large dynamic range
\( NF = 3 \text{ db (Typ) @ } 200 \text{ MHz} \)

For top performance in CATV and MATV line amplifiers and low-noise linear amplifiers.

Circle 474 Reader Service Card

new:

High-gain Class-C amplifier type for UHF service!

RCA
TA2710

\( P_{\text{out}} = 1 \text{ W (Min.) 5 dB Gain @ 1 GHz} \)
\( = 0.3 \text{ W (Typ) @ 1.68 GHz} \)

Circle 478 Reader Service Card

new:

Class-B and -C amplifier type for 24-V FM communications!

RCA
2N5071

As narrowband amplifier:
\( P_{\text{out}} = 24 \text{ W Min. @ } 76 \text{ MHz with } P_{\text{in}} = 3 \text{ W} \)

As broadband amplifier:
\( P_{\text{out}} = 15 \text{ W (Min.) @ } 30-76 \text{ MHz with } P_{\text{in}} = 3 \text{ W} \)

Circle 475 Reader Service Card

new:

Class-A and -B amplifier type for Single-Sideband Transmitters!

RCA
2N5070

\( P_{\text{out}} = 25 \text{ W (PEP) Min.} \)

13 dB gain @ 30 MHz, \( V_{\text{cc}} = 28 \text{ V} \)

Intermodulation Distortion = 30 dB (Max.)

Circle 479 Reader Service Card

For information on these and other RCA “overlay” transistors, see your RCA Representative. For technical data on specific types, write: RCA Commercial Engineering, Section IN6-2, Harrison, N.J. 07029

RCA Electronic Components and Devices

The Most Trusted Name in Electronics

Electronics | June 12, 1967
E-I GLASS-TO-METAL SEALS —

Specialized manufacture, with continual R & D pinpointed to absolute seal perfection

— PROVED IN CRITICAL AERO-SPACE PROJECTS!

Years of E-I specialized production, with research and development devoted exclusively to the ultimate in hermetic sealing, have resulted in electrical and mechanical characteristics compatible with today's highly sophisticated applications. Engineers and designers requiring high reliability in vacuum-tight sealing, should check the advantages:

- High dielectric strength, severe shock and vibration resistance
- Cushioned glass construction, maximum rigidity and durability
- Withstand wide fluctuations in temperature and humidity
- Miniaturization, design standardization

E-I sealed terminations include hundreds of stock items. Where custom seals or unusual lead configurations are required, E-I sales engineers will make recommendations from your blueprints, sketches or data.

Write for E-I Catalog — Complete data on standard types, custom seal components and sealing to your specifications. Address requests on company letterhead.

New Components

capable of repeated thermal cycling up to 850°F.

Chicago Aerial Industries Inc., 550 W. Northwest Highway, Barrington, Ill. 60010. [352]

Display storage tube provides sharp contrast

A patented design that permits high-contrast operation makes the background brightness of a new display storage tube independent of erase duty cycle and persistence. The tube is suitable for new dual-mode radar displays because it offers more halftones than conventional tubes.

Designated WX-31016, the new unit has a minimum erase time of 7 msec and can display nine shades of gray.

Other areas of application include navigation, search and fire-control radar displays, and air traffic control displays.

Two electrostatic focused and deflected writing guns in the WX-31016 give the systems designer a wide range of operating modes and offer an alternate TV display.

Westinghouse Electric Corp., Electronic Tube Division, Elmira, N.Y. [353]

Industrial trimmer is sealed for cleaning

A trimming potentiometer sealed for p-c board solvent cleaning is being offered at a price—$1.95—competitive with the cost of unsealed units.

The ¾-in.-long rectangular model 77 has a cermet resistance element
How to flatten spikes precisely and for pennies

One look at this circuit and you recognize the answer to voltage transients.

But forget about paired diodes.

A single Carborundum® varistor gives you precise suppression for pennies. “VDR” marks the spot.

Our nonpolarized varistors flatten spikes from either direction, defy installation error. They’re rugged enough to handle severe overloads, and they will do it with better reliability than diodes.

Aside from their low purchase price, Carborundum varistors can save you transistor dollars, too. Their precision damping performance means you can settle for lower breakdown ratings in transistors.

Send us your problems with transient suppression and voltage control and we'll send you precise technical and cost data.

Write to Mr. Harry Emes, The Carborundum Company, Refractories & Electronics Division, Niagara Falls, N. Y. 14302.

Precisely yours ...
Automated tools like this Cintomatic® are a vital factor in producing KAHLE automation for you!

New multi-function equipment plus advanced engineering and technological know-how, assure—
- Constant Quality Control
- Uniformity and Precision
in the design, development and building of KAHLE Automatic and Semi-automatic machines!

Used worldwide, KAHLE assembly and production machines are effecting manufacturing efficiencies and economies in practically every type of industry—electronic, pharmaceutical, glassware, photographic and numerous other high-volume operations.

Constant KAHLE research and "tooling-up" are keeping pace with today's demands for speed and accuracy, and the addition of the Cintomatic Vertical Machining Center, represents another step ahead. This machine mills, drills, taps or bores in one setting, with all the advantages of a single-function machine. Another example of automation at work for KAHLE, and for KAHLE customers.

This C.R.T. Sealing Machine for black-and-white or color gun sealing, is a 16-head, 16-index machine that takes tubes up to 27" dia. or diagonal, with all heads filled. Request Bulletin 2316 describing this unique KAHLE engineering achievement.

Used worldwide, KAHLE assembly and production machines are effecting manufacturing efficiencies and economies in practically every type of industry—electronic, pharmaceutical, glassware, photographic and numerous other high-volume operations.

Constant KAHLE research and "tooling-up" are keeping pace with today's demands for speed and accuracy, and the addition of the Cintomatic Vertical Machining Center, represents another step ahead. This machine mills, drills, taps or bores in one setting, with all the advantages of a single-function machine. Another example of automation at work for KAHLE, and for KAHLE customers.

New Components

and can be set to within ±0.05% of a required voltage. Standard resistances are available from 10 ohms to 2 megohms. Power rating is 0.75 watt at 25°C, derating to 0 at 105°C; operating temperature range is -55° to 105°C.

The manufacturer says the 15-turn adjustment unit is free from sudden failure and can withstand power surges five times its rated power. Clutching action at both ends of the adjustment screw prevents accidental damage during adjustment.

The units feature housings of glass-filled nylon and gold-plated terminal pins. Pin spacing makes the model 77 directly interchangeable with most low-cost commercial adjustment potentiometers.

Delivery is from stock.

Beckman Instruments Inc., 2500 Harbor Blvd., Fullerton, Calif. 92634.

Miniature connector comes in four forms

A microminiature connector line only 19/32 in. in diameter is designed for coaxial and multipin (up to 14 pins) applications. With an over-all plug length of only 1 inch, the series C is available in four configurations: straight plug; panel-mounted receptacle; panel-mounted with back shell and clamp; and cable receptacle.

The multipin models have a 2-amp rating, a contact-to-contact test voltage of 1.2 kv, and a contact-to-ground test voltage of 1.4 kv. Wire size is 24 or 26. Coaxial models have 50 and 75 ohm impedance and Teflon inserts.

All series C connectors feature
Complete stocks are now available of TRIMPOT® cermet element potentiometers in the full range of 10Ω to 1 Megohm.

Models 3012 and 3052 are in the familiar rectangular configurations, while the Model 3282 is a \( \frac{3}{8} \)" square unit available in five mounting configurations ... all three units are rated at 1 watt. All PALIRIUM® cermet potentiometers are designed and built to the usual Bourns high quality standards. They meet all the requirements of MIL-R-22097 and are ideal for applications requiring top performance under the most stringent environmental conditions.

Remember, Bourns is your best single source for the industry's widest selection of wirewound, cermet and carbon potentiometers. For detailed technical data sheets on these cermet units, contact your nearest Bourns office, representative or write the factory direct.

These units are stocked in depth, in all resistances and mounting configurations at the factory and by your local Bourns authorized distributor!

**SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Size</th>
<th>3012</th>
<th>3052</th>
<th>3282</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Adjustment</td>
<td>22 Turns</td>
<td>22 Turns</td>
<td>25 Turns</td>
</tr>
<tr>
<td>Resistance Range</td>
<td>100 to 1 Megohm</td>
<td>100 to 2000, 0.5%</td>
<td>5000 to 1 Megohm, 0.1%</td>
</tr>
<tr>
<td>Resistance Tolerance</td>
<td>±10% Standard</td>
<td>5000 to 1 Megohm, ±100 PPM/°C</td>
<td></td>
</tr>
<tr>
<td>End Settings</td>
<td>±500 to -100 PPM/°C</td>
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<tr>
<td>Temperature Range</td>
<td>-65°C to +175°C</td>
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<tr>
<td>Power Rating</td>
<td>1.0 watt at 70°C</td>
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<tr>
<td>Temperature Coefficient</td>
<td>+25°C to +175°C</td>
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</tr>
<tr>
<td>Humidity</td>
<td>100 to 2000, 0 to +500 PPM/°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+25°C to -65°C</td>
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</tbody>
</table>

100 Megohms minimum insulation resistance after removal from chamber.

BOURNS, INC., TRIMPOT DIVISION • 1200 COLUMBIA AVE., RIVERSIDE, CALIF. • TELEPHONE 714 684-1700 • TWX: 910 332-1252 • CABLE: BOURNSINC.
When Xerox required a dependable, precise and fast-acting temperature sensing device, they brought a space age product "down to earth".

If your products require precise temperature measurement, control or compensation with FAST RESPONSE it will pay you to investigate VECO thermistors. VECO supplies a wide range of standard thermistors in various sizes, shapes, temperature coefficients and resistance values.

VECO's engineering staff is available to assist you in product application and circuit design.

Xerox and 2400 Reg. T.M. Xerox Corporation

Write for Catalog MGP681

VECO First in Progress • First in Service

New Components

a patented snap-latch device for positive self-locking, maximum holding power, and quick, one-hand disconnect.

Multipin insert material is Nylatron. Contact material for all models is phosphor bronze or beryllium copper depending on the application; contact plating is gold over nickel over copper.

Price ranges from $2 to $15 depending upon quantity and type. Delivery is three to five weeks for quantities of up to 5,000.

Lemo Division, Frazar & Hansen Ltd., 150 California St., San Francisco 94111.

Angular-surface dials for multiturn pots

Two 15-turn dials are available for use with multiturn precision potentiometers. Although only 1 in. in diameter, the dials have an angular surface that enhances readout. Primary and secondary scale presentation is 000 to 1,499.

Set-screwed directly to a potentiometer shaft, there is no back-
Engineers working in digital computer input/output interface systems for tactical airborne equipment, aircraft and space vehicle simulation, antenna positioning or programming, and similar systems are increasingly involved in solving the digital/analog interface problem for resolver and synchro data. Accomplishing this task becomes quite simple by taking advantage of North Atlantic's family of high accuracy resolver/synchro converters. Through the use of solid-state switching and precision transformer techniques, these converters provide single-speed accuracy and resolution from 10 to 17 bits, along with solid-state reliability and calibration-free operation.

Resolver/Synchro-To-Digital Conversion

One typical North Atlantic resolver/synchro interface is the Automatic Angle Position Indicator (Figure 1), which converts angular data from both 400Hz resolvers and synchros to digits. This device uses all solid-state plug-in cards and trigonometric transformer elements (no motors, gears or relays), and operates at all line-to-line voltages from 9 to 115 volts. It can be supplied in a wide range of configurations for specific system requirements, for example, signal frequencies 60Hz to 10KHz, binary or BCD outputs, .001° resolution with 10 arc second accuracy, and multi-speed and/or multiplexed inputs. Its five-digit Nixie readout can be integral or remote.

The unit illustrated has an accuracy of .01°, and two basic modes of operation. They are read-on command (rapid acquisition) and tracking (least significant bit update). Prices start at $5900.

Digital-To-Resolver/Synchro Conversion

North Atlantic's all solid-state digital-to-resolver/synchro converters (Figure 2) accept digital input data at computer speeds in either binary angle or binary sine/cosine form and convert to either resolver or synchro data. Their high accuracy and resolution (up to 17 bits) and freedom from switching transients meets an important requirement in space-mission simulation and antenna positioning systems for smooth servo performance at low rates of data change. All models are usually supplied with input storage registers.

Modular D-R/S Converters For High-Density Systems

The plug-in converters pictured in Figure 3 were developed by North Atlantic specifically for airborne systems and for aircraft simulation systems requiring high-density multi-channel operation. The modules illustrated provide 11-bit digital-to-synchro conversion and are capable of driving up to four torque receivers. As with other North Atlantic resolver/synchro interfaces, conversion is achieved through solid-state switching and trigonometric transformers, so there are none of the stability or calibration problems associated with conventional resistor-chain/amplifier type converters. Prices, in production quantities, run about $1100. per set. In prototype quantities about $1500. a set.

If you would like to take advantage of North Atlantic's state-of-the-art experience in resolver/synchro computer interface, we would be pleased to show you how these converters can meet your particular requirements. Or if you prefer, we will arrange a comprehensive technical seminar for your project group, without cost, in your own plant. Simply write: North Atlantic Industries, Inc., 200 Terminal Drive, Plainview, N.Y. 11803. TWX 510-221-1879. / Phone 516-681-8600.
THIS IS "DIE-LESS DUPLICATING"!

Produce short runs of simple parts quicker than an order can be processed to get them "outside." Use Di-Acro "Die-Less Duplicating" equipment to cut stock to size and to form it with die-accuracy — without costly dies. Get full information in our new "Die-Less Duplicating" catalog. See your distributor, or write us — naturally!

New Components

lash and no necessity for extra panel holes. The units have been life tested to 250,000 cycles with no appreciable sign of wear.

Designated the RDK-411 (black with white figures) and RDK-461 (clear with black figures), the dials accept a 3/4-in. shaft.

Price is $6.50 each in 100-lot quantities. Delivery time is 30 days. IRC Inc., 401 N. Broad St., Philadelphia 19108. [396]

Rugged end-capped metal film resistor

The end-cap construction of a new microminiature metal film resistor gives the unit the ability to withstand greater stresses during lead cutting, forming, and soldering than resistors of larger size, according to the manufacturer.

Conservatively rated at 1/20 watt (50 mW) at 100°C and 100 V, the RE-1/20 has nominal body dimensions of 0.040-in. diameter by 0.132-in. length. The 0.016-by-1-in. leads are available in tinned copper for soldering and gold-flashed dument or nickel for welding.

Resistance range is 25 ohms to 25 kilohms in standard ±1% tolerance. The unit is also available in resistance tolerances of ±0.5%, ±2%, and ±5%. Temperature coefficients are ±50, ±100, or ±150 ppm/°C. Other features include low noise construction, low voltage coefficient, and multiple conformal coats of high-density epoxy for optimum protection from temperature and moisture.

Prices range from 59 cents to $3.51 each, depending on tolerance,
Knock off 35% of shielding material costs with Hipernom®

...and stay competitive into the 1970’s.

Of course you want to pay less for magnetic shielding against DC to 10,000 Hz fields. Solution: Get Westinghouse Hipernom alloy. Of all commonly used shielding alloys, Hipernom has the highest permeability. It lets you use thinner, lighter shields, allows easier, lower-cost fabrication. And you use less material per shield.

The 35% material cost saving per shield cited above is typical. Hipernom also brings you an important extra...the largest group of metallurgists specializing in magnetics. They’ll put Westinghouse’s 50 years of research leadership in magnetics at your service. Want specific details? Call Bob Carroll at 412-459-9400.

Free 36-page book on magnetic shielding
Any engineer who reads this book becomes one of America’s foremost authorities on magnetic shielding. It is just that complete, practical and unique. For your free copy, write for “Shielding Book.” Address Westinghouse Metals Division, Box 868, Pittsburgh, Pennsylvania 15230.
THE 104TH ELEMENT

A BLISS-GAMEWELL DISCOVERY!

The book says there are only 103 elements... not so! At Bliss-Gamewell, the variety of available conductive plastic precision potentiometer elements is infinite. Be they round or simply a sector... you call the turns with us. Extremely tight accuracies for linearity or conformity are available... so are "wide open" economy styles. Bliss-Gamewell custom-engineered conductive plastic elements and potentiometers are quality controlled in our own facilities from powder to pot. We can fill the bill, no matter what your specs. Credentials? You'll find our CP pots in Phantom II aircraft navigational computers manufactured by Bendix. In Viet Nam, our pilots bet their lives on them every day. More interested in a wire wound? Our ultra-precision, half-moon-shaped, ½-inch wire wound precision resistance elements help the Shillelagh missile strike true. In translatory or rotary single and multi-turn styles — with linear or non-linear outputs — you can go 'round in the best circles with Bliss-Gamewell precision potentiometers. Write for information on how we can help you. Bliss-Gamewell, 1238 Chestnut Street, Newton, Massachusetts 02164.

