Electronics

Charts simplify pulse analysis: page 62

Negative-impedance converters: page 82

Phased-array radar on the horizon: page 94

September 2, 1968
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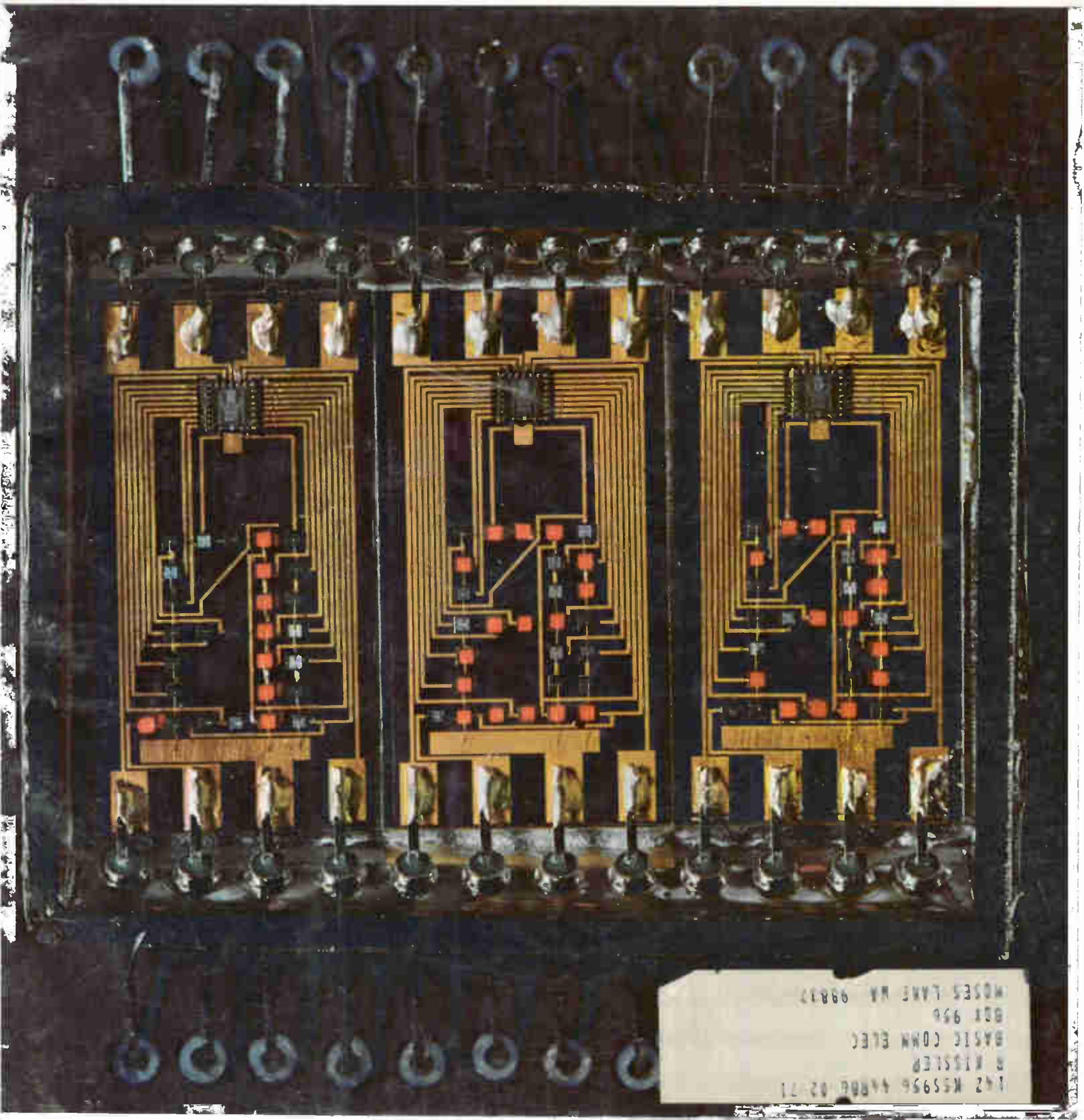
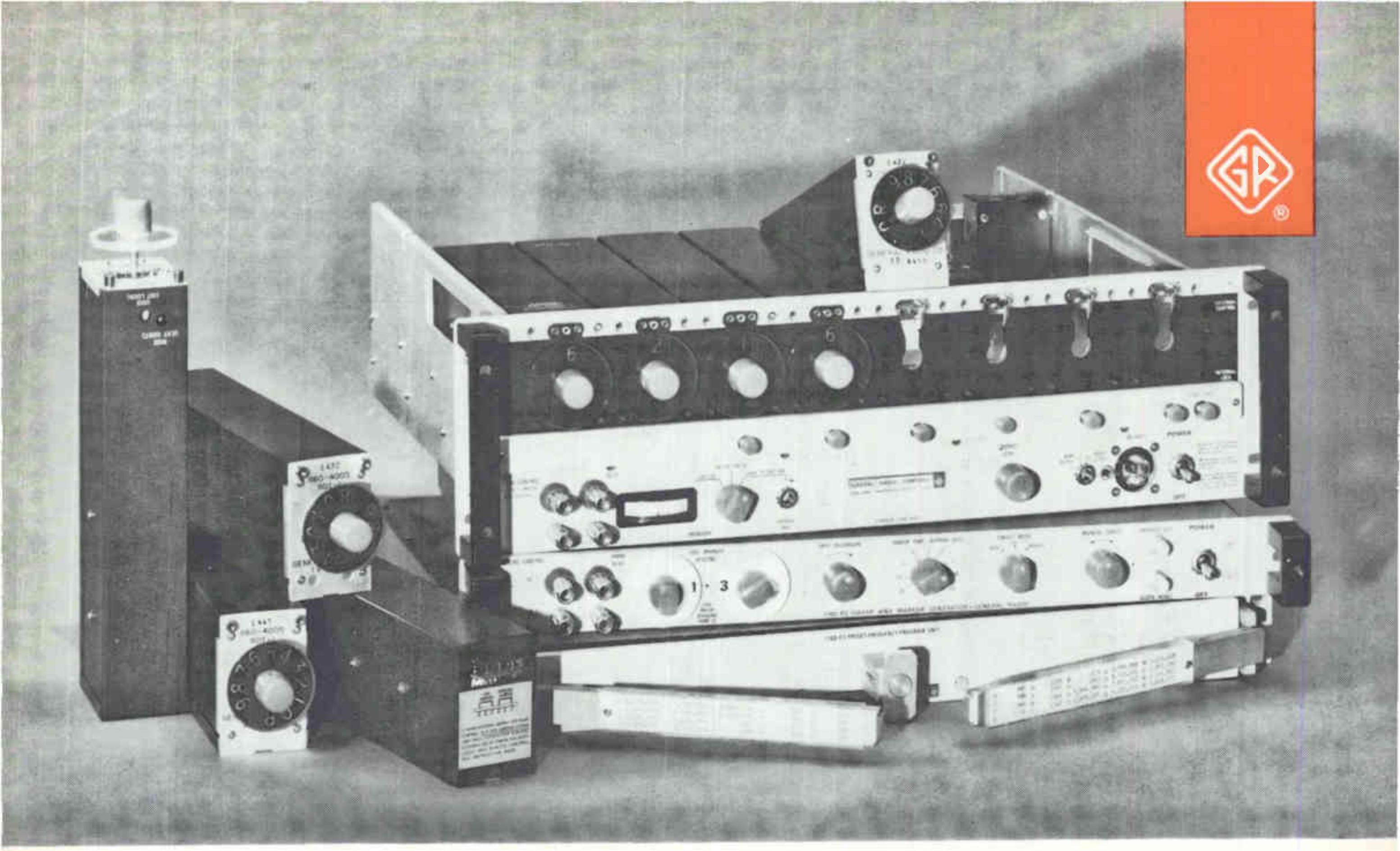
Below: Decoders drive arrays of light-emitting diodes, page 74