New Components

temperature coefficient, and quantity. The resistors are available from stock in small quantities; for production quantities, delivery time is three weeks.

American Components Inc., Conshohocken, Pa. 19428. [357]

Tiny line filters rated up to 5 amps

Hermetically sealed 115-v a-c line filters are said to be at least 20% smaller and lighter than the very smallest line filters now available.

The new units, designed for operation in 400-hz lines at 85°C and in 60-hz lines at 125°C, are available in L, T, and pi configurations with current ratings as high as 5 amps. Typical insertion loss is 30 db at 150 khz and 80 db from 1 Mhz through 2.75 Ghz.

Erie Technological Products Inc., Erie, Pa. [358]

Compact Kerr cells compatible with cameras

Small, cylindrical Kerr cells designed for compatibility with all standard makes of Kerr-cell cameras and laser Q switching equipment are offered with apertures from 0.24 in. to 0.6 in. Other sizes are available on special order.

Space charge is eliminated and the electric field is extremely uniform due to an improved method of nitrobenzene purification, according to the maker. The cells can be used to control high energies and light gains of more than 1,000 to 1.

Applications include laser Q spoiling and high-speed photographic studies of plasmas, lasers,
Solitron, now in full production of the SDT 8950/SDT 8650 families, has reduced the price of these fast switching, high power silicon transistors. As shown on the comparison Volt-Amp chart, these transistors provide more power-handling capabilities per dollar than multiples of similar, limited-source devices. In order to meet various size and weight requirements, they are available in either 1 1/16" hex or TO-68 packages. A few of their many uses include visual display circuits, converters, inverters, voltage regulators and/or space flight applications.

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Would you believe the new “VY” Thin Line Porcelain Capacitors, featuring a -100 ppm/°C temperature coefficient, have a mean-time-between-failure rate of 6,000,000 hours?

Ten million unit hours of testing “VY” Thin Line Capacitors at accelerated conditions — equal to 50 million unit hours at rated conditions — bear this out. Their proven, low failure rate is .016% per 1000 hours, at a 90% confidence level.

Users of negative T.C. capacitors gain positive features: three space-saving case sizes and two lead configurations, ratings to 500 VDC, plus the stability and low-losses a porcelain dielectric guarantees.

Thinking more positively about these negative T.C. capacitors? Then write for Data Sheet P 18 — and be more sure.

“VY” Thin Line also available with 0 ± 25 ppm/°C T.C.)

Small mercury-wetted relays featuring low noise, high speed, and long life can be used in integrated circuitry, peripheral input-output equipment, converters, and multiplex systems.

The bounce-free mercury film, hermetically sealed in a glass capsule, switches 2 amps up to 6 volts and 50 ma up to 100 volts at speeds of under 1 msec, and will operate...
High quantity production of integrated circuits with uniform quality, increased precision tolerances, greater economy in the production of micro-ceramic components—all these are yours by gang printing your circuits on Coors Strate-Breaks. No cutting apart, no multiple handling before assembly. Just SNAP!... and there are your individual components with a straight, smooth, precision edge.

Coors Strate-Breaks are made to your specifications in sizes from ½" x ½" to 4" x 4". They are available unglazed for thick-film circuits, and glazed or unglazed for thin-film circuits. Get on-the-spot answers. Dial Coors—303/279-6565, Ext. 361. For complete design criteria, write for Coors Alumina and Beryllia Properties Handbook No. 952.

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Coors Porcelain Co., Golden, Colo.

Circle 179 on reader service card
HOW CAN YOU USE THIS NEW WRINKLE IN PLASTIC TUBING?

FLEXITE SHRINKDOWN TUBING is fast becoming an "indispensable" to design engineers. It shrinks 50% in diameter, upon application of moderate heat, to form a tough, tight-fitting sheath of plastic around objects of irregular shape. Primarily intended for insulation, it is also being used in many other ingenious ways. Like binding things together — adding strength and rigidity — protecting against abrasion, wear, breakage — resisting corrosion, heat, moisture — preventing vibration and noise — etc. How can you use it? We'll be glad to send you our "Hot Idea" experimental sample kit of all 3 types of Markel Shrinkdown. Just write for it. No cost or obligation.

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HIGH TEMPERATURE WIRE AND CABLE

New Components

uniformly from $-38^\circ$ to $+100^\circ$C at rates exceeding 250 hz.

The capsule is potted together with independent drive coils and a shielded magnetic latching circuit to withstand severe environmental conditions.

Fifth Dimension Inc., Box 483, Princeton, N.J. 08540. [360]

Trimmer potentiometer for panel mounting

A panel mount configuration has been added to a line of humidity-proof trimmer potentiometers. Designated by model numbers 1684, 1685, and 1686, the pots meet or exceed the electrical and environmental characteristics of Military Style RT-12 of MIL-R-27208A.

The new pots have power ratings of 1 w at $70^\circ$ C and an operating temperature range of $-65^\circ$ to $175^\circ$ C. Resistance range is 10 ohms to 100,000 ohms with a standard tolerance of ±5%.

Three-terminal configurations are available. Model 1684 has gold-plated, hook-type solder lugs; model 1685 has 22-Awg, gold-plated wire terminals; and model 1686 has 28-Awg, color-coded, Teflon-insulated leads.

Dale Electronics Inc., P.O. Box 488, Columbus, Neb. [361]

Thermal timing relays are easily installed

Only two mounting screws are used to install the Quick Connect series of thermal timing relays. Special brackets, sockets or retainers aren’t needed. Push-on ter-
Temperature test your integrated or hybrid circuits in a 3M Brand Inert Fluorochemical Liquid and it'll drain clean, dry immediately and leave no residue.

Unlike conventional test bath fluids, with our Inert Liquids there's no costly cleaning stage to slow down production.

3M Brand Inert Liquids—FC-43, FC-75, FC-77, FC-78—also give you a wide liquid range so you can use them at both high and low temperatures, high dielectric strength for electrical insulation, compatibility to prevent adverse effects on sensitive materials, and non-flammability to make them safe.

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**PROTOTYPE DEVELOPMENT**
In the development of precision prototypes for the electronic industry, we are equipped to offer multi-shaped parts and varied-ceramic formulations to meet every possible design and economy requirement. We produce precision ceramics that are machined from alumina, die formed, isostatic pressed, extruded, molded or cast. Materials range from high-aluminas through forsterite.

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Where the tolerance or surface finish is extremely critical, we are skilled and equipped to provide the necessary ceramic machining. We offer a complete range of grinding, polishing, lapping and ultrasonic machining.

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We produce complete sub assemblies to customer specifications, as well as provide a capability to design parts to meet your requirements. Final assembly includes brazing of ceramic to ceramic and metal to ceramic for either mechanical or hermetic seals.

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OFFERING A COMPLETE CERAMIC SERVICE FROM PROTOTYPE THROUGH PRODUCTION

New Components

minals provide flexibility of wiring, part location, and equipment servicing. A Durex 11540 plastic case houses the stainless steel structure and nichrome heater windings.

The relays have a low profile and can be mounted in any position. Specifications include: single-pole single-throw contacts; 2-amp 115-v a-c or 1-amp 28 v d-c resistive ratings; 6.3-, 26-, 115-v a-c or d-c heater voltages; 5- to 180-sec time delays; ±20% time-delay tolerance.

G-V Controls Inc., Livingston, N.J. 07039. [362]

**Hybrid vidicons focus on high resolution**

Compact hybrid vidicons utilize magnetic and electrostatic fields in a focus-projection and scanning mode. Low in power consumption, the tubes provide very high resolution.

Both the magnetic focus and electrostatic deflection fields are superimposed on one another so that focus and scanning are accomplished simultaneously. The performance level for this combination of crossed fields is inherently higher than for similar devices using sequential, rather than simultaneous, focusing and deflection. Tube lengths are between 4½ and 6 in. Highest voltage required is typically only 300 v, allowing simplified circuitry to be used in the power supply section.

Applications include tv missile guidance, hand-held and space cameras.

Delivery is from two to four weeks.

General Electric Co., 1 River Rd., Schenectady, N.Y. 12305 [363]

Circle 182 on reader service card

182
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**New Semiconductors**

**Hot current measures coolant level**

The current increases substantially, activating the warning mechanism.

In effect the sensor measures the thermal conductivity of the surrounding medium to determine the presence or absence of liquid around the metal housing of the semiconductor element. Thermal conductivity of a liquid prevents the semiconductor from reaching the critical temperature. The relatively poor thermal conductivity of the air enables the device’s temperature to reach the critical level. If it’s a liquid with good thermal conductivity, such as water, oil, glycol, etc., the unit will not conduct even if the temperature is as high as 350°F. Operation is not influenced by contaminants or by the liquid’s electrical conductivity.

A typical application employs a 12-volt battery power source and an incandescent lamp or a buzzer for the warning signal, but the device works equally well on an alternating current source of equal voltage, which eliminates the need for polarity.

Custom-made samples are available within six weeks; production delivery is four months after the date of order. Cost will be based on specifications and the quantity ordered.


**Monolithic amplifier delivers full watt**

An integrated circuit amplifier offers an audio output of 1 watt with a total harmonic distortion of less than 0.4% over a frequency range of 20 to 20,000 hz. The monolithic unit, designated MC1554G, is also suitable as a general purpose amplifier for frequencies up to 300 khz. The 1-watt output is delivered to either direct coupled or capacitively coupled loads.

Housed in a 10-pin, low-profile...
Be a genius
—dream up
an application for our
MIL-R-12934E single-turn pots—
(and win your very own certificate of genius).

Submit any design, simple or complex. Use one, two or any number of functions—including trigonometric, logarithmic, and non-linear empirical. And because all Litton single-turn pots are designed to meet or exceed MIL-R-12934E requirements—especially resolution—you can list your most stringent performance specs.

Producing single-turn pots in production quantities with .0004" wire is a specialty with us. So designs requiring a high degree of accuracy and superior resolution can also be submitted. These features alone make it easy for you to become a certified genius. But here are other points to enhance your design idea.

Litton pots are lined with diallyl phthalate to insure moisture resistance, dimensional and temperature stability—a unique plus that produces far greater reliability. What's more, we can easily reduce size and weight so make your design as compact as you like. And don't worry about shunts or slope changes. Our special butt welding results in a clean, even tap that prevents distortion in the functions.

Now let's see what you can come up with. Just jot down your application and we'll send your certificate by return mail. And if yours is one of the 50 best ideas we'll publish it in our next IDEA BOOK.

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POTENTIOMETER DIVISION

If your present supplier can't solve your potentiometer problems, try us. For single-turn and multiturn, linear and functional, wirewound and conductive film, ganged or unitized with servo modules—Litton begins where others leave off.

Certified testing equipment allows simultaneous measurement of Litton potentiometers under the extremes of environmental exposure.

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☐ My idea for an application is attached. Send my certificate of genius.
☐ I have an idea, but need more data first. Send specs.
Name ______________________________ Title ______________________________
Company ______________________________________________________________
Address ________________________________________________________________
City ___________________________ State ______ Zip ______

Electronics | June 12, 1967

Circle 185 on reader service card 185
LAPP GAS FILLED CAPACITORS ARE DESIGNED FOR

HIGH VOLTAGE
HIGH CURRENT
HIGH CAPACITANCE

APPLICATIONS

These uniquely designed Lapp Gas-Filled Capacitors are completely unaffected by atmospheric or dust conditions. They are precision built and of extra strong construction to assure years of accurate, trouble-free operation. Lapp Gas-Filled Capacitors are available in either fixed or variable models. All are equipped with an external safety gap to protect against internal flashover on excess voltage peaks. Capacitance available up to 30,000 mmf, safety gap settings up to 85 kv peak and current ratings up to 400 amps at 1 mc. Write for Bulletin 302... get our complete Gas-Filled Capacitor story, Lapp Insulator Co., Inc., Radio Specialties Division, 206 Sumner St., LeRoy, N.Y. 14482.

New Semiconductors

Delay-type binary broadens IC line

A dual “D” or delay-type binary element has been added to the company’s Series 8000 integrated-circuit line, which includes both high- and low-speed TTL and low-power DTL circuits. Incorporating the element broadens the uses of ic’s. “D” type binaries are particularly suited for shift register, ripple counting, and divide-by-two applications.

Designated the S8828J, the dual binary—in a 14-lead glass-Kovar flatpack—operates over the full mil.
Where in the world... but Kansas

Beauties of nature witnessed by pioneers still stand in countless Kansas scenic locations. No fighting traffic to reach this point on the bluffs overlooking the Missouri River near Atchison. Surprised? Kansas has many pleasant surprises. We'll tell you more about Kansas, engineering opportunities at Boeing, Wichita, and send you Bill Post's recording of "Where In The World But Kansas" just for sending us the coupon on this page.

AVIONICS: Analysis and development of electro-optical sensor systems, long range airborne communications, forward looking infrared systems, ELINT/DF Systems, radar, navigation/guidance systems. Integration design and installation of aircraft electrical/electronic equipment.

ANTENNA SYSTEMS: Perform design, performance evaluation, and analysis of antennas, radomes and RF transmission systems, utilizing both digital computer and laboratory test evaluations.

FLIGHT TEST: Design airborne instrumentation. Test and analysis related to production or prototype aircraft systems.

OPERATIONS ANALYSIS: Develop conceptual missions for future military aircraft. Use advanced mathematical techniques and cost effectiveness methodology to define aircraft systems which satisfy the mission and cost requirements.

CONTROL DYNAMICS: Perform servo control analysis; involves analog and digital computer application in development of automatic flight controls. Analysis techniques include both classical and modern control theory

Inquiries are also invited in other areas of Technical Competence. Salaries are competitively commensurate with experience and educational background. Travel and moving allowances are paid to newly hired personnel. Boeing is an equal opportunity employer and complies with the provisions of the Civil Rights Act of 1964.

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187
New Semiconductors

Temperature range of -55° to +125°C. It is priced at $8.40 each in lots of 100 and up.

Two other industrial package versions of the binary are offered for applications ranging from 0° to +70°C, and from +15° to +55°C.  
Signetics Corp., 811 E. Arques Ave., Sunnyvale, Calif. [366]

Tiny silicon diodes handle high voltage

High-voltage silicon diodes, with peak inverse ratings from 1,000 v to 4,000 v, supply 10 ma maximum continuous forward current with only 10 na maximum reverse current at the rated peak inverse voltage. Maximum capacitance at 0 volt is 1 pf.

The microminiature units, series NV, are designed for high density packaging. Maximum dimensions are 0.85x 0.100 in. The lead diameter is 0.10 in. Units are designed to operate at a temperature range of -65° to +100°C.  
Atlantic Semiconductor Inc., Division of Aerological Research Inc., 905 Mattison Ave., Asbury Park, N.J. [367]

Silicon rectifier eliminates heat sinks

A high current, axial lead silicon rectifier, suited for high density packaging, uses "tungstaloid" pins that match the thermal expansion characteristics of the silicon junction to eliminate the need for heat sinks.

Basic internal structure consists of the tungstaloid pins, metallurgically bonded above 900°C to solid silver leads (0.040 in.) at the silicon junctions.

Specifications include a peak inverse voltage rating from 50 to 600 v; average rectified current, 3 amps at 55°C, 6 amps when mounted per MIL/STD-750A; and static reverse current, 10 µa at 25°C.  
Semtech Corp., Newbury Park, Calif. [368]
Searching for electronic components that are hard to describe and even harder to find?

Stop.

Let the Northern Plains Industrial Catalog search for you.

Northern's Industrial Catalog can locate a source for most any part or assembly. It is a unique find-it-in-a-hurry service of Northern Natural Gas Company that will quickly locate reliable suppliers, sub-contractors and sources for parts, components and sub-assemblies made to your exact specifications. In technical terms, the Northern Plains Industrial Catalog is a computerized compilation of all industrial fabricators in the Northern Plains area—Iowa, Kansas, Minnesota, Nebraska, South Dakota and western Wisconsin. It's the source of information that can tell you where to buy wisely, profitably and quickly. And the service is free. So if you're interested in electronic components, plastics, short run stampings, motors, precision machined parts, instruments, die castings or whatever, fill out the coupon. You'll receive complete information. And if you attach a sketch or specifications of your required components, Northern Natural Gas will send you a specially compiled list of qualified producers.
MINIATURE TEST ACCESSORIES
1/3 smaller...

1/2" SPACING for the new generation of miniaturized test equipment

Pomona created a complete line of 1/2-inch spaced Banana plugs, jacks, cable assemblies, patch cords, adapters, and binding posts to meet the industry’s continuing demand for miniaturization.

Banana plug springs formed of one piece Beryllium copper (per QQ-C-533), heat treated for long service life and low contact resistance. Tough, molded thermoplastic bodies provide maximum strength and insulation. Available in a wide selection of colors.

WRITE FOR FREE CATALOG 11-66 Lists over 230 molded test accessories, all designed to meet rigid industrial and military specifications—and built by the quality leader...

New Instruments

Permanent magnetism holds recorder paper

Chart paper held in place by permanent magnetism is a major feature of an inexpensive x-y recorder. The method of holding down the chart paper is unique with this recorder, according to the manufacturer. The platen is a magnet-impregnated hard rubber pad, and the paper is printed on one side with a magnetic ink pattern. Attraction between the two maintains paper alignment and eliminates electrostatic or vacuum hold-down devices commonly used on x-y recorders. Electronics are not used for paper hold-downs; thus it is fail-safe, requires no power, and is always on.

Designated the Series F-100, the rugged table-top recorders are highly accurate (0.25% of full scale) and have greater range sensitivity (100 µv/in.) than earlier models. Slew speed (60 Hz) is 15 in./sec, and repeatability is 0.2% of full scale.

Construction is modular, and electronic units are all solid state, with electronically-regulated (zener) reference circuits. Wide fluctuations in ambient temperature, relative humidity, and line voltage have little or no effect on performance. An electric pen-lifting mechanism is standard equipment.

Input circuits are independent, floating, and differential, offering true potentiometric operation. Input voltages range to 200 v d-c above or below ground. Rejection of 60 Hz is at least 40 db for the transverse (normal) mode, and 120 db for the longitudinal (common) mode.

Input resistance is one megohm at null. A patented circuit permits damping to be adjusted electrically without affecting calibration.

Series F-100 recorders weigh 30 lbs. They are 5x 16½ x 18 in. Power requirements are 105-125 or 210-240 v a-c, 60 or 50 Hz, 100 w.

Price is $1,395. Delivery takes 90 days.

Varian Associates, Recorder Division, 611 Hansen Way, Palo Alto, Calif. 94303.

Coherent amplifier ignores high noise

Ultralow-level signals can be measured in a high-noise environment with a coherent (lock-in) amplifier. It compares, amplifies, filters, synchronously detects, and integrates a low-level signal with virtually theoretical accuracy despite high noise.

The amplifier is continuously tunable over the range from 1.5 Hz to 200 kHz with a full-scale sensitivity of 100 nanovolts. It operates from broadband to a Q of 25 with- out gain change.

The instrument, called Model 300-A, measures the effects of biological stimuli, makes photometric measurements at low signal-to-noise ratios, converts a communications receiver to a sensitive radiometer, makes magnetic field effect studies, determines cross correlation of two periodic signals, and measures general amplification of low-level signals in presence of high noise.

The input configuration can be changed by using one of several plug-in preamplifiers. The preamps have single or differential inputs with high or low impedances. The
output is read from a built-in precision meter or from a digital voltmeter, high-impedance recorder or recording galvanometer connected directly to the amplifier. Reference voltage is obtained from an external source within a range of 0.5 to 300 v rms as well as from the internal tunable oscillator.

Supplied in a standard rack panel mount, the 300-A sells for $1,795 including the basic preamplifier.

Teltronics Inc., P.O. Box 466, Nashua, N.H. [372]

Graphic recorder combines 2 functions

A recorder combines the functions of x-y and multipoint recorders into a single unit. This permits three input x-y-z recording on a single chart. The manufacturer uses null-balancing potentiometric drives for the x and y axes, and a 24-position multipoint head for recording the z-axis inputs.

Initially intended for material flatness plotting, the recorder's other applications include automatic map plotting, recordings of such production information as sheet thickness and moisture content in paper manufacturing, temperature hardness and thickness in metal production, radiographic plots, as well as any other data which requires two or more separate recorders.

The recording of medical information is another area where the Contour/Riter recorder offers advantages. Plotting the path of radioactive tracers, or of r-f probes, is possible since the x and y axes can be synchronized easily to random scan patterns, and the z axis used to record measured intensity of the radiation. Contour electrocardio-

Ballantine Announces a New Solid State DC Digital Voltmeter

Gives you fast, accurate readings to 0.02%
± 0.01% f.s. and at a low cost of just $490

Ballantine's new Model 353 enables you to speed up dc measurements materially over those made on multi-knob differential voltmeters. And with laboratory accuracy from 0 to 1000 volts dc.

It requires just two steps: (1) Set knob to NORMAL mode and read voltage; (2) dial in the first digit in EXPAND mode and read voltage to four places with overrange to five; and, in addition, interpolate to another digit.

The NORMAL mode error becomes submerged by more than ten to one, and the operation is fast and accurate to 0.02% of reading ± 0.01% f.s. If the input signal is varying, the last digit may be followed visually, thus providing the advantage of analog display.

Note these other interesting features of the new 353: a left-to-right digital readout; an automatic display of “mV” or “V”; proper placement of the decimal point; 10 megohms input resistance; an automatic disabling of the motor during the “expand” dialing; a red light to indicate overrange or wrong polarity; and provision for a foot-operated switch for a “read” or “hold” function.

Write for brochure giving many more details

Ballantine Laboratories Inc.
Boonton, New Jersey

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CHECK WITH BALLANTINE FIRST FOR DC AND AC ELECTRONIC VOLTMETERS/AMMETERS/OMMETERS, REGARDLESS OF YOUR REQUIREMENTS. WE HAVE A LARGE LINE, WITH ADDITIONS EACH YEAR, ALSO AC/DC LINEAR CONVERTERS, AC/DC CALIBRATORS, WIDE BAND AMPLIFIERS, DIRECT-READING CAPACITANCE Meters, AND A LINE OF LABORATORY VOLTAGE STANDARDS FOR 0 TO 1,000 MHZ.
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Only Associated offers you so many advantages when you need vibration testing. You get the benefit of over a million man-hours of engineering experience! Twenty-four-hours-a-day, seven-days-a-week operation—enough capacity and support instrumentation for the most demanding tests! Quick reaction time—your test is in—and out—in far less time! And fully detailed and documented reports!

Equipment? Just one example: the 15,000 force-pound Vibration System shown above, including an 85-channel automatic equalizer/analyzer console. In fact, with its 16 systems, Associated has more vibration test systems and equipment than any other company on the East Coast!

Want more information? Call or write us today, outlining your needs. Address: Dept. E-2.

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New Instruments

Radio-frequency interference and power line switching transients produced by standard SCR temperature controllers can be a serious problem in industrial applications. This problem is overcome in the TC-720 series of indicating temperature controllers by circuitry that turns the heater on and off only when the a-c power line is passing through zero. Since there is no power the instant of switching, no switching transients are introduced and no rfi can be generated.

The TC-720 controllers have a time proportioning characteristic to ensure close temperature control. In addition, automatic reset elimi-
nates the temperature droop which occurs in simple proportioning controllers. Linearity is 0.25% standard. The dial is direct reading in temperature with a scale length of over 10 in., accommodating any temperature range between $-200^\circ$ C and $1,100^\circ$ C.

A go-no-go indicator especially adapted for automated installations continuously monitors the actual temperature and provides a visual warning when it deviates from the set point.

TC-720 controllers are solid state, with no moving parts or contacts in the power control circuits. They are vibration resistant and may be mounted on the equipment to be controlled.

Operation may be from 115, 230, or 440 v, single phase or three phase. Standard power ranges are up to 300 kw.

Harrel Inc., 16 Fitch St., E. Norwalk, Conn. 06855. [374]

Ultraflexible design in a sweep generator

Instrument flexibility is said to be carried to its ultimate in a sweep generator, every discrete function of which is a separate package. The model 2003 comprises only a chassis, a power supply, and spaces for seven modular plug-in units.

The user can select plug-in oscillator units covering such ranges as 1 Mhz to 250 Mhz, 5 Mhz to 500 Mhz, 5 Mhz to 1,500 Mhz, and 1,000 Mhz to 2,000 Mhz, depending on application. The oscillators provide both start-stop and center-frequency-sweep-width control modes.

Another chassis space permits the user to select attenuators, again depending on requirements. These attenuators range from 0 to 1 db in 0.1-db steps, to 0 to 109 db in

HIGH VOLUME COMPONENT TESTING?

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(201) 256-2800

Electronics June 12, 1967
"All right, Jeff, we'll buy your system, but you'll have to specify a more advanced X/Y recorder. We need greater versatility and more reliable operation on the job. Any ideas?"

"If you like, Craig, I'll give you the system with the latest X/Y recorder on the market: The PLOTAMATIC® built by Bolt Beranek and Newman's Data Equipment Division. Other users swear by them. The PLOTAMATIC has a paper hold-down system that always works, never gets dirty, and yet allows you to adjust the paper for proper alignment after it's mounted. Input resistance is greater than one megohm, independent of gain setting. Accuracy and input versatility are as good as anything on the market, and you don't have to buy time base if you don't want it. No high voltages to produce RFI problems, either. Just between us, Craig, I think our people are in a rut with those X/Y recorders we've been using. They use them out of habit, and aren't up on the latest the market has to offer."

BBN's PLOTAMATIC line includes a variety of 8½" x 11" and 11" x 17" X/Y recorders for virtually every application. Keep up with the market—write us for a catalog.

New Instruments

1-db steps, at 50- or 75-ohm impedances.

The r-f portion of the instrument's frequency marker system occupies two of the seven plug-in spaces, allowing the use of both variable and fixed markers in the measuring process. By means of a time-sharing circuit, closely spaced markers can be displayed simultaneously without interference.

Marker display processing is controlled in another plug-in unit. Markers may be vertical, tilted, horizontal, extra-intensity, birdy, pulse, or level-modulated, and may be processed for oscilloscope or x-y plotter presentation.

One space is allocated to plug-in r-f detector units of various frequency ranges, polarities, and impedances. This same space may be used for logarithmic amplifier-detectors and oscilloscope preamplifiers.

The last space accepts a master control unit that allows functional variations to be made, such as sweep rate regulation, single trace trigger for x-y recordings, and a-m and f-m modulation level control.

The instrument itself is a cabinet model measuring 19 in. wide by 9 in. high by 17 in. deep. It may be easily rack-mounted by the addition of two angle brackets that come with the instrument as standard equipment.

Telonic Instruments Division of Telonic Industries Inc., 60 No. First Ave., Beech Grove, Ind. 46107. [375]

Voltmeter conquers loading obstacles

A phase-sensitive voltmeter overcomes the problem of circuit loading when using isolation transformers. The instrument incorporates transformers that provide an input impedance of 1.5 megohms.
This high impedance permits floating circuit measurements without appreciable loading.

Model 240SP will measure in-phase voltages, quadrature voltages, total and functional voltages, as well as phase angle.

Price is $880. Delivery takes one week.

Dytronics Co., 4800 Evanswood Drive, Columbus, Ohio 43224. [376]

Recording oscillograph priced under $1,000

A two-to six-channel light-beam recording oscillograph is priced to compete with pen-and-ink recorders. The 460cro (general purpose oscillograph) costs less than $1,000 complete with two signal conditioners and two galvanometers ready to record.

Standard galvanometers for the cro offer a flat frequency response to 2,000 hz and make it possible to record high-frequency events that mechanical recorders can’t handle.

Plug-in signal conditioners make the cro easier to use than most light-beam oscillographs. Several different types of attenuators, amplifiers, and differential amplifiers are available.

Operators may select paper speeds of 0.1 to 80 in. per sec, depending on the type of signal to be recorded. A xenon arc lamp provides high light intensity for fast recording.

Both grid and timing lines are standard equipment with cro. Standard grid lines are 0.1-in. spacing with every fifth line accentuated. Full width timing lines every 1.0, 0.1 or 0.01 second may be selected automatically with chart speed or manually, as the operator requires.

Century Electronics & Instruments Inc., 6540 E. Apache St., Tulsa, Okla. 74115. [377]
**New Subassemblies and Systems**

**IC digital computer has many uses**

A 16-bit, integrated circuit digital computer gives the systems designer more versatility with which to handle changing requirements than is available with combinations of core buffers and special-purpose logic. Applications of the 703 computer include radar data processing, aircraft and helicopter checkout, and seismic data processing.

Besides a 16-bit word length, the machine provides 71 hardware instructions, direct and indexed addressing, byte addressing and manipulation, and memory expansion to 32,000 words. Memory cycle time is 2 μsec.

Options include direct memory access channels, real-time clock, hardware multiply-divide, and additional interrupt lines. The company’s multivertex family (multiplexer, sample and hold, and a-d converter) can be connected to the 703 by standard coupler to form data acquisition or logging systems.

Peripherals include paper tape reader and punch, magnetic tape, disk, and line printer. The M-Series ic logic system is compatible with the 703 and available from stock for special system assembly.

Software for the 703 will cover an assembler as well as executive, utility, and diagnostic routines.

The $15,000 basic 703 contains a central processor with a register display and entry control panel, 4,000 words of core memory, a priority interrupt system, and an ASR33 teleprinter. Initial deliveries are scheduled for August 1967.

Raytheon Co., Computer Division, 2700 S. Fairview St., Santa Ana, Calif. 92704.

**Modular, open-ended computer system**

Through a modular approach to data system design, a broad line of black box elements has been developed. The elements may be directly interconnected in any combination for maximum data acquisition, reduction, logging and computing system applications. Called the 4000 series, it includes input and output devices and programs, processing, and memory units.

The new series of system and computer components includes on-line digital arithmetic units, keyboards, core storage assemblies, program input sources and accessories, as well as a variety of compatible instruments such as scanners, digital voltmeters, A-to-D converters, counters and encoders. Also available are digital clocks and output drivers and devices such as incremental tape recorders, paper tape or card punches, typewriters, teletypewriters, and column printers.

The resulting systems provide several advantages over conventional systems which normally are designed for specific applications, according to the manufacturer.

- Series 4000 systems are significantly lower in cost. Prices start at $3,500 and typically a $10,000 system compares in performance with conventional computers costing as much as $25,000.
- Series 4000 systems are open-ended. A system can be expanded up to 32 modules, in any combination, without equipment modification. Alterations in system configuration and function can be accomplished at any time with plug-in ease.
- Series 4000 systems are easily programmed with algebraic statements by easily trained persons who
need not know any special computer language. Operation is simple and straightforward.

In operation, the parallel-connected system elements communicate both control instructions and data through interconnecting bus lines. One of the elements assumes control of the entire system, and other elements are assigned roles as input or output devices. The roles of input, output and control may be reassigned by control instructions issued through the bus by either operator or program. Although certain elements may be designed specifically to perform only input or output functions, any element may, theoretically, assume control, and it is possible for particular elements to assume multiple roles.

Wang Laboratories Inc., 836 North St., Tewksbury, Mass. [382]

Adaptable system for data acquisition

A stored-program data acquisition system samples a large number of analog and digital inputs, performs analog-to-digital conversion, formats data for computer compatibility, and records data on magnetic tape. The system is available in three models. Model 100 controls sampling sequence and tape block length. Model 200's expanded command list allows a more sophisticated approach to data acquisition. Model 300 has a general-purpose computer interface to handle online processing of the data collected.

Key to the flexibility of the sys-

"BLUE CHIP" TRANSFORMERS NOW AVAILABLE IN CASE SIZE #7

IN STOCK—is the latest addition to the versatile family of Blue Chip transformers for printed circuit applications. This still smaller size; (Height .340 inch maximum, volume .060 cubic inches), transformer offers design engineers more flexibility for electrical and mechanical transistor circuit applications. The size #7 Blue Chip transformers provide a response of ± 2 db from 300 to 100,000 Hz in a number of impedance ranges and are designed to meet Mil-T-27B, Grade 5, Class S. Write for your copy of complete electrical and mechanical specifications.

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Electronics | June 12, 1967

Circle 197 on reader service card 197
How versatile is your leak detector?

Can the complete instrument fit into spaces as small as 8 cu. ft.?
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The following advantages explain why the 24-120B Leak Detector has become the instrument for virtually every aspect of commercial use, as well as for critical government programs. (Federal stock number 6635-698-8086.)

Compact size plus complete mobility assures access to difficult-to-reach locations.
Building block construction allows you to make substantial savings by buying only what is essential to the operation...then to add to it, if or when the need is called for, from the most complete line of accessories available.

Special models. Although the basic 24-120B is a helium detector, special models are available for monitoring argon, neon and hydrogen.

CEC backs you up with the most efficient sales, service and training organization in the field today.


And be sure to ask for the free booklet: LEAK DETECTION HINTS

CEC ANALYTICAL INSTRUMENTS

New Subassemblies

System is a high-speed core memory that furnishes a data buffer as well as program steps—100 of which can be stored. Program steps, consisting of input channel identifiers and control functions, are entered via a 10-key keyboard as decimal digits. Nine commands, including unconditional transfer, store immediate, delete, recycle, and delay N cycles permit applications in which short cycling and variable sample rates, variable output tape formats, and other special data acquisition techniques are required.