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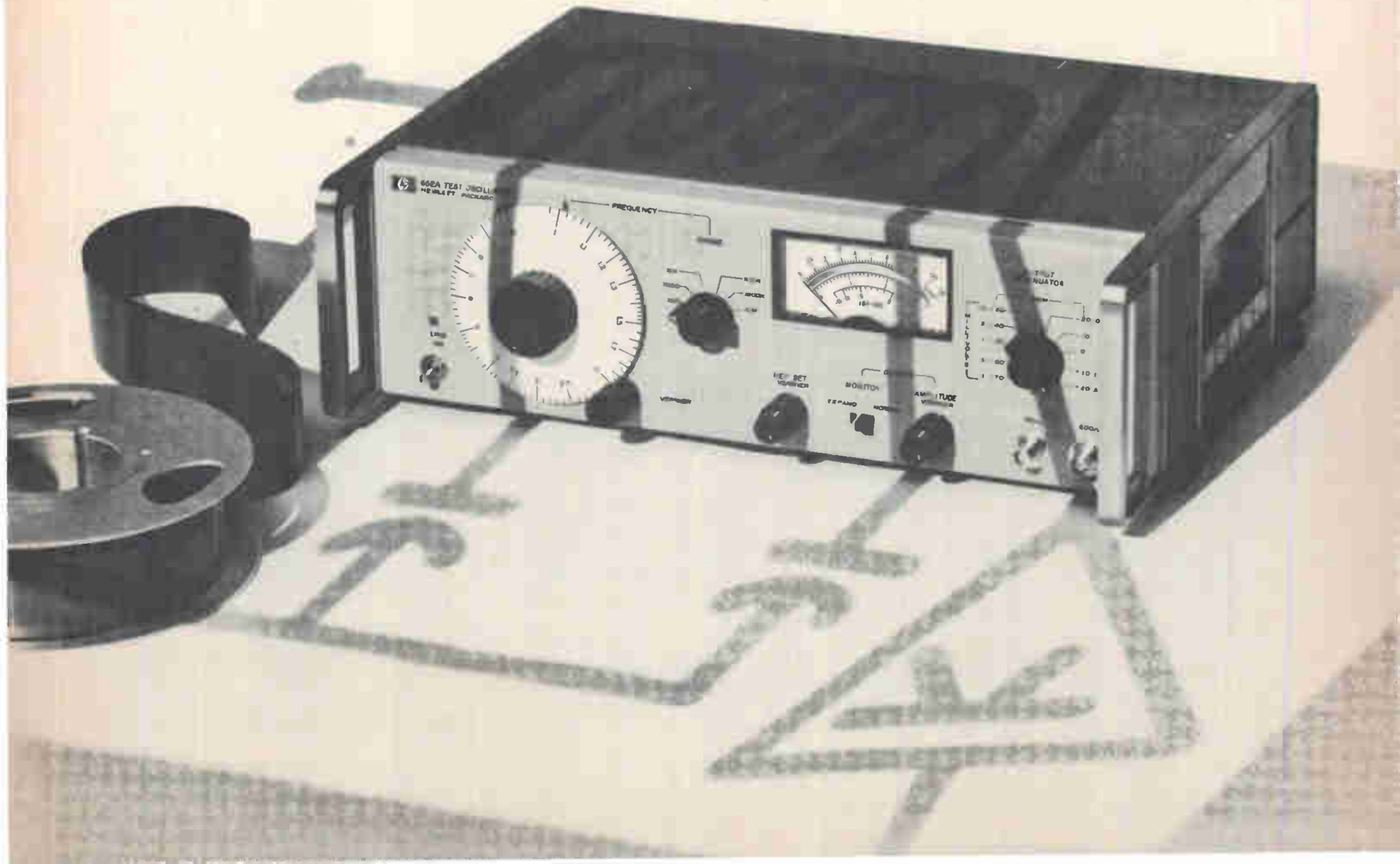

Electronics

Volume 41, Number 18 September 2, 1968

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Electronics Abroad

New Products

Technical Articles

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Readers Comment

Voicing the case for ssb

To the Editor:

It is difficult to comprehend why a natural resource like spectrum space is wasted by the proliferation of f-m voice communication. Man, as he harnesses the higher frequencies, finds progressively more inefficient methods of using them.

I don't argue against f-m and other noise-improvement techniques, such as pcm, for data transmission or high-quality broadcast, but they have no place in the transmission of voice information. Voice does not require transmission over a redundant media for the exchange of intelligence. Both a-m and single-sideband techniques provide more reliable communications per watt of power than f-m, which provides a higher signal-to-noise ratio only for an already strong signal that does not require it for syllable intelligibility.

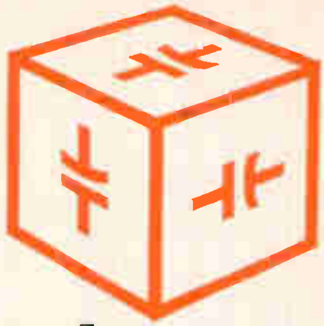
Two arguments are usually presented against ssb for the higher vhf ranges: complexity and the existence of Doppler and path a-m.

The complexity argument is weak. It has been shown that ssb results in smaller and less expensive units than a-m sets of equivalent range. The low power required for vhf and uhf sets using ssb could result in equally small and inexpensive units. Frequency stability required is little better than 10^{-7}, which is within easy reach of elementary crystal oscillators even for the 450-Mhz band.

Doppler shift between two cars going at the legal limit in opposite directions amounts to no more than 100 hertz at the 450-Mhz band. But ssb can tolerate this amount for voice work without affecting intelligibility very much, and fine frequency control (also called "clarifiers" on h-f sets) or a pilot carrier can correct the situation.

Anybody who listens to f-m broadcasts while driving far from the transmitter or in mountainous terrain can testify to the deficiency of f-m under marginal conditions. It is true that near the transmitter, f-m quality is excellent and ssb would always suffer from some small amount of flutter. However,

Obviously from Sprague Electric!



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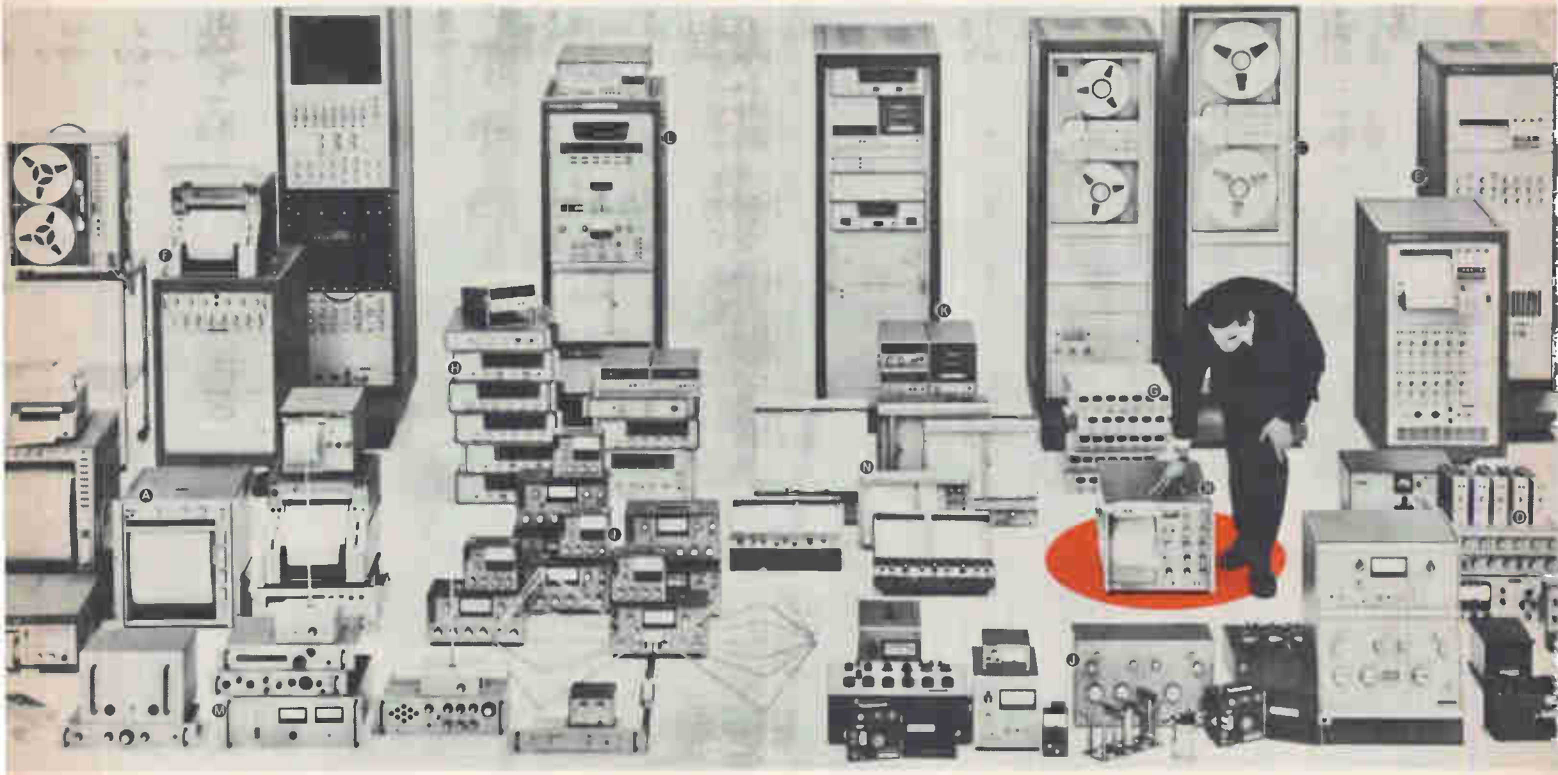

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when it comes to transmitting intelligence by means of voice, flutter is preferable to the typical dropouts and locks on other stations so typical of f-m. Ssb offers approximately 10 times more channels per megacycle than f-m. It gives a minimum of interference because of the intermittent nature of the mode. At least 200,000 radio amateurs operating ssb in no more than 2 Mhz of spectrum space on the h-f bands can testify to the very high load factor possible with ssb.

In view of the limited amount of spectrum space available, I'd urge that both a-m and f-m be phased out for all person-to-person voice transmission. The technology to do this is here.

Peter Laakmann
Hughes Aircraft Co.
Culver City
Calif.

That's the law

To the editor:

As a patent attorney, I was dismayed to read some of the statements in your article "Focus on CO_2" [Aug. 5, p. 51], which reported the award of the CO_2 laser patent to R.C. Vickery et al. after an interference with C.K.N. Patel. The article said that "many scientists and engineers expressed surprise that Patel lost the bid because he is well known in the field," and that one CO_2 laser scientist called the award a "gross injustice" because "Patel worked for years on this, and he's probably responsible for bringing the art to its present level."

For your information, in a U.S. patent interference, the patent is awarded to the inventor who was first to "reduce the invention to practice" (i.e., build and test the invention or file a patent application thereon) unless the other inventor conceived the idea first and was diligent in reducing it to practice. In most other countries, the patent is awarded to the first to file a patent application on the invention. No country awards a patent to the one who is best known in the field or who is most responsible for developing the art. It's hard enough in a patent interference to determine the first inventor without making the proceeding a popularity contest.

David R. Pressman
Philadelphia

What's in a name?

To the Editor:

As the manufacturer of the low temperature dry asher pictured in the article "Cool stripper" we would like to protest the omission of our name [July 8, pp. 56-58].

T.J. Gallagher
Tracerlab
Richmond, Calif.