The standard system includes a 16-channel multiplexer, expandable to 100 channels, an a-d converter, a 4,000-word eight-bit core memory and a digital tape transport.

Information Control Corp., 1320 E. Franklin Ave., El Segundo, Calif. 90245.

Digital integrator offers wide range

A digital integrating recorder performs as an electronic integrator for linear signals (as from gas chromatographs), and also handles logarithmic conversion as required in amino acid analysis.

The model DIR-1 computes seven-digit integrals in real time, along with retention time to six digits, and reads out these values via a built-in printer. It is a wide-dynamic-range (1,000,000 to 1) autoranging analog-to-digital converter which records on paper tape, punched cards, or magnetic tape (or may feed digital values directly into an on-line computer).

For instruments other than chromatographs (spectrophotometers, fluorimeters, and slow-scanning...
mass spectrometers), either the linear signal or its log conversion can be digitized and—if required—integrated. Independent controls insure optimum performance.

The DIR-1 makes extensive use of integrated circuits, and measures 17 1/4 x 17 x 5 in. Price, depending on options, ranges from $6,400. Delivery takes 90 days.

Datex Division, The Conrac Corp., 1600 S. Mountain Ave., Duarte, Calif. 91010.

Carbon dioxide laser
rated at 40 w minimum

Developed for advanced scientific and industrial applications, a CO₂ laser is rated at 40 watts minimum and 50 watts typical output power at 10.6 microns, and has efficiency in excess of 10%. Spatial mode purity allows the infrared output beam to be collimated for high density transmission over great distances, and the 10.6-micron single frequency output is useful where wide bandwidth cannot be tolerated.

The system, designated Model 420, includes the laser head (7 ft long) and an associated power supply, with an optional self-contained coolant heat exchanger. Safety interlocks and warning lights caution users when high-power invisible radiation is emitted.

A unique optical system allows the beam to be focused to a point inside the laser housing itself. The sample chamber provides a convenient means of irradiating small samples for materials studies.

Applications include communications and optical ranging, metal-working functions such as milling, cutting, drilling, welding, brazing, soldering, gas chromatography, atmospheric and materials re-

121 TIMES
LESS DRIVE
POWER
with Contiguous Comb Filter Sets
by Damon

Damon has produced a bank of 200 contiguous comb crystal filters that requires a total of 6.6 watts of drive power to obtain 10 milliwatts from each of the Gaussian (non-overshoot) response filters. This is only 1/121 of the 800 watts of drive power normally required to achieve the same output using conventional resistive padding techniques.

This significant achievement is the result of two advances in crystal filter technology: high efficiency contiguous comb crystal filters combined with new synthesis techniques. These advances permit the adherence to both frequency and time response specifications and offer a new concept in the design of radar and other spectrum-based systems.

Contiguous comb crystal filter banks are also the most reliable, efficient, compact and economical precision systems available for multichannel signal processing of all kinds.

Write for data on Gaussian Response Contiguous Comb Crystal Filters to Damon Engineering, Inc., Needham Heights, Mass. 02194, Tel. (617) 449-0800.

Electronics | June 12, 1967
With 22 years of achievement in space and defense programs, MELPAR continually expands horizons of R & D into broad new capabilities. Intimately associated with Mercury, Gemini and Apollo, we are now pioneering creative efforts on Voyager, Nimbus, Delta, and advanced Technical and Orbital Satellites.

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- Design of small special purpose digital computers and programming for real time and control applications, mathematical modelling.
- Theoretical and experimental design of missile and ground-based microwave antennas and microwave receivers and Microwave Components
- Advanced circuitry development and computer application related to information handling and processing.

**SIMULATION & TRAINING DEPARTMENT**
Computer systems design, programming, analysis and Human Factors for advanced weapon systems and tactics trainers.

**THE AVIONICS DEPARTMENT**
Radar, countermeasures and microminiature packaging techniques for aircraft avionics systems —video, HF transistor circuitry design

**ELECTRONICS RESEARCH CENTER**
- Data Compression Systems
- Redundancy Removal Coding Techniques
- Phonetic Pattern Recognition
- Signal Enhancement Techniques
- Wave Propagation-Acoustic-Electromagnetic
- Underwater Systems Research
- Thin Film Microelectronic Circuits
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**FIELD SERVICE ENGINEERS**
- Flight Simulators
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**CHEMISTRY & LIFE SCIENCES CENTER**
Develop methodology for detecting low levels of microbial contamination in and on spacecraft and space hardware to include Apollo and other major space programs.

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Instrumentation and technology of physical and chemical properties to include gas chromatograph, aerosols, measurements and particle size determinations.

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New Subassemblies

search, absorption spectroscopy, and biological and medical research.

Price for the laser and power supply is $8,500, with delivery quoted at 60 days.
Varian Associates, Eimac Division, 301 Industrial Way, San Carlos, Calif. [385]

Plug-in servo aimed for use in systems

A versatile, plug-in servo can be used to position and actuate a variety of loads as part of an automatic control system. Mounting is achieved by three standard synchro clamps. The 0.18-in.-diameter output shaft of the CS-195 is positioned in response to a d-c command signal applied to the unit. Torque produced is 250 in.-oz and the following speed is 36° per second. Accuracy of positioning is 0.1%. All electrical connections are by means of plug-in connector.

The unit contains a servomotor-generator, clutch-protected multi-turn feedback potentiometer, stable silicon transistor amplifier, and associated gearing. Variations are available for a-c and synchro command signals as well as for higher torque outputs.
Control Technology Co., 41-16 29th St., Long Island City, N.Y. 11101. [386]

No nonlinear devices in analog multiplier

A four-quadrant d-c voltage multiplier also squares, divides, and extracts square roots without either special nonlinear or magnetic devices or external amplifiers. The solid state, encapsulated Model
M101 allows mode selection by shorting pins, has no critical supply regulation requirements, and no zero adjustments.

Specifications include ±10 v differential inputs; 75,000 ohms minimum input impedance; output, ±10 v at 5 ma maximum, short-circuit protection; output impedance, less than 1 ohm; full scale linearity better than 0.25%; offset error, ±10 mv maximum; temperature stability of output offset, 1 mv/°C; operating temperature, -25°C to +85°C; frequency response in multiplication mode, d-c to 1 khz; power requirements, ±15 v d-c at 50 ma maximum; size, 3x2x5/8 in. The unit meets MIL standards.

Applications include electromechanical multiplier replacement, voltage-controlled linear attenuators, cross and auto correlation, power measurement, suppressed carrier modulation, servoanalyzers, and error correcting circuitry.

Price is under $500; availability, 3 to 4 weeks.
Intronics Inc., 57 Chapel St., Newton, Mass. 02158. [387]

Amplifier modules in 10-db increments

Extremely wide bandwidth (1 khz to 500 Mhz) and a modular building-block design are provided by a series of multiple decade amplifiers. The devices are called Unit Amplifiers because each module furnishes a fixed unit of gain in a single stage. A unit of gain is 10 db, and the modules weigh ½ oz. The concept makes it possible to cascade a series of modules with excellent impedance matching to achieve any amount of gain from 10 db to 60 or 70 db.

Unit Amplifiers have a flat gain

Bausch & Lomb has added a new dimension to metallurgy. You get all the advantages of the Dynazoom II Bench Metallograph plus full-range stereo viewing. Simply flip a lever and you can differentiate between inclusions and holes, scan a surface for fractures or study various surface levels caused by polishing and etching. Available as a complete stereo model or convert existing Dynazoom Metallographs by adding the zoom-stereo body. Send for Brochure 42-2211. Also available, the free booklet, “High Power Stereo” by Harold E. Rosenberger, No. S-513.

Transmitted light available on all models

For the study of transparent and translucent specimens on your Dynazoom Metallograph, there is now a Transmitted Light Accessory. Adapts readily to all models, including stereo. Can even be used with high N.A. 75x oil immersion objectives. Plastics, glass, thin films, evaporated coatings, oils and other liquid specimens can be examined. Send for our Brochure 42-2212.

Ask for a no-obligation demonstration of this equipment. Write Bausch & Lomb, 62342 Bausch Street, Rochester, New York 14602.

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Not much of a plot, but a great cast of characters.
The characters are 6,000 manufacturers and more than 4,000 product listings. Even if you’re not the literary type, you’ll be interested in the unprecedented opportunity the Electronics Buyers’ Guide affords you to reach readers. Over 445,000 engineer users go to EBG year round as a one-stop shopping center for all their electronic needs.
Closing date: July 14th. Book some space now!
First come, first served.

Q-switched laser systems that provide high peak powers and are water-cooled are available in the LHO1 series. They are solid state systems with a two-pulse-per-minute operation, using either ruby at 6,943 angstroms in the visible, or response from 1 khz to 500 Mhz in a single stage. The input and output 50-ohm impedance matching techniques provide a vswr of 1.5 to 1 maximum and are typically 1.2 to 1. The bandpass flatness is less than the 1 db over this multi-decade range. Input and output impedance levels are 50 ohms in all modules.

According to the manufacturer, the line is tailored for radar, electronic countermeasures, radiometry, communications, industrial electronics, computers, instruments, and the education equipment market.
Avantek Inc., 3001 Copper Road, Santa Clara, Calif. [388]
neodymium-doped glass at 10,600 angstroms in the infrared. The lasing subsystem is packaged as the model LH8 water-cooled laser head. A model LPS-28 power supply is used with the system.

Maximum peak pulse power of the series is 300 Mw. Typical pulse width is 9 to 10 nsec half height.

The LHOI series can be operated in the normal mode by removing the Q-switch, using the external mirror to complete the cavity, and modifying the flash-lamp pulse-forming network. Output in the normal mode is 35 joules with a pulse length of 1.5 nsec.

With a Kerr cell, the model is designated LHO1A. The Pockels cell model is LHO1B. Raytheon Co., 130 Second Ave., Waltham, Mass. 02154. [389]

Operational amplifier uses FET input

General-purpose operational amplifiers that employ a FET input stage provide $10^{13}$ ohms differential and common-mode impedances. Output characteristics ($\pm 10 \text{ v at } \pm 10 \text{ ma}$) are high for the size of the package ($1.12 \times 1.12 \times 0.58 \text{ in.}$). Typical input bias current is 10 picoamps. Common-mode rejection is 86 dB.

Due to the amplifiers' loop dynamics, the settling time is less than that of many competitive operational amplifiers with higher frequency response, the manufacturer claims. A fast slewing rate of 10 v/sec permits full output to 200 kHz.

The QFT-2, QFT-2A and QFT-2R have maximum temperature coefficients of 35, 10 and 5 $\text{uV/}^\circ\text{C}$, respectively. Prices are $45, $70, and $85, respectively. Delivery
New Subassemblies

takes three weeks for small quantities.
Nexus Research Laboratory Inc., 480 Neponset St., Canton, Mass. 02021. [390]

Light-coupled telemetry system

A telemetry system has been developed for use in environments where accurate measurements must be made and electrical isolation of the sensor is critical. Consisting of sensor, light transmitter, fiber optics, light guide, and light receiver, it can measure electric and magnetic fields and current or voltage, and can transmit data from field probes, ion detectors, accelerometers, and strain gauges.

The portable, battery-operated system covers a frequency range from 10 kHz to 30 MHz, and can be supplied with up to 48 ft of fiber optics.

In operation, the sensor monitors a signal that is then passed through a gallium arsenide diode to appear as a modulated light output. This light output is transmitted through the fiber optics guide to the light receiver where it is demodulated and the original monitored signal is reconstituted.

Price of a single-ended version is $2,250; a differential version costs $2,450.
Develco Inc., 440 Pepper St., Palo Alto, Calif. 94306. [391]

Switching matrix has 200 crosspoints

A video switching matrix can route any one of 10 video signals (telemetry receiver outputs) to one or more of 20 data distribution points; distribute closed circuit tv and wideband data signals; and provide nondestructive selection memory.

Major feature of the matrix is a network of 200 crosspoints, each of which incorporates its own magnetic latching Loc-Reed relay and has its own control address. Actuated by a 3-msec pulse, crosspoints require no holding power to remain operative or inoperative. In addi-
tion, a confirming signal insures that the selected source is routed to the correct output.

Integrity of signal is such that crosstalk is ordinarily held to 75 db or better.

Adaptable to rack or panel mounting, the switching matrix is less than 800 cu. in. in volume.

Price is approximately $7,500 each. Delivery takes about 12 weeks.

McKee Automation Corp., 7315 Greenbush Ave., North Hollywood, Calif. 91605. [392]

Miniature indicator for air navigation

A small indicator, with flag display or pointer, is suitable for aircraft navigation instrumentation. The unit utilizes a microminiature moving coil, core magnet mechanism. Sealed against dust and dirt, it operates in a wide variety of electrical sensitivities and functions at temperatures from -55°C to 85°C.

The AI-21 is \( \frac{7}{8} \) in. in diameter, \( \frac{3}{8} \) in. in length and weighs 11.5 grams.

Ammon Instruments Inc., 346 Kelley St., Manchester, N.H. 03105. [393]

20-section delay line for space telemetry

An unpotted, cordwood-type delay line has been developed for use in space telemetry equipment where light weight, small size, and reliability are prime requirements. Composed of 20 sections, the line is 2 in. long, \( \frac{3}{8} \) in. high and 0.600 in. wide. Weight is approximately 10 grams.

With a delay time of 2 µsec, the unit has a rise time of 250 nsec and an impedance of 1,000 ohms. Many of these parameters may be altered as required. A companion line, for example, fulfilling the same applications, with a delay of 0.5 µsec and a rise time of 165 nsec, is only 1 in. in length. When potted, it fulfills all applicable MIL specs.

Price is under $50 each. Delivery takes approximately six weeks.

Valor Electronics Inc., 13214 Crenshaw Blvd., Gardena, Calif. 90249. [394]

how activates ideas!

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There are other brands of industrial plastics but only one

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Circle 205 on reader service card 205
Richard Bruce is a member of our technical staff. He’s defining the atmospheric forces that act on earth satellites. (He calls it “the weather of outer space.”) He’s had to teach himself nearly everything he knows about the subject. There is no formal curriculum. Even basic facts are hard to get. Very few places have them. Aerospace is one.
New Microwave

Acoustic line gives 4-\(\mu\)sec delay

A microwave acoustic delay line designed for operation at the 1.25 GHz range can be used in moving-target indicators, electronic countermeasures and counter-countermeasures, altimeters, r-f checkout systems, and very-high-speed digital scratchpad memories. The unit is electrically matched into 50 ohms impedance.

At its center frequency, the delay line has a bandwidth of 600 Mhz and time delay of 4 \(\mu\)sec. Other parameters include: insertion loss, 56 db; spurious, -15 db; and vswr, 2:1.

The device measures \(\frac{1}{2} \times 2\frac{1}{2} \times 3\frac{1}{4}\) in. and weighs 4\(\frac{1}{2}\) oz.

Andersen Laboratories Inc., 1280 Blue Hills Ave., Bloomfield, Conn. 06002. [395]

Pulsed amplifier tube delivers up to 3 Mw

A pulsed-type Ampliton amplifier, a form of magnetron, is capable of power output levels from 0.5 to 3 megawatts over a frequency range of 5.4 to 5.9 Ghz. Called the QKS1343, the amplifier is an integral magnet tube with waveguide input and output. Modulators to be used with this tube can be designed to operate across the specified band without electrical or mechanical adjustment. Cooling is accomplished with forced liquids.

In a typical operation, peak power would be half a megawatt with average power output of 15 kw. With a duty cycle of 0.03, its pulse duration would be 200 \(\mu\)sec. Peak anode voltage would be 48-53 kv; peak anode current, 16 amps; driver peak power, 40 kw.

The QKS1343 weighs 75 lbs.

Raytheon Co., Waltham, Mass. [396]

Balanced mixer with high-density packaging

A miniature balanced mixer for microwave applications in the 1-to-5-Ghz range is said to be the smallest ever developed. The BMM-2 series mixers utilize the manufacturer's new ultraminiature quadrature (90°) hybrids, which permit drastic size reductions. Hot-carrier diodes are employed as active elements.

The mixers measure \(\frac{3}{4} \times \frac{3}{4} \times \frac{3}{8}\) in. and weigh less than \(\frac{1}{2}\) oz. Typical applications include spaceborne and aircraft systems and systems requiring high-density packaging, such as phased-array radars and portable military communications equipment.

Model BMM-2.2K was designed for telemetry applications in the

Electronics | June 12, 1967

The Aerospace Corporation performs systems engineering and provides technical direction for the U.S. Government on military space and missile programs.

Space Communications Systems Engineers Responsible for manned and unmanned spacecraft communications and data handling systems engineering which includes coordination of subsystem and user requirements, interface definition, specifications preparation review and technical direction of manned and unmanned spacecraft contractors and subcontractors. Requires a sound communications background and familiarity with space systems. Space vehicle design, experience in tracking, telemetry, command, and voice communication systems is desirable. A balance between analytical and practical engineering experience is preferred.

Satellite Systems Engineers Conduct systems analysis in support of advanced satellite programs. Must be capable of defining system performance requirements to establish ground and airborne systems specifications for contractor hardware fabrication. In addition to systems analysis background, depth required in some of following systems: electro-optical, communication, data processing and displays, attitude control.

Computer—Display Engineers Should be experienced in design, development and analysis of display generation and display presentation computer systems; experience in systems engineering and technical direction of large-scale digital and software systems development and testing programs. To participate in the advanced planning, systems engineering and technical direction of displays for both ground and spaceborne systems.

Radar Systems Engineers Perform analysis and program support on advanced radar systems. Analytical and hardware design experience required in phased array, pulse compression, receiver signal processing, current pulse, cw and pulse doppler techniques as applied to airborne and missile radar systems.

If you have an advanced degree and a minimum of five years experience, contact The Aerospace Corporation, an equal opportunity employer. Write to Stephen D. Robinson, P.O. Box 95085, Los Angeles, Calif. 90045.

The Aerospace Corporation
DID YOU SAY INSIDE?
YES!
Delevan will put
MICRO SWITCH
Inductors & Transformers

INDUCTORS
- Size .100, .150, .250 SQ x .065 HIGH
- L Range .015 uh to 1000 uh
- Shielded, Encapsulated, Excellent T.C.
- Meet MIL-C-15305C Grade & Class 5

TUNABLE INDUCTORS
- Size .150, .250 SQ x .125 HIGH
- L Range .10 uh to 1,300 uh
- Tuning Range 1.7 to 1
- Excellent Resolution, Non-Retractable Tuning

RF TRANSFORMERS
(FIXED AND TUNABLE)
- Size .100, .150, .250 SQ x .125 HIGH MAX.
- Frequency Operation — 500 KHz to 50 MHz
- IF & Wideband Designs Available
- 30 MHz & 60 MHz IF Designs in stock

HI-Q COILS
- Size .250 SQ x .125 HIGH
- L Range .12 uh to 1000 uh
- Q values in area of 100
- Direct replacement for toroids
- L tolerances as low as ±1%

need a mountain of data on, say, the rumblings of Vesuvius?

New Microwave
2.2-to 2.3-Ghz range. Other models covering frequencies down to 1
Ghz or up to 5 Ghz are available on special order.
Typical characteristics of the
BMM-2-2.2K include: noise (at 1.5
db i-f), typically 6.3 db; isolation,
12 db; typical vswr for all three
ports, 1.25:1; and an operating r-f
bandwidth in excess of 10%.
Price is $225 in small quantities,
and delivery is from stock to 30
days.
Merrimac Research & Development
Inc., West Caldwell, N.J. 07006. [397]

High stability offered
by local oscillator

Lockheed’s 28-lb.
417 recorder
goes and gets it.

You can’t top the 417’s portability.
Carry it almost anywhere with one
hand. Any comparable recorder scales
at least 50 lbs. more. And accuracy?
The 417 matches even large rack
machines.
Durability is another advantage. The
417’s dual capstan transport provides
precision operation under vibration
and in any position.
The 417 operates from its internal
battery or from 110/220 volts AC with
power consumption as low as 10
watts. Frequency response is 100kc
direct, 10kc FM. And it comes in a
neat 14” x 15” x 6” package—small
enough to fit under an airplane seat.
The price is compact, too. Starting at
$7,000.
Next time you’re smoking-out data,
remember the lightweight 417. For
information, write Boyd McKnight,
Dept. E, 612 Edison, New Jersey.
input. They are also available with voltage control of frequency for phaselock operation.

The oscillator is packaged in a lightweight, 25-cu in. aluminum alloy housing. All circuits are etch wired and are encapsulated. Mean time between failures is in excess of 10,000 hours.

Applied Technology Inc., 3410 Hillview Ave., Palo Alto, Calif. [398]

Solenoid switches
waveguide attenuator

A solenoid control designed for remote controlled equipment and systems applications switches an attenuator in and out of the circuit to produce an on-off fixed level of attenuation across the full frequency range of a waveguide.

Designated model M15SA, the unit has the following specifications: frequency range, 10 to 15 GHz; attenuation, 40 dB; accuracy, ±2.0 dB; insertion loss, 0.3 dB maximum; vswr, 1.15 maximum; r-f power, 5 w c-w maximum; actuator power, 15 w at 28 v d-c (continuous duty); waveguide type, WR-75.

Price available on request. Delivery takes 45 days.

E&M Laboratories, 7419 Greenbush Ave., North Hollywood, Calif. [399]

Double-balanced mixer spans 0.20-500 Mhz

A double-balanced mixer for applications at frequencies ranging from 0.20 to 500 Mhz can be operated as a mixer, phase detector, current-controlled attenuator, frequency doubler, balanced modulator, amplitude modulator, or pulse modulator.

Called the DM-1-250, its performance characteristics vary...
HV Rectifiers
from .150 to 7 in. long
Diffused High Voltage silicon rectifiers available with 300 nanosecond recovery time (optional) and in custom designed assemblies.

A .060 diameter.
.150 long.
1,000 to 3,500 volts PIV.
25 to 50 ma average rectified current.
Transfer molded epoxy package.

B .100 diameter.
.400 long.
1,000 to 6,000 volts PIV.
50 to 100 ma average rectified current.
Transfer molded epoxy package.

C .500 diameter.
1 to 7 inches long.
3,000 to 70,000 volts.
15 to 75 ma average rectified current.
Epoxy encapsulation.

For use in diode-capacitor voltage multipliers, cathode ray tube power supplies, RF power supplies (up to 200 KC), precipitator power supplies, and photo multipliers. Also available in diode-capacitor multiplier assemblies.

New Microwave

Frequency converter
for telemetry systems

A frequency converter is available for use in S-band telemetry systems. Input signals of 2,200 to 2,300 MHz are converted to signals of 215 to 265 MHz. Called the SFC-2250, the converter is a wide-dynamic-range, self-contained, solid-state unit that includes bandpass filters, tunnel diode amplifier, local oscillator-frequency multiplier, amplifier mixer, amplifier detector, and power supply.

The unit has an 8.5-db max. noise figure and ±0.001% frequency stability for any 24-hr period. Phase modulation error at output does not increase more than ±5° from 1.5 kHz to 1 MHz. Phase linearity is ±9° over any 5-MHz passband portion. Gain stability is ±1 db at any given passband frequency spanning a minimum time of 24 hrs.
Adjustment with a screwdriver enables the nominal 40-db gain to be varied ±2.5 db minimum for input levels between -80 and 0 dbm. Automatic gain control maintains the output power within limits (0 dbm ±2 db) for input power levels up to 0 dbm. Intermodulation distortion is 3% or less for input levels to 0 dbm max. Temperature range is +20° to +150° F.

Convection-cooled load handles 20 kw

An S-band dummy load has been developed that handles fully rated peak power and 20-kw average power without the use of liquid cooling. Designed for a transportable radar system, the dummy load features a built-in forced air cooling system with an air flow safety interlock switch. It operates over a frequency of 2.7 to 3.3 Ghz, and has a maximum vswr of 1.20.

Designated model W1-A03, the high-power dummy load withstands internal gauge pressures of 45 psi and operates over a temperature range of -54° to +65° C in 100% relative humidity. The design techniques can be applied to other waveguide bands, according to the manufacturer.

Microlab/FXR, Ten Microlab Road, Livingston, N.J. [402]

DIAL-A-SOURCE

(DIALABLE "ZERO IMPEDANCE" VOLTAGE SUPPLY)
- 1 PPM RESOLUTION
- SECONDARY STANDARD
- 25 M.A. (ZERO IMPEDANCE)
- 1 MICROVOLT TO 10 VOLT RANGE
- 5 PPM OUTPUT REGULATION (NO LOAD TO 1 M.A.)
- DIALABLE IN-LINE VOLTAGE READOUT
- ±10 PPM STABILITY
- FLOATING OUTPUT; 1000 MEAS ISOLATION
- REMOTE SENSING SUPPLIES .0025%
- CALIBRATED VOLTAGE AT THE LOAD
- NOISE AND RIPPLE LESS THAN 3 PPM OF OUTPUT OR 20 MICROVOLTS PEAK

Also available Model DAS46 ±.005%, $375.00. Write for Bulletin #512

DIAL-A-VOLT

(DIALABLE VOLTAGE REFERENCE)
- D.C. VOLTAGE ACCURACY, 5 MODELS - .0015% TO .005%
- RANGE 1 MICROVOLT TO 10 VOLTS
- 6 DIAL, 1 PPM RESOLUTION
- 10 PPM STABILITY
- TEMPERATURE COEFFICIENT TO ±1 PPM/°C
- DESIGNED FOR D.C. CALIBRATION AND REFERENCE
- FINGERTIP DIALABLE CONTROL

Priced from $399.00. Write for Bulletin #407

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in West Palm Beach, Florida is its EXTRA INDUSTRIAL ASSETS!!

ITT, Solitron, Pratt & Whitney, and R.C.A. have found them to be an important recruiting tool. Let us tell you more about how our EXTRA INDUSTRIAL ASSETS can become your most valuable asset.

For Color Brochure and information about our Extra Industrial Assets write in confidence to: E. Vincent Burkhardt, Chairman, West Palm Beach Industrial Commission, P.O. Box 1506, West Palm Beach, Florida 33402.
PIGTAIL FUSES
BODY SIZE ONLY .145 x .300 INCHES

For use on miniaturized devices, or on gigantic space tight multi-circuit electronic devices.
Glass tube construction permits visual inspection of element.
Smallest fuses available with wide ampere range. Twenty-three ampere sizes from 1/100 thru 15 amps.
Hermetically sealed for potting without danger of sealing material affecting operation. Extremely high resistance to shock or vibration. Operate without exterior venting.

INSIST ON Buss QUALITY
BUSSMANN MFG. DIVISION, McGraw-Edison Co., St. Louis, Mo. 63107

Tell us what you need or... Write for BUSS Bulletin SFB.

FOR PROTECTION OF CIRCUITS OF 600 VOLTS OR LESS

Watertight construction; resistance to damage by weather, water, salt spray or corrosive fumes permit use of TRON fuseholders in exposed locations where safety and long life are of vital importance.

TRON fuseholders are available to take two sizes of fuses, \( \frac{5}{16} \times \frac{1}{2} \) and \( \frac{5}{16} \times \frac{3}{8} \); and take many sizes of solid or stranded wire.

Write for BUSS Bulletin SFB-11

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

Circle 212 on reader service card

3" dia. x 3¼" long, 16 ounces

NEW VANEAXIAL AC/DC UNIVERSAL BLOWER

Globe's VAX-3-GN Universal Blower gives you 110 cfm, free air, with a design point of 68 cfm at 1.5" static pressure. It's a design point of 68 cfm at 1.5" H₂O on either 115 v.d.c. or 115 v.a.c., 60 cycle power. Other voltages can be supplied. Nominal speed is 14,000 rpm.

You can standardize on this extremely versatile blower for ground support and commercial electronic cooling. It's designed to meet MIL specs, having passed shock and vibration per MIL-E-5272. Production tooling makes this blower economical. Prototypes can be in your hands tomorrow (telephone BA-2-3741 for part no. 19A908); production orders normally delivered in a short time.

Rugged mechanical protection is provided by the black anodized aluminum housing and propeller. Mount by clamping to servo ring at either end. Nominal life exceeds 1000 hours. Max. current is 0.47 amps at free air delivery. Request Bulletin GNB from Globe Industries, Inc., 2275 Stanley Avenue, Dayton 4, Ohio.

GLOBE
New Production Equipment

Trimmer-former handles IC leads

A new tool called the Versitron forms and trims the leads of TO-5 cans with a 90° turn of the operating lever. The leads are angled outward to the diameter of the TO-5 housing, directed downward, and then sheared to a predetermined length.

Because of the accurate forming, the can is easily mounted on p-c boards; it stands clear by 3/8 in. and doesn’t need a spacer. The formed leads can be flow-soldered along with other components on the card without fear of the solder shorts that often occur with flush-mounted cans.

The Versitron processes 500 cans an hour. Its slotted and chamfered head makes for easy can insertion. The unit stands 9 in. high and weighs 4 lbs. Forming and shearing components and mechanical linkages are of tool steel.

Basic price with one of several standard forming and shearing heads is $275; additional heads are optional.

Versitron Inc., 6310 Chillum Place, N.W., Washington, D.C. 20011. [403]

Copper-free coating with vapor system

Phosphors for color tv tubes, coatings for optical devices, and other organic coating compounds can be applied with a copper-free vapor carrier system. The vapor-generating console and spray guns are built of steel, mostly stainless, and Teflon so there is no danger of copper contamination of the coatings. The unit also can be used to apply photoresist to ic substrates and p-c boards, as well as conformal coatings of epoxy and polyurethane to electronic assemblies.

In operation, Chemsine or Freon

Copper-free coating with vapor system

Phosphors for color tv tubes, coatings for optical devices, and other organic coating compounds can be applied with a copper-free vapor carrier system. The vapor-generating console and spray guns are built of steel, mostly stainless, and Teflon so there is no danger of copper contamination of the coatings. The unit also can be used to apply photoresist to ic substrates and p-c boards, as well as conformal coatings of epoxy and polyurethane to electronic assemblies.

In operation, Chemsine or Freon

Fuseholders of Unquestioned High Quality

SUB-MINIATURE FUSEHOLDER COMBINATION

For space-tight applications. Fuse has window for inspection of element. Fuse may be used with or without holder.

Fuse held tight in holder by beryllium copper contacts assuring low resistance.

Holder can be used with or without knob. Knob makes holder water-proof from front of panel.

Military type fuse FM01 meets all requirements of MIL-P-23419. Military type holder FHN42W meets all military requirements of MIL-P-19207B.

Write for BUSS Bulletin SFB

QUICK-ACTING FUSES

“Quick-Acting” fuses for protection of sensitive instruments or delicate apparatus;—or normal acting fuses for protection where circuit is not subject to current transients or surges.

Write for BUSS Bulletin SFB.
Ceramic Capacitors

MOLDED CERAMIC TUBULARS
for computer applications. The ultimate in reliability (failure rate 0.001%/1000 hours at 85°C and twice rated voltage.)

DISC CERAMICS
for all commercial and military applications. New production techniques give Skottie a big edge in price, quality and delivery. Ask for a quote and find out if it's not so.

Do you have a problem in ceramic capacitors with special designs, quality, reliability, guaranteed delivery or price? If you do, it might pay you to look into Skottie Electronics. We specialize exclusively in the design and manufacture of ceramic dielectric capacitors. Skottie is a major supplier of ceramic capacitors to the largest computer and radio/TV manufacturers in the world.

Sure we do the military and commercial standards. But in ceramics, when you have special needs (particularly design or delivery) we think you'll find Skottie Electronics your best supplier. Representatives in major cities throughout the United States.

SKOTTIE ELECTRONICS, INC. / Archbald, Pennsylvania 18403
Phone 717-876-1686 TWX 510-658-2979

Small kiln fires films on substrates

A small kiln fires conductive, resistive, and dielectric materials on ceramic substrates during experimentation and process development. The Explorer I has operating...
MAGNETIC SHIELD REFERENCE GUIDE
TO STOCKED NETIC & CO-NETIC
MAGNETIC SHIELDING FOIL AND
SHEETS FOR YOUR FABRICATION

<table>
<thead>
<tr>
<th>THICKNESS</th>
<th>NETIC S3-6 SHEET WIDTH</th>
<th>CO-NETIC AA SHEET WIDTH</th>
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<tbody>
<tr>
<td>.014&quot;</td>
<td>30&quot;</td>
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Maximum length is 120".
Also sold in 15", 30" and 60" lengths.
After fabrication, shields made from sheet must be heat treated for maximum shielding. No further annealing required.
Pre-annealed stock also available.

<table>
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<th>CO-NETIC AA FOIL IN COILS:</th>
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<td>(Specify length desired)</td>
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<tr>
<td>.004&quot; thick x 15&quot; wide</td>
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<td>.004&quot; thick x 4&quot; wide</td>
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<td>.002&quot; thick x 4&quot; wide</td>
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<th>BLUE NETIC FOIL IN COILS:</th>
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<tr>
<td>(Specify length desired)</td>
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<tr>
<td>.004&quot; thick x 19½&quot; wide</td>
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<tr>
<td>.004&quot; thick x 4&quot; wide</td>
</tr>
<tr>
<td>.002&quot; thick x 4&quot; wide</td>
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</tbody>
</table>

All foil also available adhesive backed.
Other widths available to maximum above.