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Who's Who in this issue

Like the engineering development it describes, the article on the light-emitting diode display, page 74, was a team effort. M.M. Atalla, director of Hewlett-Packard's Solid State Laboratory, guided an array of talent so diverse that, as one member of the team put it, "you wouldn't normally expect us to be able to talk coherently together, much less work all at once on the same device."

Atalla is shown in the photo with some of the contributors. Seated left to right are Robert J. Archer, Paul E. Greene, and John E. Price; standing left to right are Robert A. Burmeister, Atalla, Gerald P. Pighini, and Egon E. Loebner.

Solid state physicists defined the design parameters that would yield useful light emission. Materials scientists and metallurgical engineers devised an efficient method of producing the tricky gallium-arsenide-phosphide alloy. Psychophysics—the science relating physical phenomena to human responses—was a factor in the decision on the tradeoff between light wavelength and efficiency. And specialists in hybrid and monolithic integrated circuits, optics, and even vacuum-tube manufacturing (for the final glass-to-metal hermetic seal) made their contribution.

"The number of those who contributed content, correction, and clarification to the article could hardly be contained on a believable byline," Atalla says. "Even the list on the title page is not complete."

"Failure to comply with performance specs has become all too common," says Robert B. Cowdell, author of the article on pulse analysis [p. 62]. The noise spectrum created by waveforms in a system, he notes, reveals the amount and type of isolation (filtering or shielding) required to guarantee inter- and intra-system compatibility.

Cowdell

Cowdell has designed digital and communications systems as a consultant for Philco, General Dynamics, RCA, Autonetics, Control Data, and Collins Radio. He is now manager of systems engineering for the Genisco Technology Corp.'s consulting and research operation.

de Pian

Active-filter design isn't new to either Louis de Pian or Arnold Meltzer [p. 82]. De Pian is chairman of the electrical engineering department at George Washington University and published a book, "Linear Active Network Theory."

Meltzer did research on active filters for his doctorate from George Washington, where he is now teaching.

Meltzer

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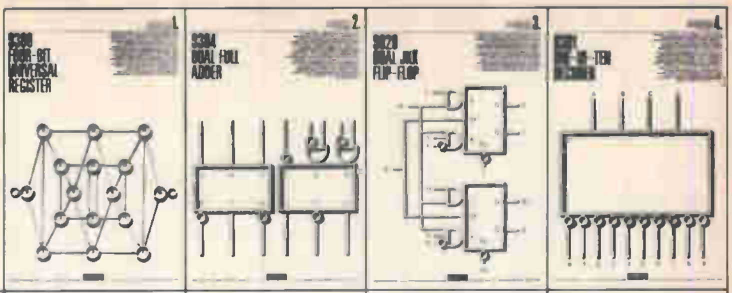

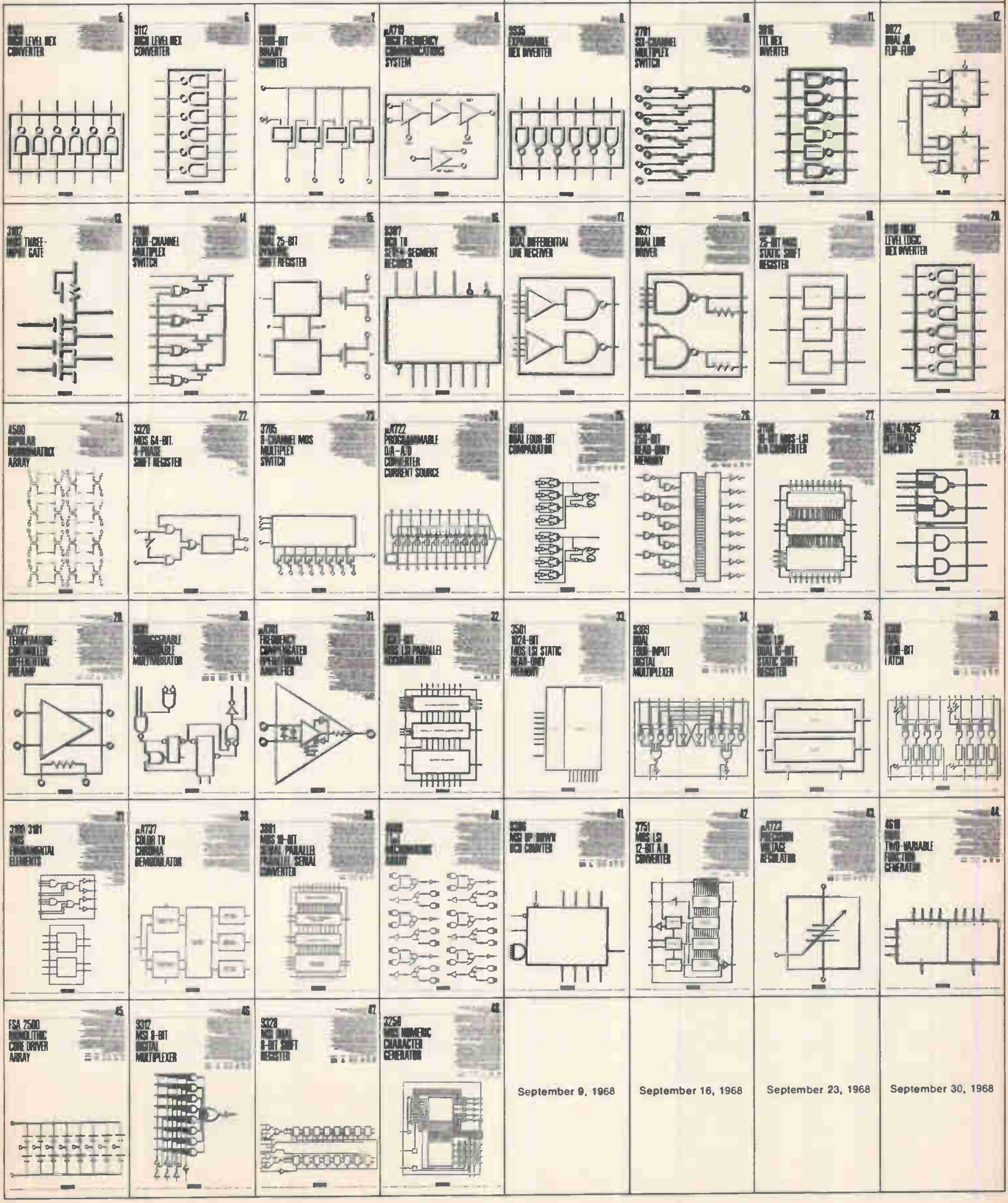

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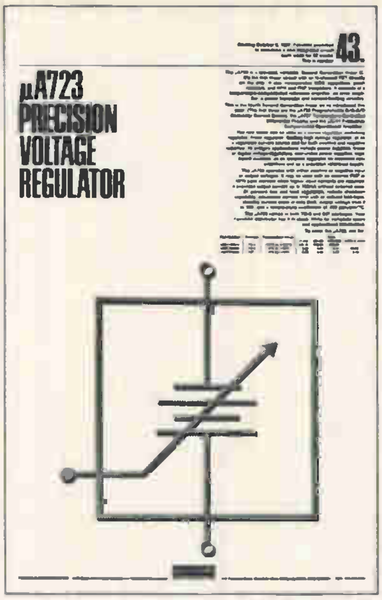

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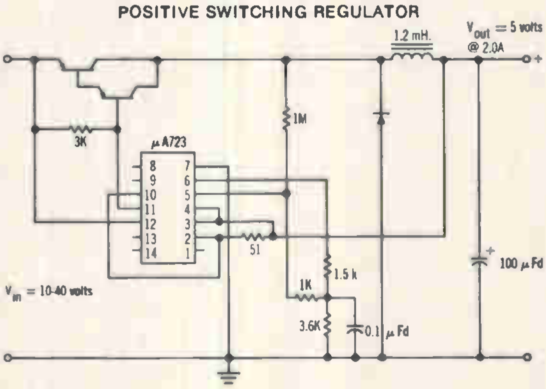

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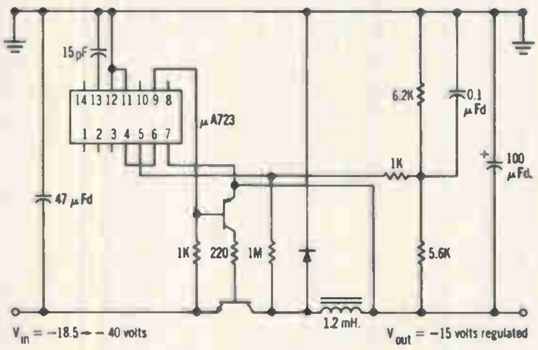

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Output Current: 1 Amp
Regulation: 0.05%

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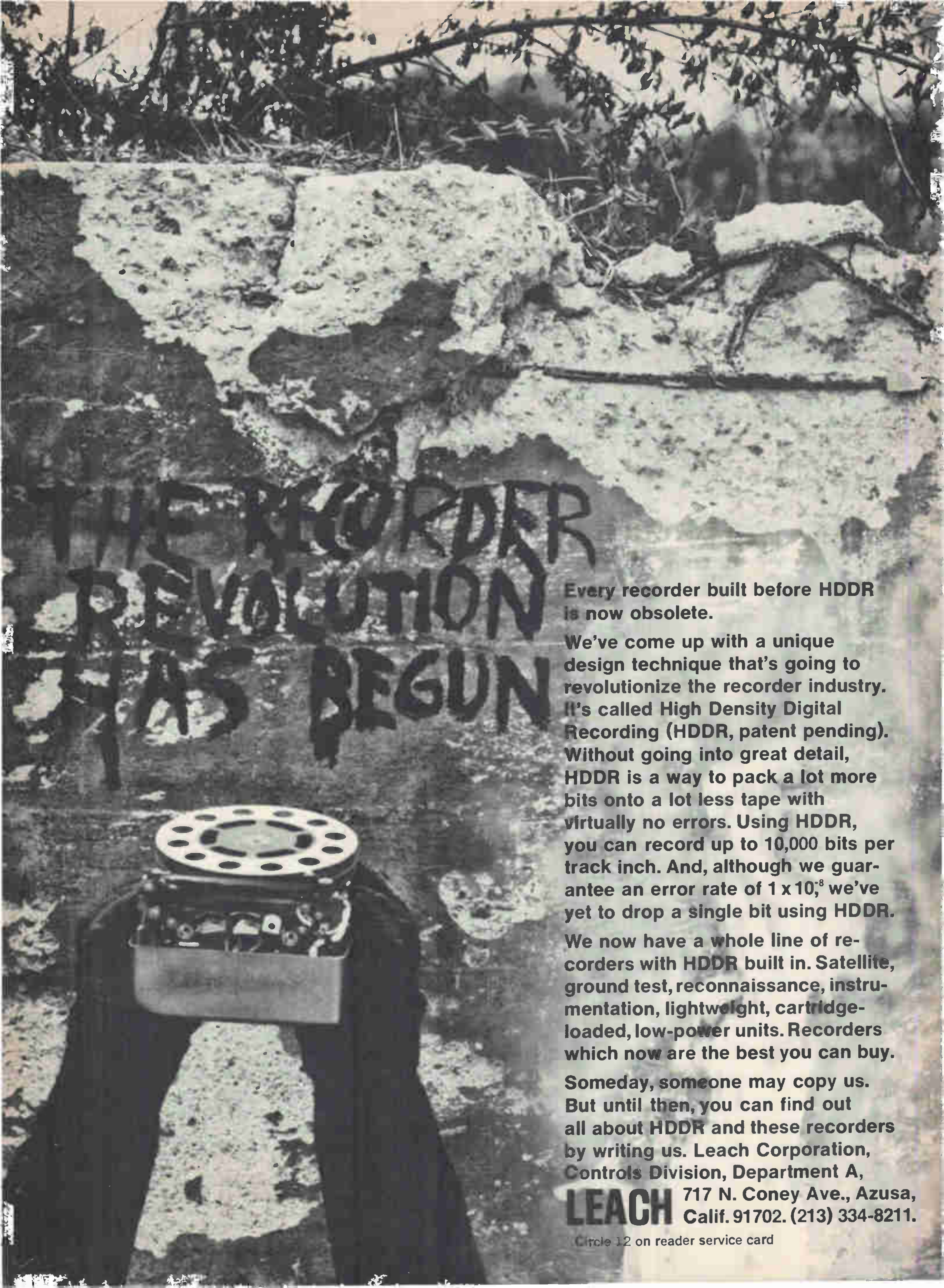
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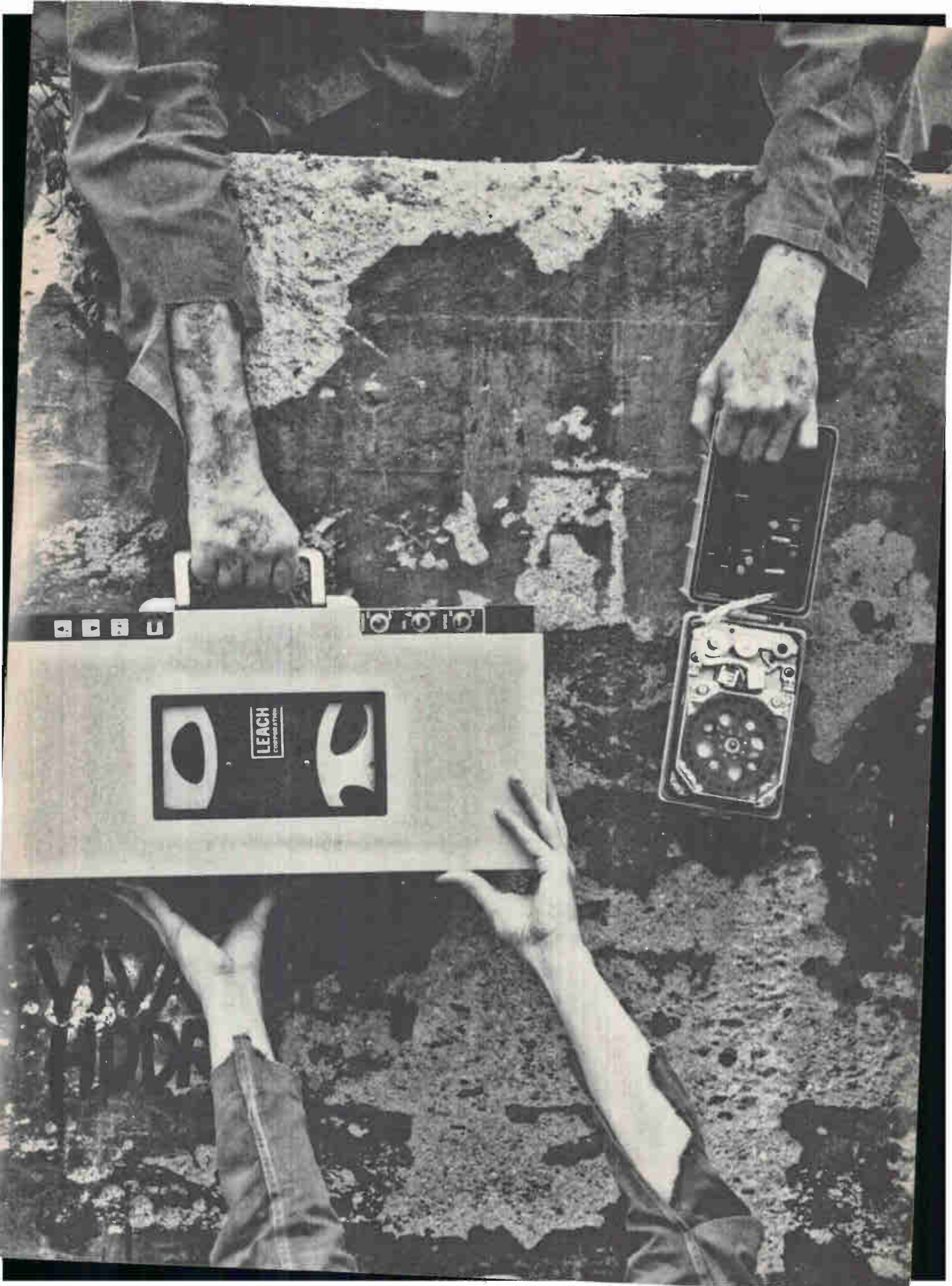
LEACH

Who's who in electronics

Stephen Levy of Motorola: "I don't think our ability to compete has been harmed because some of the talent left. . . . We are stronger than we were before. . . . If we're not No. 1 this year, we'll be so close it will be insignificant"

How well the Semiconductor Products division of Motorola Inc. can survive the greatest raid in electronics corporate history will depend on the men who replaced C. Lester Hogan and the group that accompanied him to Fairchild Semiconductor [see story on p 40]. Each man was replaced by the assistant he had selected as backup man for emergencies. "And in at least one respect," said Stephen L. Levy, 47, Hogan's successor as general manager, "we are stronger than we were before: we have John Welty back."

Welty, 46, had already been scheduled to return to Motorola from the Philco-Ford Corp., whose Microelectronics division he had headed for seven months. Levy says Welty's presence in Phoenix gave him much more flexibility in reorganizing than he might otherwise have had.

Move up. Levy's other chief lieutenant will be John C. Haenichen, who moved up from group operations manager to become director of operations, with essentially the same responsibilities as those borne by Leo Dwork before Dwork departed for Mountain View, Calif.

Welty wasn't replaced when he left Motorola; his duties were divided among Dwork, Levy, and George Scalise when Scalise was manager of support operations. As a corporate vice president, Welty now has most of his old responsibilities back, with some of Dwork's. Specifically, he will be in charge of product reliability and quality assurance, equipment and plant operations, materials, facilities, and administrative areas.

Haenichen, 33, cedes some administrative functions to Welty, but retains Dwork's responsibilities for thyristor, zener, varactor, trigger, and optoelectronic product groups and for central research and development. He had all of those groups, except R&D, when he reported to Dwork.

Motorola has two other manufacturing segments besides Haenichen's. Patrick D. Lynch, 35, has taken over the discrete silicon product group previously headed by Wilfred Corrigan, and Robert H. Lyon, 34, has been named director of integrated-circuits operations, replacing Eugene Blanchette. Lynch moves up from the direction of Motorola's very productive plastic transistor operations. Lyon was previously operations manager for current-mode products and linear circuits.