- Non-shock sensitive; requires no periodic annealing
- DELIVERY TIME—normal delivery time on stock widths is 1 to 2 days after receipt of order. For adhesive backed foils, approximately one week, and for foils slit to desired width, approximately 1 to 2 weeks.

Both BLUE NETIC and CO-NETIC AA foils, plain and adhesive backed, can be furnished slit to any desired width, at additional cost—Ask for prices.

Maximum length is 120".
Also sold in 15", 30" and 60" lengths.
After fabrication, shields made from sheet must be heat treated for maximum shielding. No further annealing required.
Pre-annealed stock also available.

MAGNETIC SHIELD DIVISION
Perfection Mica Company
1322 N. ELSTON AVENUE • CHICAGO, ILLINOIS 60622
Phone: 312, EV 4-2122 • TWX 910, 351-0155.

Circle 258 on reader service card

All you need to solve most transformer design problems is a TRIAD catalog...

And your phone.
TRIAD distributors are practically everywhere, offering you over 1700 off-the-shelf transformers for immediate delivery. Chances are the unit you thought would have to be custom-made is at your TRIAD distributor's now. Of course, when you do need a custom job, turn to TRIAD too, for the best answer to your transformer, inductor and filter problems.
Send for your catalog today. TRIAD Distributor Division, 305 North Briant St., Huntington, Indiana.
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(Electrical and Mechanical)

Lockheed offers important assignments for experienced microwave antenna engineers. Work on large unfurlable reflector antennas and phased array systems for satellite and deep space vehicles. Design antennas for hostile reentry conditions of the new Poseidon Fleet Ballistic Missile and for tactical applications. BS or advanced degree in EE, ME or Physics, plus 5 years or more antenna design experience. A few positions are available for selected recent graduates. Reply to: R. C. Birdsall, Professional Placement Manager, Post Office Box 504, Sunnyvale, California 94088. Or call collect: (408) 743-2200 until midnight, Pacific Coast time. Lockheed is an equal opportunity employer.

BEST vacuum
THERMOCOUPLES

Standard and UHF patterns; high output and square law types; matched pairs.

Used by prominent instrument manufacturers in the U.S. and abroad for:
- true RMS measurement
- transfer standards
- sum and difference multipliers
- low range UHF applications.

For example, by HEWLETT-PACKARD:

H-P's Model 3400A true RMS voltmeter uses a matched pair of Best UHF type thermocouples to give high accuracy, broad frequency response, DC calibration and long term stability.

If you are designing or manufacturing an AC instrument, why not make it true RMS?

See Sec. 5300, '67 EEM. Catalog on request. For free application notes, write on company letterhead to

BEST ELECTRICS DIV.
HARRY LEVINSON CO.
1211 E. Denny Way, Seattle, Wash. 98122
Tel. (206) 323-5100 TWX 910-444-2154

Production Equipment

characteristics that allow easy conversion from pilot to volume production, according to the BTU Engineering Corp.

The kiln is inclined 2° from the horizontal to induce a laminar flow of muffle atmosphere over the product. Volatile contaminants released in the initial heat-up are quickly carried out.

Operating temperature range of the model EXP-I-2000 three-zone kiln is 400°C to 1,000°C, with accuracies better than ±2°C. Dimensions are 78 x 19 x 51 in.

Optional equipment includes an air preheater, radiant dryer, special speed controls, and overheat protection.


Replaceable glass tip cuts bonding costs

Easy-to-clean, replaceable glass tips for thermo-compression bonders are being marketed at prices only 1/6 to 1/16 as much as those for conventional metal tips. The manufacturer says the new tips also provide a better bond for IC's because of the natural smoothness of glass. Unlike metal, the surface of glass isn't granular and is completely inert. Because of this, the firm says, the bore doesn't deteriorate, a common defect of metal bonding tips. There is less buildup of gold floss within the tip bore and considerably less plugging.

When plugging does occur, the glass tip can be replaced in a mat-
General Technology's Rubidium "atomic clock" records over million hours operational time.

Reliability now proven; MTBF established at 22,000 hours per unit.

Records kept since 1961 on every Rubidium Frequency Standard made by GTC show the average time between random component failures to be 87,000 hours — almost 10 years!

The Model 304-B shown here is but one in a complete family of all solid-state atomic frequency standards made by GTC for use in field and laboratory. Maximum deviation is ± 5 parts per 10¹¹ in a year, or better. Special versions meet environmental and other requirements for tactical and missile/aircraft use.

For solutions to your stable-oscillator problems, write General Technology Corporation, subsidiary of TRACOR, Inc., 6500 Tracor Lane, Austin, Texas 78721. Phone 512-926-2800.

Air variables from JFD solve your high Q high frequency problems

These new JFD air variable capacitors are specially designed for high frequency applications that demand ultra stability, small size and high Q — greater than 2000 measured at 10 pf and 100 MC. These rugged, miniature units are offered in both printed circuit (VAM 010W) and panel mounting (VAM 010) models with capacitance ranges from 0.8 through 10.0 pf measured at 1 MC.

These units which measure less than ½” in length are completely interchangeable with competitive devices.

Internal air meshing shells are silver plated to provide good surface conductivity and to prevent corrosive effects. Internal contact springs assure positive electrical contact of rotor at all times. Leads on printed circuit model are tinned for ease in soldering . . . and these units are engineered to resist heat, won't come apart during soldering.

Bulletin VAM-65 gives more details. Write for your copy today.
The Man from E.A.G.L.E.* presents two samples that show the range in his bag of timing tricks. The CA100 solid state timer provides split-second control of continuous, high-speed, "on-off" cycles from 3 to 2000 times a minute. Housed in Eagle's famous Cycl-Flex case, the CA100 can be plugged in and taken out in seconds. Solid state circuitry eliminates moving parts, makes this timer great for dusty, dirty locations. At the other extreme the HG100 electromechanical dual-function timer does the job of two ordinary timers. With a single, easily-set dial it provides adjustable "on" and "off" time periods for cycles ranging from 30 seconds to 60 hours. It gives you unmatched ease of adjustment without setting cams or changing gears.

For detailed descriptions of one or both of these timers, get our CA Series Bulletin 322 and our HG Series Bulletin 320. Write Eagle Signal Division, E. W. Bliss Company, 736 Federal Street, Davenport, Iowa 52808; or call (319) 324-1361.

*E.A.G.L.E.—Engineering Assistance Given Locally—Effectively.
ter of seconds. Plugged tips are cleaned by a soaking in a solution of aqua regia; no poking or probing is required. And because of the chemical inertness of the glass, cleaned tips are as good as new ones. Also, the natural transparency of glass permits easy visual inspection.

The new glass tips are designed for standard thermo-compression bonders. They are available in various sizes with bores as small as 0.0005 in. in diameter. Bores are accurate to ±0.0001. Outside diameters of the tips are held to ±0.0005 in.

Specialty Glass Products Inc., 144 Terwood Rd., Willow Grove, Pa. 19090. [406]

Hand gun applies hot-melt adhesives

A hand gun for applying hot-melt adhesives has been designed to be used with the company’s Thermo-pulse unit, which converts solid adhesives into liquid form. Its primary application is to apply the adhesive in cases where fully automatic equipment is not practical.

Called the X77300, the gun has a trigger that enables the operator to control the on and off functions. It can be used either to place small dots of adhesive or lay down continuous lines. When used with control equipment, the gun can lay down precisely measured lines or exact-sized dots.

Temperatures up to 500°F are maintained with built-in heaters, a solid state controller, and a thermistor.

Spraymation Inc., 52 Sindle Ave., Little Falls, N.J. 07424. [407]
New Materials

Silicone adhesive adaptable and rapid

A translucent nonflowing silicone rubber that cures rapidly without addition of a curing agent is suitable for a variety of applications. Eccosil 1776 bonds to glass, ceramics, metals, and plastics. According to the manufacturer, no other adhesive product can match it for flexibility, extreme environment performance, long life, and ease of use.

Cartridges fit a standard caulking gun for use in the field or on the production line.

Cured properties are: hardness (Shore A), 35; tensile strength, 400 psi; elongation, above 350%; temperature range, $-100^\circ \text{F}$ to $+450^\circ \text{F}$; dielectric strength, 450 volts per mil; volume resistivity, $10^{16}$ ohm-cm; dielectric constant (1 kHz), 2.8; dissipation factor (1 kHz), 0.003.

Eccosil 1776 comes in a single cartridge (11 oz) or ten-cartridge packages. Price is about $8$ per cartridge.

Emerson & Cuming Inc., Canton, Mass. [408]

Indium-tin alloy solders glass

A low-melting-point alloy, composed of 50% indium and 50% tin, will adhere to glass, mica, quartz, thermosetting plastics, and many glazed ceramics. Cerroseal-35 is reported to be particularly suitable for fastening glass to glass and glass to metal joints. It can be used for sealing glass domes to metal bases, attaching metal fittings to the end of glass cylinders, soldering electrical conductors to glass, and as a metal-to-metal solder in assembling electronic components.

Cerroseal-35 softens at approximately $240^\circ \text{F}$ and is liquid above $260^\circ \text{F}$. Because of its low vapor pressure, it can be used in high vacuum apparatus. The alloy, its developer reports, will bond to any metal tinned with ordinary lead-tin solder, providing tinning is done at the same temperature ($450^\circ \text{F}$ to $500^\circ \text{F}$) required for ordinary solders with flux.

Cerro Copper & Brass Co., Stamford, Conn. [409]

Dielectric lacquer features high Q

Extremely low loss and high Q characterize a radio-frequency dielectric lacquer. Called Q-Lac, the material is applied as a protective coating and an insulation for electronic components and circuits.

Q-Lac is composed of a cross polymer of iso-polystyrene, formulated in accordance with the Clausius-Masotti equation for a low-loss dielectric material. The absence of electrical dipoles assures a low loss factor.

The lacquer is strongly adherent and resists moisture. It displays high surface resistivity because of the strong hydrophobic character of the Q-Lac films. Exposure to 98% relative humidity doesn't alter the surface conductivity. The product can be used as a dielectric coating for coils and other electronic components where circuit Q is important.

Properties of Q-Lac film include: volume resistivity of $1 \times 10^{15}$ ohm-cm; surface resistivity, $5 \times 10^{14}$ ohm; dielectric constant, 2.53 (1 MHz) and 2.52 (50 MHz); dielectric strength, 2,200 volts/mil; power factor, 0.001 (1 MHz) and 0.0005 (50 MHz); loss factor, 0.002 (1 MHz) and 0.001 (50 MHz); dissipation factor, 0.0001 (1,000 Hz); $\text{H}_2\text{O}$ absorption coefficient, less than 0.01; temperature range, $-40^\circ \text{C}$ to $+100^\circ \text{C}$.

Transene Co., Rt. 1, Turnpike, Rowley, Mass. 01969. [410]
BOBBINS

RADIO —
Moldcrafters of transformer bobbins oscillator I.F. and R.F. coil forms and stereo tape cartridges.

TELEVISION —
Producers of color yoke insulators, terminal boards, housing and convergence coil bobbins.

COMPUTER AND TELEPHONE —
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New Books

Tracking the field
Phase-Lock Techniques
Floyd M. Gardner
John Wiley & Sons, 182 pp., $8.95

Although the phase-lock principle has been known for quite some time, it has only been in the last decade that intensive work was directed toward engineering applications. This increased interest is a direct result of the requirements for modern communications, and for tracking and guidance of space vehicles at great distances.

The author has compiled the first comprehensive text to appear on phase-lock techniques. He has wisely allowed a certain settling period to take place after the initial flood of new knowledge on the subject before putting together his book. Currently, there is a great need among engineers for a focal point of information in this area, and this book meets that need. It offers an accurate and illuminating description of the important topics in theory and practice, and a wealth of references.

There are still unresolved problems in phase-lock techniques dealing with the more esoteric questions of loop threshold. However, at the engineering level the author utilizes experimental and analytical data to provide the reader with sound evaluations. In areas difficult to quantify, such as threshold performance, the author incorporates the theoretical knowledge and experimental evidence currently available into a logical, impartial discussion.

The book is directed to the engineer with a background in control systems and communications, and is particularly useful for those engaged in the analysis and design of phase-lock devices.

Jean A. Develet Jr.
TRW Systems
Redondo Beach, Calif.

On course
Range Instrumentation
Edited by Ernest H. Ehling
Prentice-Hall, 634 pp., $16.75

Radar engineers interested in developing new systems for missile test ranges should find this book helpful and instructive, but so should radio, computer, and optical-instrument designers. There's something here for everyone concerned with range instrumentation.

Each of the 10 chapters covers a specific area of the technology involved and is written by an expert in that field. The reader is first introduced to the objective of the technology and is then shown the design processes leading to the development of an instrumentation system. Actual range instruments are used as examples.

Range instrumentation and indirect measurements are generally discussed from the systems point of view, but the editor has included the mathematics of data reduction wherever it is helpful. The reader is thus offered a combination of engineering data and analytical and statistical solutions to instrumentation problems. Many of the problems and solutions are common to other areas of engineering.

The book assumes the reader has some knowledge of radar, optical systems, and so on. To develop theory, the reader must look elsewhere, but the practical solutions to problems are well documented.

After an introductory chapter, optical instrumentation, instrumentation radar, doppler systems, phase comparison systems, and radio telemetry systems are discussed. The remaining chapters describe instrumentation support systems, range ships, on-board measurements, and missile launch vehicles, while appendices review the mathematics of statistics and probability.

The chapter on instrument support systems is particularly useful. It defines the relationships between range instrumentation systems and is helpful for flight test work.

The editor explains the theory of normal equations, the techniques of least squares, the laws of propagation of covariance, and interpolation. Naturally, the relation of these theories to the range tracking problem is stressed.

W.J. Evanza
Avionics editor
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New Books

Recently published

Modern Analytical Design of Instrument Servomechanisms, Bruce A. Chubb, Addison Wesley Publishing Co., 228 pp., $11.95

In presenting the latest analytical techniques for designing instrument servomechanisms, the author considers all component tolerance effects. Specification techniques are discussed, with emphasis on obtaining design data from component specifications.


A mammoth volume dividing the basic sciences underlying engineering practice into seven sections—mathematics, physics, chemistry, graphics, statistics, experiment theory, and mechanics. Discussion of basic definitions and derivations in each of these areas is followed by examples of their use in engineering calculations.


Another in Texas Instruments Incorporated's Electronics Series, the book looks at the basic principles of the metal oxide semiconductor field effect transistor as they apply to circuit design. Included are discussions of the device's theory of operation, characteristics, and usage in both discrete and integrated-circuit form.

Threshold Logic, P.M. Lewis and G.L. Coates, John Wiley & Sons Inc., 483 pp., $15

Directed at both the circuit designer and the engineering student, the book presents a complete exposition of the subject, with emphasis on synthesis for prescribed sensitivity constraints. The function tree is used as a unifying concept in this presentation.


A monograph describing a solid state pulse generator configuration for high-power outputs. A detailed analysis of the basic circuit is presented as a starting point for adaptation to particular requirements. The design and construction of an experimental model illustrates the application of the analysis given.

Basic Switching Circuit Theory, Moshe Krieger, Macmillan Co., 256 pp., $9.95

An introductory work on modern switching circuit theory aimed at the advanced undergraduate. Basic concepts of Boolean algebra are reviewed. A symbolic representation of switching devices as gates is developed and used in a presentation of the theory and design of combinational and sequential circuits.


Basic circuits using semiconductor devices are analyzed in detail, along with discussions of the basic physical theory and principles of semiconductor devices.

RCA Receiving Tube Manual, Radio Corp. of America, Harrison, N.J., 608 pp., $12.50

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**Technical Abstracts**

**Small loss**

A new class of low loss reactive wall waveguides
R.P. Larsen
Grumman Aircraft Engineering Corp.
Bethpage, N.Y.
A.A. Ol ner, Polytechnic Institute of
Brooklyn, New York

Experiments and theoretical analysis have established the feasibility of achieving very low attenuation in a new class of waveguides employing reactive walls. Such waveguides would be of great value in millimeter wave or high-power microwave systems. The reactive walls are designed as periodic structures formed by an array of parallel dielectric slabs. Initially, the analysis was made on the basis of an infinite parallel plate waveguide in which both conducting plates are replaced by identical one-dimensional, semi-infinite dielectric structures. Design parameters and excitation frequency are chosen so that operation lies well within the stopband of the transverse, periodically-loaded transmission lines. Thus, the electromagnetic field is rapidly attenuated in the direction perpendicular to the direction of propagation. Under ideal conditions, this produces a purely reactive impedance in the direction of propagation, resulting in low loss.