Levy also named Richard P. Abraham, 38, to be director of advanced IC programs, in which capacity he will keep responsibility for Motorola's Sentinel program; Joseph Flood, 42, to be director of reliability and quality assurance, a job he previously handled for IC's only; and Harry J. Geyer, 39, to be manager of equipment and plant operations. Geyer had been manager of mechanical equipment engineering and maintenance for

MACHLETT

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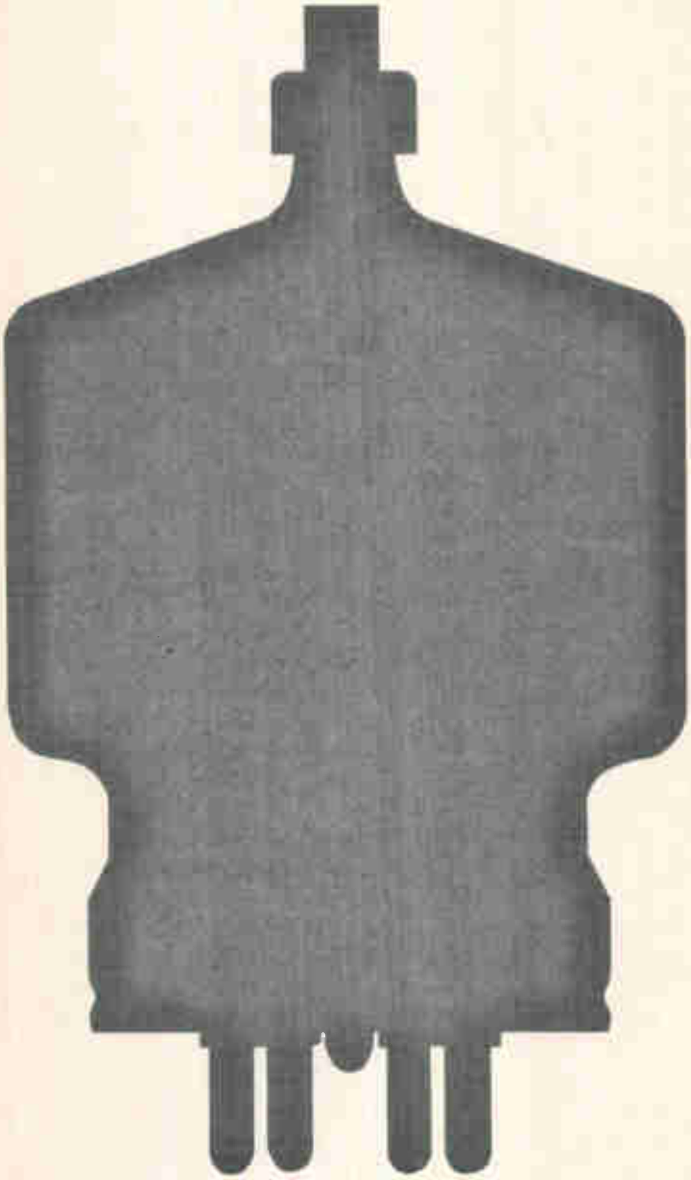


ML-EE64Y
Actual size.

RAYTHEON

THE MACHLETT LABORATORIES, INC.

A SUBSIDIARY OF RAYTHEON COMPANY

Circle 15 on reader service card

integrated circuits.

First big loss. "You can see that these people had the same responsibilities, but over a narrower base, before the defections," says Levy. "I don't think our ability to compete has been harmed because some of our top people left. This is the first time that we lost any significant group of people, and consequently we have a great depth of management talent in the company."

Levy's own promotion, from assistant general manager to general manager, was probably merely moved ahead by Hogan's departure. Since Levy joined the division four years ago as product marketing manager for IC's, his rise at Motorola has been swift and seemingly inexorable. His appointment as assistant general manager in April made the outside world sure that when Hogan became president of Motorola, Levy would take over the Semiconductor Products division.

Levy is credited with carrying out Hogan's plans for expansion in the IC market so well that the company threatened to pass Fairchild this year. Hogan's departure may delay that event, but Levy says that Fairchild's own predictions indicate that "if we're not No. 1 this year, we'll be so close that it will be insignificant."

Company strategy to capture that top spot is unchanged; Levy isn't impressed with talk of medium- and large-scale integration today. "Some day you will sell a system on a chip," he says, "but there are a lot of problems to solve between now and then. If you can't show an economic advantage, LSI is a myth. The question is, when is it real, and at what level. I think some manufacturers have tried to put over a compressed timetable."

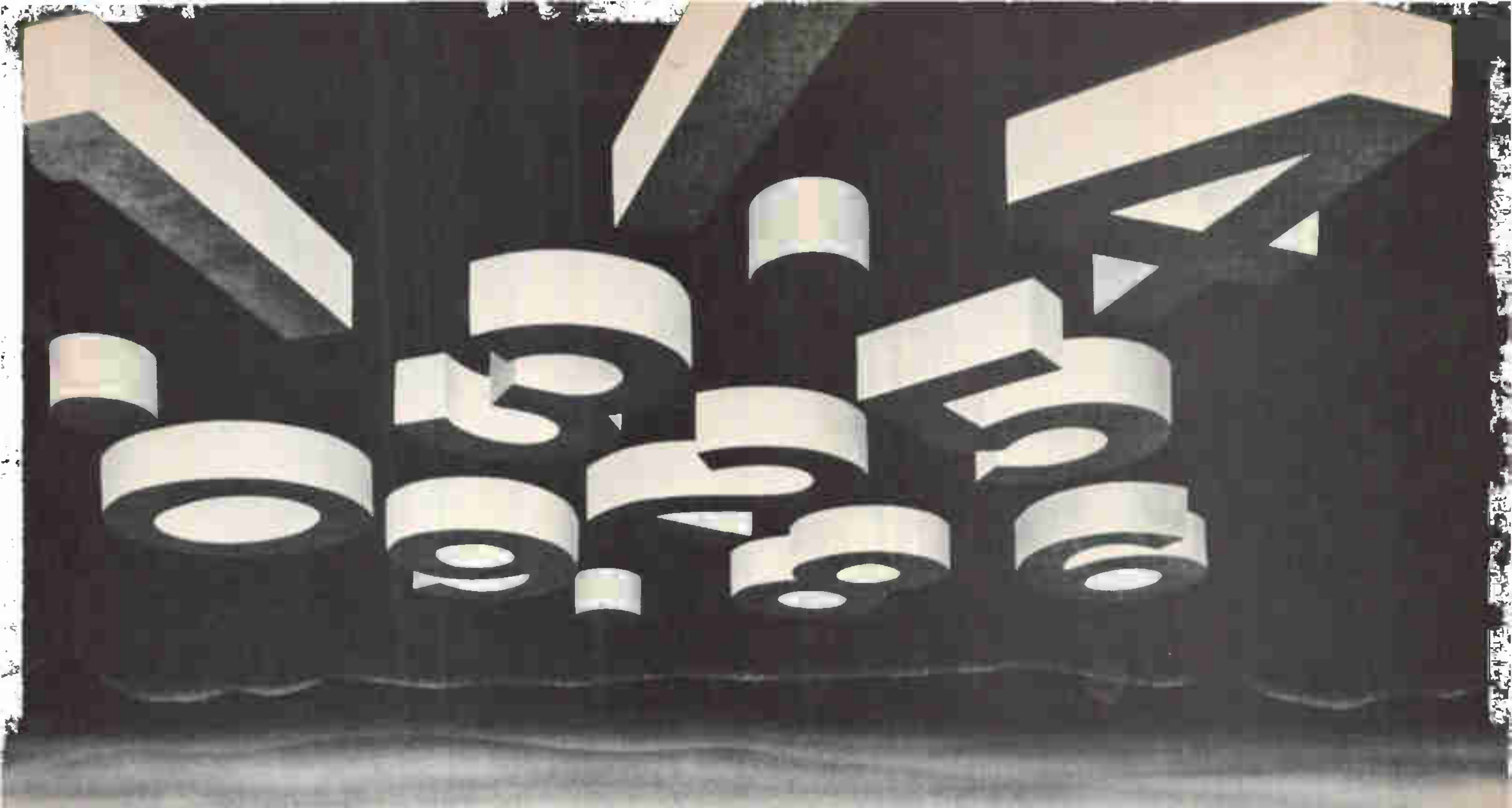
Change of plans. Levy's reliance on Welty during the stress period must have made the latter's return to Phoenix a pleasant one after a sojourn at Philco that can only have been disappointing. A corporate decision to cut losses in Philco's Microelectronics division made Welty's plans for it seems irrelevant to some. Yet he left the corporation on good terms and showed no signs of bitterness. Seemingly unflappable, he picked up at Motorola almost where he left off, and was in close consultation with Levy on the new executive lineup.

Welty made no effort to minimize the effect of the Fairchild raid, but at the same time he left no doubt that Motorola expected to survive. "The question is academic: of course we've been hurt," he said. "But there's a hell of a lot of self-confidence here; that's Hogan's heritage. He convinced the organization that it could do things that it didn't believe it could. Now Hogan is gone, but the organization is here."

Where it's at. Haenichen, an engineer turned into a manager, partly by Motorola's policy of paying more for administrative talent, is perhaps best known outside Motorola for his work in developing annular structures to prevent channeling in high-voltage, high-power pnp transistors. But he says that a young engineer at Motorola soon discovers that production is where the action is; Haenichen himself displays no nostalgia for the laboratory.

It is in his areas that Fairchild is weakest, and Haenichen expects to maintain Motorola's advantage. "They just don't have a broad line," Haenichen notes. "In discretes, we only see them in silicon transistors. But it took us a long time to build our product line; in nine years we've just encircled them in silicon controlled rectifiers, thyristors, germanium devices, power, and so forth. Right now they're not fighting me anywhere."

Lynch echoes Haenichen's belief in the effect of Motorola's long head start in some areas. "We're so far ahead now that he can't catch up," Lynch says of his old boss, Corrigan. Lynch even asserts that where the old management team built Motorola into some leadership positions, the new one may be better suited to keep it there. "All you can say right now," he says, "is that it's different."



Charlie Straightarrow was dazzled digitally. Don't let it happen to you!

Charlie Straightarrow is a good engineer. He's been at it for about ten years now. Like a lot of us, Charlie's bought his share of scopes, counters, voltmeters and other assorted test and measurement equipment during that time.

And also like a lot of us, Charlie has been impressed with the digital instrumentation he's seen on the market lately. (So are we, especially since we make the only true RMS digital voltmeters. But back to our story.) In fact, for awhile this winter Charlie was dazzled digitally. Everything he bought had to be digital. Recently, Charlie was looking for a digital scope when, quite by accident, he stumbled across our little pamphlet. **Differential or digital, the unvarnished truth about precision voltmeters.**

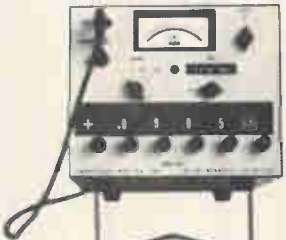
Charlie got perspective after that. Charlie found out that the most accurate digital voltmeter on the market today costs upwards of $4.000. He also found several Fluke differential voltmeters with twice the accuracy of the best digital and ten times the resolution for far less money. Lowest price units are less than $1.000. Highest, only $1.535 and that includes AC capability as well. Or, put another way. Is analog dead?

So as Charlie reasonably decided, the problem of choosing a voltmeter comes down to application. A Fluke differential such as our 895A should be your choice in laboratory applications where the ultimate in precision measurement without ambiguity is required. Accuracy of the Model 895A is 25 parts per million. The best digital is always limited by its parts per million accuracy and plus or minus 1 digit. Resolution of the Model 895A is 1 ppm compared to 10 ppm for the best digital.

It's in systems applications that the digital voltmeter offers the most promise. If your problem involves making a great number of measurements using relatively untrained personnel and if accuracy demands are modest, then the digital voltmeter is usually the best answer. But if you need accuracies better than even 100 ppm, then the dollar-performance bias is in favor of the differential voltmeter.

If you would like to stop "digital dazzle" too, write for the same pamphlet Charlie read. We'll even send one to digital design engineers. Please address Frank Peep for your free copy.

(P.S. our readout is digital, too!)



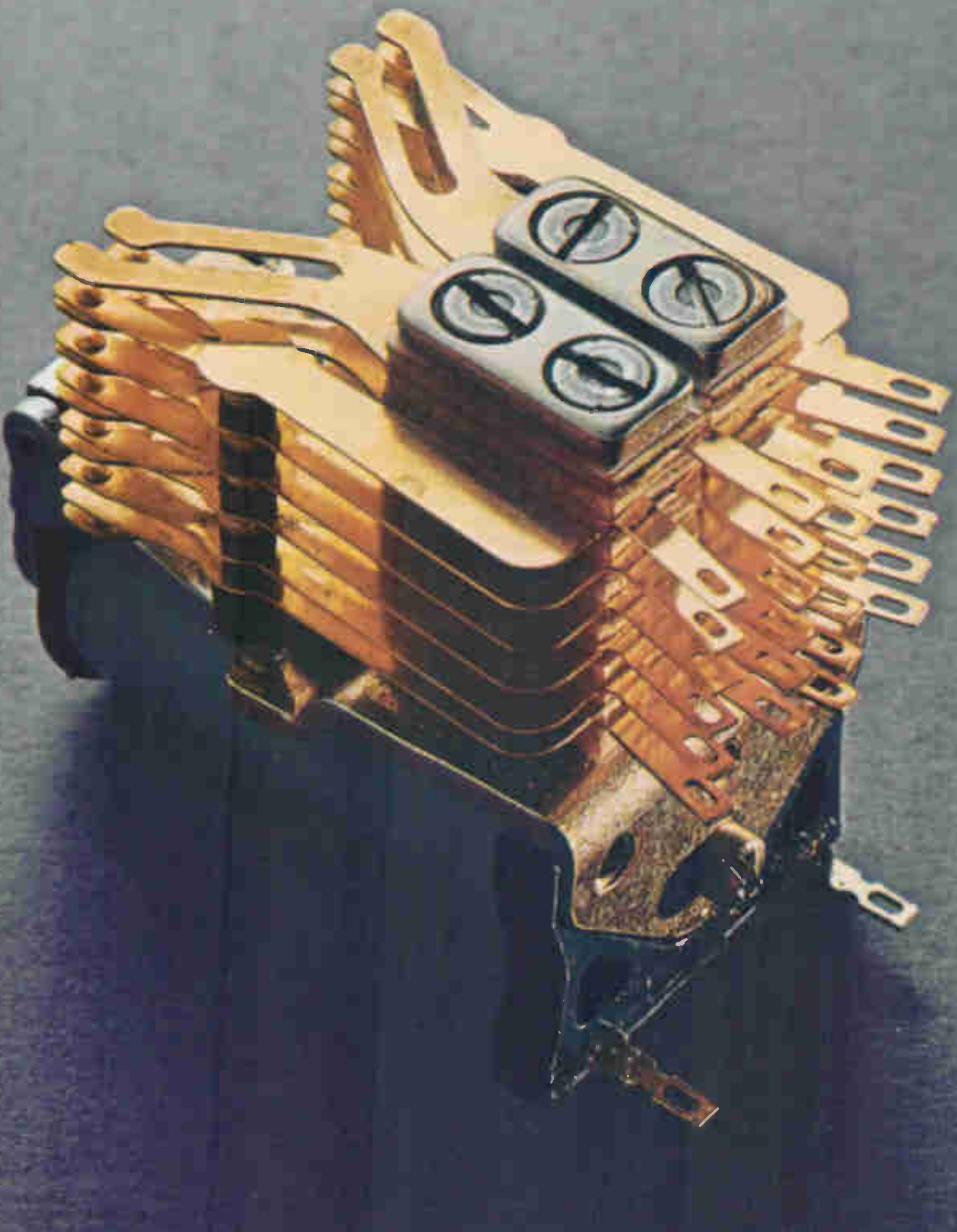
The Fluke Model 895A solid state differential voltmeter is but one of more than 150 precision voltmeters, calibrators, power supplies, and frequency and time instruments. Components for Fluke instruments are tested and checked out in one of the best standards labs anywhere (the only lab more complete is operated by the NBS). Fluke instruments are guaranteed to work in your environment. Or put another way, if the Fluke instrument doesn't work there, you can't live there.

FLUKE

Fluke, Box 7428, Seattle, Washington 98133. Phone: (206) 774-2211. TWX: (910) 449-2850. In Europe, address Fluke International Corporation, P.O. Box 5053 Ledeboerstraat 27, Tilburg, Holland. Telex: 844-50237 In U.K., address Fluke International Corporation, P.O. Box 102, Watford Herts, England.

See the latest in precision instruments from Fluke at the Instrument Fair, Washington, D.C. Sept. 25 & 26, 1968.

Reliability is six things we do that nobody else does.



We're fanatics.

We build our relays stronger than we have to. That way, they last lots longer than they ever have to. Our Class E relay (shown on the opposite page) is a good example of our way of thinking.

The industry's strongest heelpiece.

We make the strongest heelpiece in the industry. A gigantic machine bangs them out extra fat and extra flat.

Extra fat to carry a maximum of flux. To handle big loads. Extra flat so that once an AE relay is adjusted, it stays adjusted.

Since our backstop is part of the heelpiece, it's just as thick and flat. But, tough as it is, the slightest wear here would throw the entire contact assembly out of whack. So, to be safe, we weld two tiny, non-magnetic pads where the armature arms meet the backstop. You might say we created the no-stop backstop.

Three parts that'll wear like crazy.

When you build a relay like a small tank, you have to think of everything. We try. Right down to the tiniest part. For example, we make our armature arms and bearing yoke extra thick.

Thicker than years of testing and use say they have to be. Then, to make sure they don't cause wear problems, we insert a hardened shim between the hinge pin and the frame. The pin rides on the shim, instead of wearing into the heelpiece. (You can forget the bearing, it's permanently lubricated.)

Buffers with lots of muscle.

We make our buffers of a special tough phenolic material that lasts. And lasts. And lasts. All without wear or distortion. Another reason why our relays stay in whack.

To make sure our buffers stay in place, we weld the buffer cups to the armature arms. We weld, instead of using rivets, because our lab found that rivets have a habit of falling out.

For the very same reason, we weld buffer cups to the contact springs. And also use the same special tough phenolic buffers.

No, we didn't forget the contact springs.

We have some strong feelings as to what makes a contact spring reliable. Our sentiment is that two contacts are better than one. So, we bifurcate all the springs, not just the make and break. This slotting and the addition of another contact to each spring means you get a completed circuit every time.

We make each set of contact points self-cleaning. The bad stuff doesn't have a chance to build up.

Now, what's different about our bobbin?

Our bobbin is one piece—molded of glass-filled nylon. This provides the maximum in insulation resistance.

Because our bobbin is nylon, we don't have to impregnate with varnish. Moisture and humidity have no effect on the stubborn nylon material. No effect means no malfunctions for you to worry about.

What all this means to you.

What this all adds up to is reliability. The kind of toughness no one else can give you. It means an AE relay works when it's supposed to, longer than it has to.

Isn't this the kind of reliability you really need? Automatic Electric Company, Northlake, Ill. 60164.

AUTOMATIC ELECTRIC

SUBSIDIARY OF GENERAL TELEPHONE & ELECTRONICS

Circle 19 on reader service card

THE TOMORROW MOSFETS.

Meetings

Electrochemical Society: Materially significant

The trend in electronics is clearly toward a materials-oriented science, and the Electrochemical Society meeting in Montreal, Oct. 6 to 11, is one of the best places to find out who's doing what with what materials.

Sandwiched among the papers on batteries, fuel cells and corrosion are several papers of immediate interest to electronics engineers who are looking ahead to better semiconductor devices. The semiconductor papers will cover such topics as ohmic contacts, epitaxial compounds and phosphors, metal-insulator devices, and photosensitive materials for electronics applications.

From the lab. Though these papers are coming from the research labs, the semiconductor industry's record of bringing techniques from the laboratory onto the production floor quickly is well known.

Two papers on ohmic contacts are aimed at further improving a device that is, itself, just now moving out of the research lab: the Gunn-type oscillator. In one, Ronald H. Cox and Turner E. Hasty, researchers at Texas Instruments, Dallas, will discuss the metallurgy of alloyed ohmic contacts for the gallium-arsenide oscillator.