The parallel plane configuration is capable of supporting two types of modes, one for which the field contains only magnetic field components perpendicular to the plane of the dielectric slabs (transverse H-mode), and a second which contains only electric field components (transverse E-mode). Structures to support the transverse E and H modes can be combined to form a rectangular waveguide with four reactive walls. Theoretical analysis shows that such a waveguide has an attenuation constant almost one-third of an equivalent all-metal rectangular guide—6.55 x 10^5 decibels per meter compared with 21.2 x 10^5 decibels per meter.

To verify the theory, a length of the reactive waveguide was built as a single-ended cavity, and resonant frequency and Q measurements were taken. The results, at a nominal frequency of 3,000 Mhz, showed rather good agreement with the theoretical analysis.

Preliminary studies by the authors indicate that circular reactive waveguides operating in the H_0 mode would also exhibit smaller losses than all-metal circular guides of corresponding dimensions designed to carry the low-loss circular electric mode.

Presented at the 1967 G-MTT International Microwave Symposium, Boston, May 8-11.

**Averaging capacitors**

Multiple-Curie-point dielectrics
R.A. Delaney and H.D. Kaiser
International Business Machines Corp.,
Hopewell Junction, N.Y.

Designers of thick-film integrated circuits usually prefer to pay the extra cost of adding discrete capacitors to the circuit, rather than making a screen-printed and fired capacitor part of the circuit. One reason for this is that printed capacitors generally remain stable in value only within a limited temperature range—their dielectric constant goes haywire around the ferroelectric Curie point.

Now, the capacitance value of thick-film capacitors can be made fairly stable over a wide temperature range. Making the printing paste of several different dielectrics allows the temperature characteristics to be tailored and improves adherence to the substrate.

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Circle 227 on reader service card
Technical Abstracts

about 120°C. At about 80°C, its dielectric constant begins rising sharply from the normal value of about 2,000. At about 120°C, the constant is nearly 5,000. When it is mixed with strontium titanate, the Curie point falls. Adding lead titanate or lead zirconate raises the Curie point.

Merely mixing such materials, however, doesn't solve the problem. When the mixture is fired—a necessary part of the circuit production process—the dielectrics combine and capacitance still varies widely with temperature. The way around this hurdle is to prepare the mixture so that discrete particles of each dielectric are separated from each other in an inert material. Then, the capacitor has several Curie points and its dielectric constant doesn't peak at any temperature. One such mixture has a dielectric constant between 380 and 400 over a temperature range of 0 to 100°C.

The dielectric constant is reduced from the bulk value of the barium titanate primarily because the particles are suspended in a glassy matrix with a relatively low dielectric constant. The composition is sintered at a temperature well above the IC firing temperature, so that the dielectric particles will remain separated after firing. After sintering, the composition is powdered and mixed with an organic binder to form the printing paste. The organic binder escapes when the circuit is fired. After firing, the capacitor is glazed.

Presented at the Electronic Components Conference, Washington, May 3-5

Old trick, new turns

Broadband cable chokes
Ernest T. Harper*
U.S. Army Electronics Command, Ft. Monmouth, N.J.

Throw away those tuning slugs, a way has been found to make cable chokes broadband. They will isolate antennas from their feed cables over a band as wide as 10 megahertz, or more, without the necessity of tuning the choke to

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Coarse & Fine Weave Cotton Fabric Phenolic Graphitized Grades
Coarse & Fine Weave Cotton Fabric Phenolic Molybdenum Grades
Fine Weave Fabric Carbon Inclusions Phenolic Grades
Cotton Mat Phenolic Resin Grades
Asbestos Paper Phenolic Resin Grades
Asbestos Fabric Phenolic Resin Grades
Asbestos Fabric Melamine Resin Grades
Asbestos Fabric Phenolic (High Temperature) Resin Grades
Asbestos Fabric Phenolic Graphitized Grades
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Presented at the Electronic Components Conference, Washington, May 3-4

Technical Abstracts

resonance every time the operating frequency of a radio set is changed. Ordinary chokes require tuning with either a slug in the inductor or a variable capacitor.

To make a broadband choke, miniature coaxial cable is wound around a ferrite toroid; the ends of the cable's outer conductor are connected to metal plates that are separated by an insulator. Properly wound, the choke reduces losses in the cable while providing more than 5,000 ohms of radio-frequency isolation in the outer conductor.

The design stems from a trick often used by amateur radio operators to protect themselves by reducing the r-f energy leaking along an antenna feed. The operators slip an inductor on the feed, forming a one-turn inductor. Winding the feed around the inductor multiplies the isolation many times.

Isolation is essential when a coaxial cable feeds the antenna. The outer conductor acts as a radiating antenna when currents from the antenna flow into the conductor or are created by radiation from the antenna. This alters the antenna system's radiating characteristics, and causes antenna losses.

Simply winding a cable around a toroid will not make the chokes broadband. The dimensions of the toroid and cable, the number of turns, and the separation between turns must be carefully chosen to control electrical characteristics. Bandwidth rises with susceptance, for example, and falls with self-capacitance of the winding.

Choke design theory and formulas have been worked out, and proven experimentally. For instance, isolation is provided across the high-frequency range of 2 to 30 Mhz by three chokes: one with a bandwidth of 6.3 Mhz covers frequencies from 2 to 8 Mhz; another, 12.7 Mhz wide, isolates at 8 to 20 Mhz; and the third, with a bandwidth of 11 Mhz, takes over at 20 to 30 Mhz. Similar groups of chokes can cover the very high frequency range of 30 to 80 Mhz.
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Polycarbafil® has toughness needed for new hospital speaker

Impact strength important in speaker for hospital patients

The pillow speaker for individual hospital patients made by Dictograph Products, Danbury, Conn., must be able to withstand accidental dropping on the floor. Dictograph looked for a material that would have the impact resistance and toughness for this, plus rigidity, dimensional stability and low coefficient of thermal expansion. They chose Polycarbafil, fiberglass reinforced polycarbonate. Fiberglass reinforcement increases all of these properties.

In addition, Nylafil, fiberglass reinforced nylon, was chosen for push-buttons, volume control wheel and switch housing for its strength and wear resistance.

<table>
<thead>
<tr>
<th>Property</th>
<th>Physical Properties</th>
<th>Unreinforced Polycarbafil</th>
<th>Polycarbafil 66/55</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength @ 73°F</td>
<td>PSI</td>
<td>8,000</td>
<td>18,500</td>
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<tr>
<td>Flexural Strength @ 73°F</td>
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<td>Con./Linear Thermal Expansion //F</td>
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<td>Heat Distortion Temp. @ 150°F</td>
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<td>308</td>
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<tr>
<td>Water Absorption %</td>
<td>0.15</td>
<td>0.11</td>
<td></td>
</tr>
</tbody>
</table>

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New Literature


Molding powders. Emerson & Cuming Inc., Canton, Mass. 02021. A foldout chart for notebook or wall mounting presents the Eccomold line of general purpose and specialty epoxy molding powders, and illustrates several applications. [421]

Variable attenuator. Weinschel Engineering, Gaithersburg, Md., has published a completely updated version of the series 905 variable attenuator data sheet. [422]


Indicator lights. Dialight Corp., 60 Stewart Ave., Brooklyn, N.Y. 11237, has issued catalog L-160F on Datalites, ultraminiature indicator lights suited for computer, data processing and automation applications. [424]

Microminiature chopper. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif. 91343, has available a bulletin on the model 30 Microchopper, a low-level spindle switch for operation from —55° C to —90° C. [425]

Reset timer. Eagle Signal Division of the E.W. Bliss Co., 736 Federal St., Davenport, Iowa. A two-page bulletin describes the model 88 reset timer with a meter-type dial. [426]

F-m subcarrier discriminator. Genisco Technology Corp., 18435 Susana Road, Compton, Calif. 90221. Specifications of an F-m subcarrier discriminator, designed for portable and mobile applications, are provided in a data sheet. [427]

High-temperature solders. Hi-Grade Alloy Corp., 17525 South Laffin St., East Hazelcrest, Ill. 60429, has published a brochure describing two high-temperature solder alloys, both containing pure silver and both of which will remain solid at up to more than 570° F. [428]

Traveling-wave tube. Microwave Associates Inc., Burlington, Mass. Bulletin 1826 describes the MA-2015 traveling-wave tube, said to be the smallest wt. available within its power and frequency range. [429]

Digital plotting system. Milgo Electronic Corp., 7620 N.W. 36th Ave., Miami, Fla. 33147. A 12-page brochure discusses the DPS-6 digital plotting system, a data display system that includes an x-y plotter, an input source, and supporting software. [430]

Programming switches. Sealecto Corp., 225 Hoyt St., Mamaroneck, N.Y. 10543. The use of Sealectowitch programming switches for sequencing, timing, scanning, multiplexing, integrating, code generation, and general programming is described in a six-page illustrated catalog. [431]

Printed circuits. Circuiron Inc., Baldwin, Wis. 53402. A color brochure shows the facilities and standards used by the company for manufacturing printed circuits. [432]

Solvent-free resin. Isocem Resins Co., Cook St., Lincoln, R.I. 02865, has issued a technical bulletin on Isochem-Carb 163, a capacitor or electronic resin for use with polycarbonates films. [433]

Materials for multilayer circuitry. The Budd Co., 70 S. Chapel St., Newark, Del. 19711. Flame retardant grades of ultrathin materials for making multilayer printed circuits are described in technical bulletin No. 12,100. [434]

Electronic components. General Precision Inc., Kearfott Products Division, 1150 McBride Ave., Little Falls, N.J. 07424. A revised catalog on electronic components describes more than 100 different units. [435]

Crystals. Clark Crystal Corp., 344 Boston Post Road, Marlboro, Mass. 01752. A four-page brochure discusses crystals, ovens, and crystal oscillator circuits. [436]

Small motors. General Electric Co., 1635 Broadway, Fort Wayne, Ind. 46804. Publication GEA-8254 provides basic design, selection and application information for fractional horsepower a-c induction motors. [437]


Hermetic seals. Greenfield Components Corp., 184 Shelburne Road, Greenfield, Mass. 01301, has issued a catalog showing its line of hermetic seals, and discussing its ability to supply industrial customers with molecular bonding of practically any similar or dissimilar materials. [439]

Power supplies. Sola Electric Division, Sola Basic Industries, Elk Grove Village, III. 60007. A complete line of regulated
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Electronics | June 12, 1967
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Video waveform monitor. Ball Brothers Research Corp., P.O. Box 1062, Boulder, Colo. 80302. A two-page bulletin covers the Mark 21 waveform monitor which provides an oscilloscope presentation of black-and-white or color video signal information. [448]

R-f power measurement. Bird Electronic Corp., 30303 Aurora Blvd., Cleveland, Ohio 44139, has available a short form catalog (SF-67) of quality instruments for r-f power measurement. [449]

New Literature

d-c power supplies is described in brochure DC-100. [440]

Miniature decade counters. United Computer Co., 930 W. 23rd St., Unit B, Tempe, Ariz. 85281, offers a bulletin on the model F1850 miniature decade counters that have many industrial applications and are suited for OEM applications as well as for one-time users. [441]

Electronic counter. The Rowan Controller Co., Oceanport, N.J. 07757, has available a brochure on its series EC electronic counter, which consists of 15 different models. Included are dimensions, technical specifications, design and construction features. [442]


Cylindrical connectors. Elco Webster Corp., Watertown, Mass. 02172. A 20page catalog describes and illustrates a complete line of cylindrical connectors that conform to MIL-C-26482. [445]

Voltage-temperature modules. Gulton Industries Inc., 212 Durham Ave., Metuchen, N.J. A line of voltage-temperature modules with over 200 times the sensitivity of chromel-alumel thermocouples is discussed in bulletin T110. [446]

Strobing voltmeter. E-H Research Laboratories Inc., 163 Adeline St., Oakland, Calif. 94607. A six-page brochure on the model 153 strobing voltmeter details design concepts of the unit, which is said to offer a unique approach to the problem of making voltage measurements on fast waveforms at precisely located points on the time axis. [447]

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Reliability Test Engineers—with experience in test planning, test equipment, reliability test procedures, overstress testing, and other related test disciplines essential in establishment of reliability testing requirements and evaluation of vendor generated documents. Engineering degree with several years work in a related field is desired.

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Fighting in the Middle East between Israel and the Arab nations will set back U.S. adherents of closer trade ties between the West and Soviet-bloc countries. Soviet backing of the Egyptian blockade of the Gulf of Aqaba, the incident that triggered the war, forced those urging more East-West trade to recognize that the Soviets still continue their policy of making mischief around the world. Moves by President Johnson to ease the technological embargo will run into stiffer resistance in the Congress as a result.

In the Middle East, the war has crystallized a change in the historic supplier pattern for electronic equipment. To further entrench themselves in the Arab market, Communist countries took advantage of the hostilities while Western countries embargoed shipments of military equipment. The Soviet Union has been building up the Arab war machine since 1956. Czechoslovakia signed an agreement to give military aid to the Arab states in March. And now the German Democratic Republic is eyeing the area for still another reason: East Germany would like the Arab states to recognize its sovereignty, something Western countries do not.

By the end of the first day's fighting, Israel's own infant electronics industry—hit by a mobilization callup that pulled up to 25% of the workers out of plants—met schedules by working overtime on a seven day week. French avionics producers who had supplied the electronics equipment for the Israeli Air Force's Mysteres were shut out of the replacement market. But just before hostilities broke out, three El Al commercial liners picked up full loads of spares in France and flew them to Israel. The U.S. was holding up processing of Israel's orders for Hawk Missiles and 24 Phantom fighter-bombers.

British companies that had supplied large quantities of electronics equipment to Arab nations ran into a similar embargo. But Associated Electrical Industries Ltd., which has a contract to supply an air-warning network to Saudi Arabia, expects no delay in delivery.

A German equivalent of the French "Plan-Calcul" is fast taking shape. Anxious about the dominant position of U.S. computer companies in West Germany, the Kiesinger government has two schemes in the works that will sharply step up its support of native computer makers.

Under a five-year plan, the Ministry for Scientific Research intends to dole out about $75 million for research and development of computers that will be put on the market by the early 1970's. The funds will underwrite up to half of manufacturers' R&D costs.

In addition, the Ministry of Economics wants to offer long-term, low-interest credits for computers already under development. The Ministry plans to earmark $16 million for 1968 and then $19 million annually through 1972.

The two schemes do not add up to the national concerted effort that the de Gaulle government set up with its Plan-Calcul [Electronics, Oct. 7, 1966, p. 224] but West German computer makers are hailing them. Siemens AG, the country's largest electronics firm, has been prodding the government for years to help the computer industry stand up to the competition of well-heeled U.S. data-processing giants, who have captured an estimated 85% of the German market.

After West Germany, Holland may be the next to follow de Gaulle's
France and West Germany made official their agreement to build a telecommunications satellite, and surprised some aerospace companies in the process. Plans now call for a launch from French Guiana in early 1970—pushed up from the late-1970 target talked about just a few weeks ago—and a circular 24-hour orbit at 23,000 miles. What particularly surprised some industry men was the announcement that the craft—to be called Symphonie—will be boosted by a Europa-2 rocket being developed by the European Launcher Development Organization. Use of the Europa would limit the weight of the satellite to about 400 pounds.

Some reports from West Germany had put the weight of the craft at 1,770 pounds—too heavy to be lifted by a Western European rocket—and this had led to speculation that Paris and Bonn would turn to the Soviet Union for a launch vehicle.

The new target date for the joint satellite is timed so that the French and Germans can make a case for a smaller U.S. share of the International Telecommunications Satellite Consortium when the agreement comes up for review in late 1969.

The French and West German aerospace industries are convinced they can build the hardware for the $50 million satellite project. But some companies likely to get contracts have already sounded out U.S. firms about technical help in systems integration, assembly and testing.

The Australian government has started plumping for a single national effort in integrated circuits. Official planners are pushing for a government-led consortium grouping the country's major electronics firms. They say such a consortium is the most economic way to set up a production facility that could produce a wide range of IC's for the small Australian market. Outlook for IC use in the country is a climb from 40,000 devices last year to 1 million packages by 1970.

The IC consortium is being touted as the first step toward Australian self-sufficiency in defense electronics. It will probably be supported by Australian producers who long have claimed that the government imports military hardware that could be manufactured domestically.

West German color-television set producers may be spared the doldrums that plagued U.S. receiver manufacturers for 10 years after color sets first went on the American market.

Market researchers at Deutsche Philips Industrie GmbH, who came up with remarkably accurate forecasts of black-and-white sales in 1955 and 1960, predict color-tv sales will bounce up 140% annually from this year's estimated 85,000 sets to hit a level of 575,000 sets by 1970.

Deutsche Philips' estimates are based on initial set prices of about $625 and on the belief that West German network officials will fast add to the eight hours weekly now scheduled for the start-up of colorcasts in August. Deutsche Philips' parent company, NV Philips' Gloeilampenfabriken of the Netherlands, has made heavy investments throughout Europe to prepare for the coming of color.
Great Britain

Jeep ground station

Convinced that military commanders will one day want a go-anywhere ground station to work through the U.S. Initial Defense Communications Satellite Project (IDCSP), Britain's Signals Research and Development Establishment has developed a jeep-hauled terminal that can be set up and put on the air in 45 minutes.