Cox and Hasty will point out that alloyed contacts made directly to the device's active n- region form a thin high-resistance region that can produce a nonuniform electric field in the device, which in turn, limits output power and efficiency. They'll discuss ways to reduce the dislocation density at the contact-gallium arsenide interface, the main result of the poor contacts. They say that the bad effects of alloy contacts can be largely avoided by using an n^+ n^- n^+ gallium arsenide structure, with the top n^+ layer made either by vapor-phase or solution-regrowth epitaxy. The defects formed by alloying are then formed in the n^+ layer, not the active n^- layer, and thus don't affect device behavior.

In the second paper on ohmic contacts to gallium arsenide, two Bell Telephone Laboratories researchers, Carl Paola and Stephen Knight of the Murray Hill, N.J., facility, will discuss such contact alloys as indium-gold, tin-gold, and germanium-gold, as well as such pure elements as indium, gold, silver and tin.

For additional information write Charles Moore, Electrochemical Society, 30 E. 42 St., New York 10017.

Calendar

Electronics and Aerospace Systems Conference, IEEE; Sheraton Park Hotel, Washington, **Sept. 9-11.**

Meeting of the Union Radio Scientific International; Hotel Somerset, Boston, **Sept. 9-12.**

Group on Antennas & Propagation International Symposium, IEEE; Northeastern University, Boston, **Sept. 9-12.**

International Conference on Microwave and Optical Generation and Amplification, IEEE; and the University of Hamburg; University of Hamburg, West Germany, **Sept. 16-20.**

Cedar Rapids Conference on Communications, IEEE; Veteran's Memorial Coliseum, Cedar Rapids, Iowa, **Sept. 19-21.**

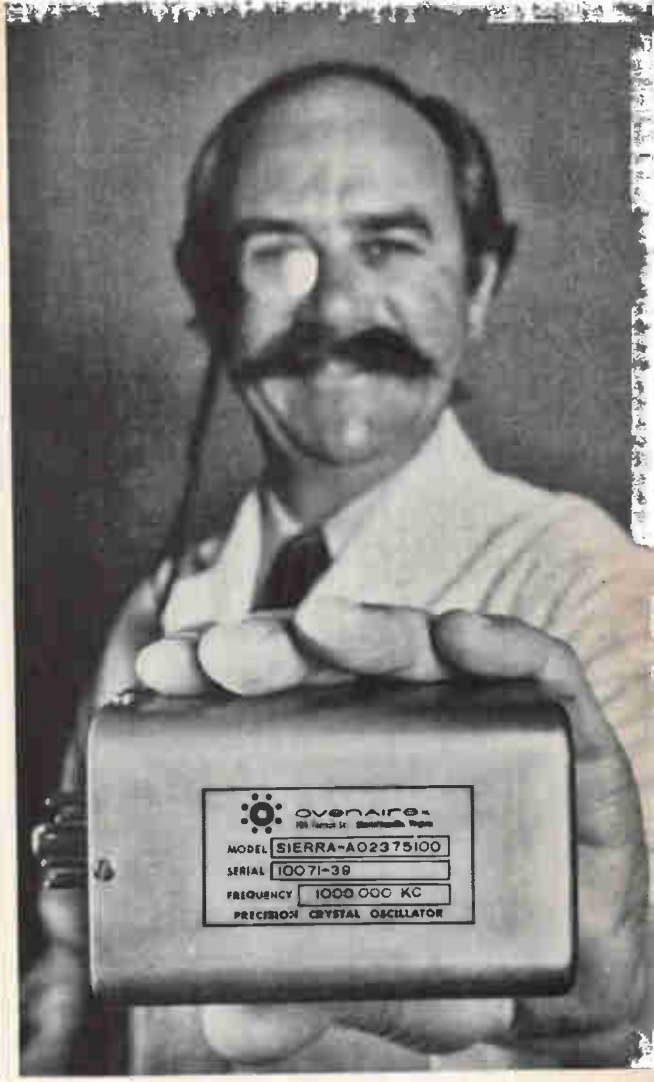
Aerodynamic Deceleration Systems Conference, American Institute of Aeronautics and Astronautics; El Centro, Calif., **Sept. 23-25.**

Conference on Electronics Design, Institution of Electrical Engineers, Institution of Electronics and Radio Engineers, IEEE; Cambridge University, England, **Sept. 23-27.**

Symposium on Physics & Nondestructive Testing, Gordon & Breach Science Publishers; O'Hare International Inn, Schiller Park, Ill., **Sept. 24-26.**

Instrumentation Fair, IEEE; Sheraton Park Hotel, Washington, **Sept. 25-26.**

(Continued on page 24)



Precise!

(resolves envelope delay to 0.1 μsec)

Bright digital displays pinpoint relative delay and indicate carrier frequency to the nearest 10 Hz on Sierra's solid-state Model 340B Envelope Delay Test Set. Range of 300 Hz to 110 kHz spans both voice (4 kHz) and group (60–108 kHz) frequencies. A three-position switch sets you up for end-to-end, end-to-end with return reference path, or loop-back operation. Another selects your modulation frequency (25, 83⅓, and 250 Hz now standard).

Accurate end-to-end delay measurements without a separate reference circuit are assured by the stability of Model 340B's precision internal master clock. To compensate for slight long-term frequency drift, a high-resolution, multiturn potentiometer helps keep the two clock oscillators synchronized.

Each modulation frequency has a single delay range: ±20,000 μsec at 25 Hz, ±6000 μsec at 83⅓ Hz, ±2000 μsec at 250 Hz. The 10V analog outputs for frequency and delay, with internal electronic scan, allow you to record a delay contour in seconds, then tune to any number of discrete points for closer analysis. Optional: A third analog output to record levels of received signals.

Among the numerous other features a Model 340B has to offer: Built-in transformers for balanced or unbalanced 135-, 600-, and 900-ohm, as well as 75-ohm circuits; built-in 1-MHz frequency counter with digital readouts accurate to 1 Hz.

Your signal will produce a product bulletin without delay. Write Sierra/Philco-Ford, 3885 Bohannon Drive, Menlo Park, California 94025. Or call (415) 322-7222, ext. 328.

...stability guaranteed by this oven-controlled master clock oscillator

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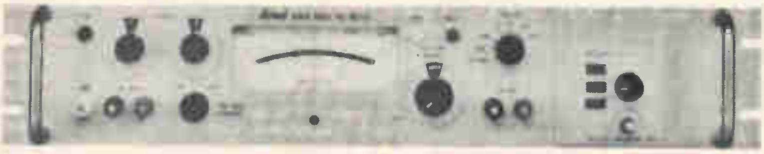

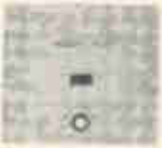

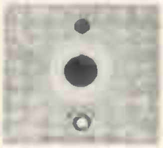

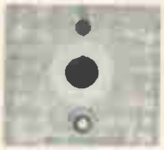

Meetings

(Continued from p. 22)

Ultrasonics Symposium, IEEE; Statler Hilton Hotel, New York, Sept. 25-27.

International Fair for Electronics, Automation, and Instruments; Copenhagen, Sept. 27-Oct. 4.

Engineering Management Conference, IEEE; Marriott Motor Hotel, Philadelphia, Sept. 30-Oct. 1.

Government Microcircuit Application Conference, Department of the Army; Washington, Oct. 1-3.

Allerton Conference on Circuit and System Theory, IEEE; Allerton House, Monticello, Ill., Oct. 2-4.

Symposium on Multivariable Control Systems, International Federation of Automatic Control; Duesseldorf, West Germany, Oct. 7-8.

International Telemetering Conference, Foundation for Telemetering, IEEE; Ambassador Hotel, Los Angeles, Oct. 8-11.

Joint Engineering Management Conference, American Society of Mechanical Engineers, Instrument Society of America, American Institute of Aeronautics and Astronautics, IEEE; Jack Tar Hotel, San Francisco, Oct. 9-10.

Symposium on Applications of Ferroelectrics, IEEE; Catholic University, Washington, Oct. 10-11.

International Astronautical Congress, American Institute of Aeronautics and Astronautics; Waldorf Astoria Hotel, N.Y., Oct. 13-19.

System Science and Cybernetics Conference, IEEE; Towne House, San Francisco, Oct. 14-16.

Annual Symposium on Switching and Automata Theory, IEEE; Schenectady, N.Y., Oct. 15-18.

Symposium of Reliability in Electronics, Hungarian Academy of Sciences; Budapest, Oct. 15-18.

Conference on Electrical Insulation and Dielectric Phenomena, National Academy of Sciences—National Research Council; The Inn, Buck Hill Falls, Pa., Oct. 20-23.

Meeting and Technical Display, American Institute of Aeronautics and Astronautics; Philadelphia Civic Center, Philadelphia, Oct. 21-25.

Shock and Vibration Symposium, Naval Research Laboratory; Asilomar Conference Grounds, Pacific Grove, Calif., Oct. 22-24.

(Continued on p. 26)

whatever direction your design takes...

Allen-Bradley thick film networks will put you out front in...

Packaging—Advanced manufacturing capability covers virtually every type and every configuration of resistive and/or capacitive networks—single or dual in-line, as well as flat-packs, with or without hermetic sealing.