The terminal, with its 6-foot antenna dish and most of its electronics carried on a two-wheel trailer, had its first full-scale workout at the Paris Air Show which ended last week. During the show, the mobile station exchanged teletypewriter messages via IDCSP satellites between Paris and Fort Dix, N.J. and between Paris and Christchurch, England, the home base of the Signals Establishment, run by the Ministry of Technology.

With the exchange of messages through Idex (for initial defense experiment), Britain became the first to work through a satellite with a truly peripatetic ground station. In the United States, the first mobile station for use with IDCSP will be delivered shortly by Radiation Inc. to the U.S. Army. Radiation's Mark V equipment (AN/TSC-34) is much heavier and larger; it weighs 12 tons and has a folding cloverleaf antenna array made up of four 10-foot-diameter reflectors.

Limited access. To get a small mobile terminal that can be hauled by a jeep or airlifted in by helicopter, the Signals Establishment limited its capacity to a single vocoded voice channel or 50 teletypewriter channels. The transmitter power is just 1 kilowatt, meaning the mobile terminal can't get into a frequency-division multiple-access satellite unless big fixed stations cut down their power. For the demonstration at Paris, the U.S. Defense Communications Agency, which controls the IDCSP satellites, allocated an hour daily for Idex. Up frequency was 8 gigahertz, down frequency 7 GHz.

To hold down the terminal's weight, its designers dispensed with elaborate cooling systems. The transmitter's klystron is air cooled and the receiver's parametric amplifier is uncooled. Both transmitter and receiver are mounted on wings at the rear of the antenna dish, doing away with rotating microwave joints. The wings also serve to balance the equipment on the two-wheel trailer, as do the power supply packages, one at either end of the trailer.

On-vehicle. The jeep itself carries a gasoline-powered generator and five electronic modules: the transmitter module, satellite beacon receiver, information receiver, antenna controls and transmitting-receiving controls.

Stable mates

The nuisance of compensating for temperature in quartz frequency-control oscillator crystals may soon be banished. The trick: pairs of crystals mounted in parallel but operating as one.

Two British researchers who hit on the double-crystal idea say it gives frequency-temperature curves flat to one part in 1 million over a range of about 80°C. What's more, they say the range could be extended to meet British military specifications of -40° to 80°C by mounting three or more crystals in parallel. Since the scheme works with relatively low-cost crystals that have parabolic frequency-temperature curves, the multicrystal oscillators figure to be competitive with compensated devices using AT-cut single crystals.

Good guess. Research engineers D.J. Fewings and C.R.S. Ince of the Marconi Co., a unit of the

Itinerant. Radome of fixed station dwarfs Land Rover and two-wheel trailer that make up mobile ground station developed in Britain to work with IDCSP military communications satellites.
English Electric group, played a hunch to hit on the two-crystal arrangement. For their experimental oscillator they used parabolic-law crystals whose frequency-temperature curves centered at 5 meghertz. One crystal's center point was at 25°C, the other's at 75°C. The circuit also had a pair of capacitors in series with the crystal combination. The oscillator showed a flat output over a large part of the range between the two center points at a frequency slightly higher than 5 Mhz.

Reporting on the theory of two-crystal oscillators at a London conference last month, Fewings and Ince said the physics of the effect still aren't fully understood. But they've worked out the mathematical relationship between the frequencies of the individual crystals and the combined frequency, which is always slightly higher. The exact shape of the curve for the two-crystal combination depends on the value of the two capacitors in series.

Trio. The Marconi men also have calculated the values for a three-crystal combination to meet military requirements. Frequency at the center point would be 10.5 Mhz at -50°C for the first crystal 20°C for the second, and 90°C for the third. The only drawback with such a setup that Fewings and Ince can see is the problem of different aging rates for the three crystals. They might need rematching about once a year.

Soviet Union

Showmanship

Russian aerospace officials apparently have developed a knack for upstaging Western countries at the biennial Paris Air Show.

Two years ago, the Soviets stunned showgoers by flying a brand-new giant turboprop transport to Le Bourget. At this year's show, which wound up a 10-day run last week, the Soviets put themselves front and center again by displaying a Vostok launcher and a pavilion full of mockups of their latest unmanned spacecraft, most of them never before displayed publicly.

Heavyweight. Most impressive of the spacecraft was the massive Proton research satellite. It weighs in at 12.2 tons and has panel-tip spread of 33 feet. An official manning the Russian exhibit at Le Bourget said three of the spacecraft had been launched to study cosmic particles in the energy range of \(10^{11}\) to \(10^{15}\) electron-volts. In addition, the missions included checks on solar radiation, the chemical composition of primary space particles, and interactions among high-energy particles.

In Proton, an on-board computer controls the electronics in the experiment package. Data collected by instruments is stored and transmitted to earth on command. Because of intense atmospheric braking on the massive satellites, their effective life was 100 days in orbits with perigees of 120 miles and apogees of 390 miles.

Queried on future Proton launchings, the Russian official was noncommittal. But some Western space experts think the vehicle may eventually be adapted for use as one module for an assembled-in-space manned vehicle.

Lightning. Space experts from the West also had their first look at the Soviets' Molnya 1 (for Lightning) communications satellite. Over the past 26 months the Russians have launched five of them, the fifth one late last month. It, apparently, is the only one still operating.

With the Molnya 1 satellites, which have 12-hour, highly elliptical orbits, the Russians are trying out long-range transmission of television, radio, telephone, and telegraph signals. The satellites also carry dosimeters to pick up data on radiation belts, say Soviet officials.

Power for the satellite comes from six foldout solar panels. Transmission power is 40 watts and the two antennas are parasols fitted with three-gun albedo sensors for earth acquisition. Antenna diameter is about 3.5 feet, indicating a sensitive stabilization system for accurate pointing.

Weather watch. The Russians also had on view Cosmos 144, the weather satellite put up early this year. It covers the earth twice a day, picking up meteorological data like cloud cover, air-mass movements, temperatures, and wind speed. The on-board hardware includes a television camera, an infrared camera, and heat sensors.

A Soviet engineer at the Paris show said the Cosmos 144's camera was designed strictly for weather applications. But the satellite may well serve for reconnaissance. Among the display of photographs relayed back from Cosmos was a clear shot of the Sinai Peninsula, at whose tip lies the Gulf of Aqaba, focal point of the current Arab-Israeli crisis.

Comparing computers

It was an unlikely occasion for sizing up Russian computer capability; but technology watchers got a precise fix on the Soviet lag in data processing at the food and packaging machinery trade fair staged in Moscow last month.

At the U.S.-sponsored show, Scientific Data Systems Inc. sold the Soviets a $400,000 SDS 930 computer that had been on display. Although SDS has been selling the...
machine in the U.S. for three years, it will be the fastest computer in the Soviet Union when it goes into service later this year, presumably at the Moscow Telemechanics Institute.

**Bested.** Although middle-aged by U.S. standards, the SDS 930 bests the BESM-6, the fastest known computer built so far by the Russians. The 930 has a cycle time of 1.75 microseconds, compared to about 2 usec for the BESM-6. The Russians claim their machine can perform 1 million operations per second. But a Western expert who has seen it points out the figure holds only for a few simple operations. The average speed, he says, is probably about 600,000 operations per second.

BESM-6 apparently is the only Soviet computer built so far with time-sharing in mind. And thus it has considerably more peripheral equipment than previous Russian computers. All the same, the peripherals the Russians will get with their SDS 930 will be vastly superior to those of BESM-6 according to Arthur Hyatt, who handles Eastern European sales for SDS.

**Leader.** SDS' sale of the 930 makes the company a U.S. leader in computer sales to the Soviets. Before the latest deal, SDS had pocketed Russian orders for two 910 and two 920 computers. The two 910's, worth $380,000 between them, were installed last month at two Moscow research institutes.

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**West Germany**

**Teutonic tutor**

Educators long have complained they spend too much classroom time teaching basic facts and definitions, a job that can be admirably handled by a computer-controlled teaching machine.

Trouble is, expensive computer-based systems are out of the question for most schools. And low-cost audio-visual teaching machines now on the market generally provide branched instruction—backtracking when a student hasn’t understood or skipping him ahead when he shows he knows—only in the visual channel.

For West German educators, the single-channel drawback is ending. Brown Boveri and Cie AG, a Heidelberg subsidiary of the Swiss company with the same name, will start series production this August of a $370 machine that backtracks or skips forward in both audio and visual channels.

Peter Koehler, manager of Brown Boveri's teaching machine department, hopes to capture a 20% share of the country's teaching machine market with the low-cost entry, called the Probiton. Koehler expects the market will rise to between $60 million and $65 million by the early 1970's. Spending for software, he thinks, will run 10 times higher than that for the machines themselves.

**Nine-track code.** In the Probiton, visual instruction materials are presented on a paper strip 9 inches wide and up to 30 feet long. About 100 lesson segments can be put on each strip. The accompanying audio information comes from the machine's tape system, which plays through earphones. Each tape cassette can handle up to one hour of audio information.

The paper strip and tape drives are programed by a nine-track code punched into the paper strip. After completing a lesson segment, the student punches one of four buttons to answer a multiple-choice quiz. When he does, electrical connections are made through contact heads, actuated by the code holes, that feed relay logic. The signal of the logic circuits drives the strip and tape forward if the answer is correct, back if the answer is wrong. The nine-track code is flexible enough so that backtracking to the beginning of a lesson is possible should the student select a senseless answer.

Since the blocks of audio information on the tape vary in length, each block is separated by an unmodulated gap 3.5 inches long. By detecting the gaps, the tape drive control keeps the audio and visual blocks synchronized.

**Portable.** Although it most likely will be most used in the classroom, the Probiton was designed with homework in mind. The unit is about the size of a portable typewriter, weighs 18 pounds and is powered by rechargeable batteries.

And Koehler is convinced the market won't be limited to schools. He says that businesses and government agencies are considering the machine for their training operations. Eventually, Brown Boveri will try to move into export markets with the Probiton. The big problem, though, is finding companies abroad that can produce software—the programed visual strips and tapes—adapted to the peculiarities of foreign teaching methods.

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**Tracking down defects**

Although the use of electronic gandy dancers to locate internal defects in tracks isn't new, West Germany has lurched ahead of the rest of Europe by placing ultrasonic test gear aboard a rail inspection train. The train is capable of checking both rails of a 20-mile section of track in one hour.

Developed for the Federal Railroads at Minden, the new system is a marked improvement over an
earlier inspection train. Internal fractures and fissures can be located accurately within 4 inches. Test and fault indications are displayed on scopes and recorded on film strips.

The ultrasonic equipment was built by the firm of J. & H. Krautkraemer, the same company that supplied the ultrasonic gear for the first U.S. rail inspection train.

By the bounce. The German detection system is based on principles used in some nondestructive methods of metal testing. Short pulses of ultrasonic energy sent into the rail are reflected at points where different propagation characteristics exist. Thus pulses penetrating faultless rail go through the metal before bouncing back. Pulses hitting a fracture in the metal are reflected sooner.

The pulses are picked up by transducers, disk-shaped piezoelectric crystals that resonate at a frequency between 2 and 4 megahertz. By damping, pulses about 5 microseconds long and 2 kilovolts in amplitude are produced. Pulse repetition rate is 3,000 hertz. The relatively weak echo pulses are boosted to a level of 120 decibels by broadband amplifiers before being applied to a scope.

Because of the high information content at the 3-kilohertz repetition rate and the 20-mpf train speed, an evaluation of the test results by merely observing the scope is impossible. Photographing the pulses as they appear on the scope is impractical because a very high frame rate would be necessary, resulting in a large expenditure of film.

Reference points. To overcome the problem, the pulses are fed both to a regular scope and a cathode-ray tube that produces an intensity-modulated horizontal line. A pulse returning from a fault shows up as a bright spot on the line. An optical system projects the line onto a light-sensitive strip that moves under a lens at a rate proportional to the train speed but slower by a factor of 100. One-meter reference marks which facilitate fault location are also recorded on the strip.

The system uses eight test heads, four under each side of the train. Six of the heads glide along the rail and beam the energy through the metal vertically and at angles of 35° and 70°. The remaining test heads are mounted about a foot above the rail. The pulses from these scan the rail surface to detect faults in the rail web and foot.

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Japan
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Sharp and flat

Television sets about the size of a book will be on the market in two or three years if the plans of the Hayakawa Electric Co. pan out.

Hayakawa this month demonstrated a development version of the flat cathode-ray tube around which its book-size set will be built, presumably with most of the electronics packed into integrated circuits. Images on the 8-inch screen were rated by viewers as fair. Hayakawa engineers claim that production versions will stand comparisons with the best conventional picture tubes.

Improved copy. Hayakawa admits that it is not the first to develop a flat tube. The General Electric Co., NV Philips' Gloeilampenfabrieken of the Netherlands, and others hold patents on flat CRT's. Hayakawa, though, says it's carried the development to the point where it hopes to have the tube in production within two years. The company would like to persuade Hitachi Ltd., its principal tube supplier, to produce the flat version. If Hitachi balks, Hayakawa will try to line up a smaller tube producer and may even try making the flat tube in-house.

In the Hayakawa tube, the front-to-back dimension is just 2 inches. The neck with the electron gun extends straight down, parallel to the faceplate, rather than to the rear as in conventional CRT's. Walls of the bulb are about 0.4-inch thick.

With a tube shaped like that, an ordinary electron gun can't be used because the electron path length varies with the vertical position of the faceplate and focus would be poor. The Japanese flat tube has a gun that produces an almost-parallel beam. The spot size is less than 0.7 millimeter at all points on the faceplate.

Deflection. Hayakawa's kingpin improvement over earlier experimental flat CRT's apparently lies in its electrostatic vertical deflection system. Instead of a series of deflection plates switched on and off sequentially, Hayakawa uses just two plates. One is along the rear of the bulb, the other is formed by the aluminum backing on the faceplate phosphors. Hayakawa says the rear deflection plate could be made transparent so the image could be seen from either the front or the back of the tube.

The two-plate deflection makes possible almost constant voltage on the plates. Vertical sweep is obtained by changing the angle at which the gun injects electrons into the space between the plates. The electron-beam angle is varied by magnetic yokes. This arrangement does not give a truly linear sweep, but linearity is bettered by applying a dynamic correction voltage to the plates.

Current probe

Pioneer developers of the laser saw the device as a useful tool for physics measurements, but few expected it to find a place as a measurer of electrical power.

However, a laser current transformer to measure transient currents in extra-high-voltage (EHV) transmission lines is now being tested by the Central Research Institute of Japan's electric power industry.

Use of the instrument would eliminate the huge ceramic bushings required by conventional current transformers. The new setup electrically isolates the measuring apparatus from the power line. Test engineers also report that current waveforms of high fidelity can be produced with the new technique.

A helium-neon gas laser is used in the test project. It puts out one milliwatt of power and has a wavelength of 0.633 angstroms. The
Electronics Abroad

beam is directed into a flint-glass rod parallel to the ehv transmission line. The magnetic field set up by current in the ehv line also passes through the rod. The Faraday rotation—change in polarization—of the laser beam as it traverses the rod provides a measurement of the magnetic field, and this in turn gives a measurement of current.

The system’s rise time, 200 nanoseconds, is limited by the bandwidth of the detectors and amplifiers. The dynamic range of the apparatus—30,000 amperes down to 30 amperes—is extended on the high end by choosing a high amplifier-saturation level, and on the low end by suppressing excess laser noise, accomplished by operating the laser in the fundamental mode. Induction interference is minimized by careful shielding and grounding, and by isolating the power source of the electronic apparatus from the high-voltage circuit.

Joji Hamasaki of the University of Tokyo reported on the project last week in Washington at the Conference on Laser Engineering and Applications.

Around the World

Great Britain. The first commercial test instrument based on a Gunn-effect oscillator has been put on the market by Flann Microwave Instruments Ltd. Flann’s S-16 gigahertz signal generator, which uses a solid-state diode signal source instead of the conventional klystron, will sell in the U.S. for about $2,800. The company displayed the instrument at the Microwave Exposition held in New York last week.

France. The General Electric Co. will invest another $30.2 million in Bull-GE, raising its interest in the joint venture to 66%. But GE’s French partner, Compagnie des Machines Bull, retains the right to repay half the added investment within the next few years and thereby restore the 50-50 partnership.
Every ITT 2N3375 gives you 66% more $P_{OE}$ than EIA specs demand

When you apply ITT 2N3375s, you get 5 watts minimum saturated power output at 400 MHz and $V_{CC}=28$ V, tested 100%.

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