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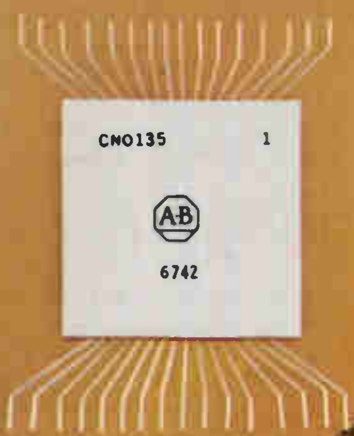

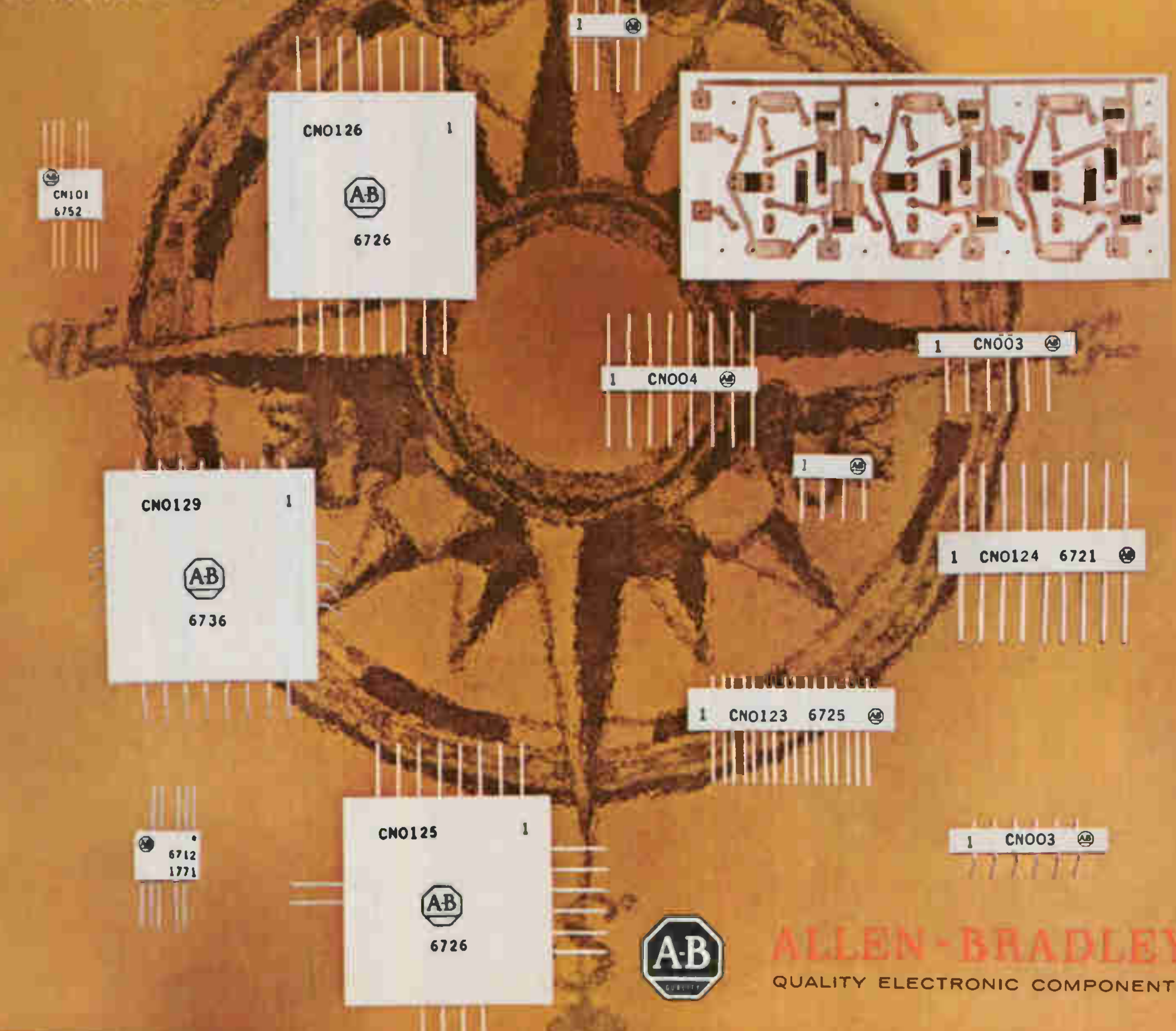

ALLEN-BRADLEY
QUALITY ELECTRONIC COMPONENTS

Meetings

(Continued from p. 24)

International Electron Devices Meeting, IEEE; Sheraton Park Hotel, Washington, **Oct. 23-25.**

Nuclear Science Symposium, IEEE and United States Atomic Energy Commission and Atomic Energy Commission of Canada; Bonaventure Hotel, Montreal, Canada, **Oct. 23-25.**

Seminar in Depth—Image Information Recovery, Society of Photo-Optical Instrumentation Engineers; Benjamin Franklin Hotel, Philadelphia, **Oct. 24-25.**

Call for papers

Electronic Components Conference, IEEE; Washington, April 30-May 2. **Nov. 1** is deadline for submission of summaries to James A. O'Connell, technical program chairman, Electronic Components Conference, ITT, 320 Park Ave., New York, N.Y. 10022.

International Communications Conference, University of Colorado and IEEE; University of Colorado, Boulder, June 9-11. **Jan. 1** is deadline for submission of abstracts and papers to Dr. Martin Nesenbergs, Environmental Science Services Administration, Institute for Telecommunications Sciences, R614, Boulder, Colo. 80302.

Joint Automatic Control Conference, American Institute of Aeronautics and Astronautics, American Institute of Chemical Engineers, American Society of Mechanical Engineers, Fluid Power Society, IEEE Automatic Control Group, Instrument Society of America, and Simulation Councils; University of Colorado, Boulder, Aug. 5-7. **Nov. 15** is deadline for submission of papers to W.E. Schiesser, program chairman, 1969 JACC, Department of Chemical Engineering, Lehigh University, Bethlehem, Pa., and five copies for review to J.B. Lewis, department of electrical engineering, Pennsylvania State University, University Park, Pa. 16802.

Short courses

Avionics systems engineering, University of California, Los Angeles, **Sept. 9-20;** $375 fee.

Fundamentals of nondestructive testing, Ohio State University, Columbus, **Sept. 9-20;** $350 fee.

Process dynamics and control, Purdue University's Schools of Engineering and Laboratory for Applied Industrial Control, Lafayette, Ind., **Oct. 28-Nov. 2;** $150 fee.

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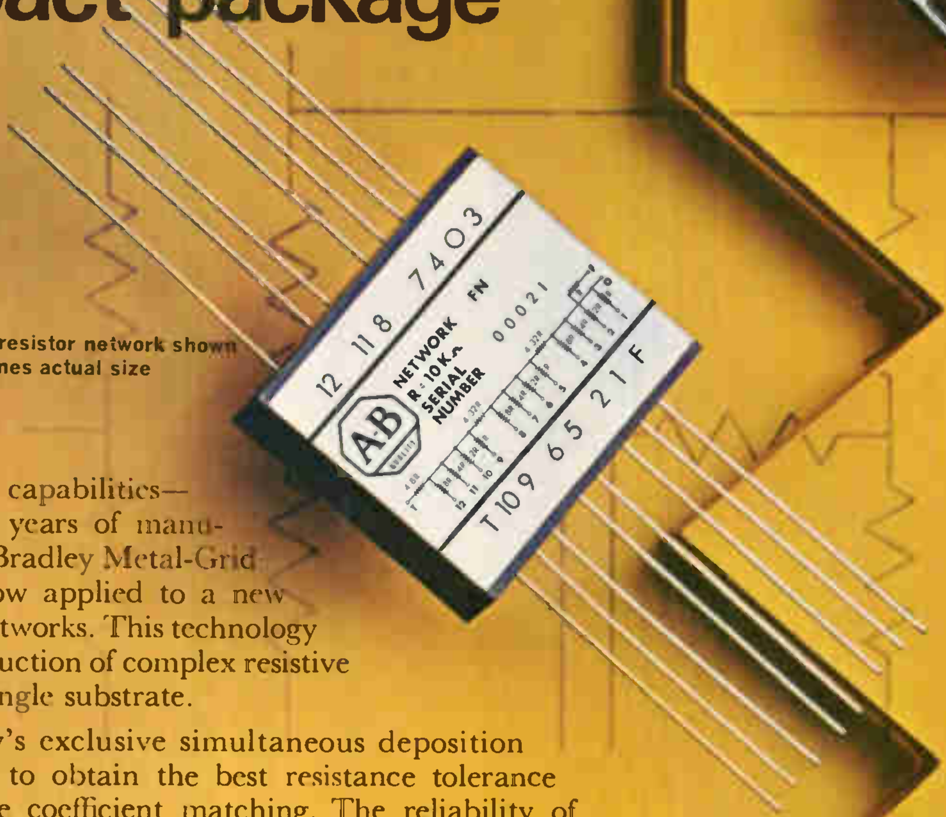
Metal-Grid resistor networks
combine a new measure of

precision, stability and performance in a sealed, compact package



Precision Metal-Grid resistor network shown approximately 1½ times actual size

The advanced capabilities—developed from years of manufacturing Allen-Bradley Metal-Grid resistors—are now applied to a new line of resistor networks. This technology enables the production of complex resistive networks on a single substrate.

Allen-Bradley's exclusive simultaneous deposition method is used to obtain the best resistance tolerance and temperature coefficient matching. The reliability of interconnections on the common resistance plane is incomparable. Uniformity and quality are inherent in A-B networks. To illustrate, 2 PPM temperature tracking is normal.

A-B Metal-Grid networks offer a wide range of values—with individual resistances as low as 25 ohms and as high as 2.0 megohms. Both the inductance and capacitance are low, permitting efficient operation at high frequencies.

A-B engineers will be pleased to cooperate in developing networks for your specific need. For additional details, please write to Henry G. Rosenkranz, Allen-Bradley Co., 1315 S. First Street, Milwaukee, Wisconsin 53204. In Canada: Allen-Bradley Canada Ltd. Export Office: 630 Third Avenue, New York, N. Y., U.S.A. 10017.

BRIEF SPECIFICATIONS

Resistor Networks

Tolerances: ±1.0% to ±0.01%

Resistance Matching: to 0.005%

Temperature Range: −65°C to +175°C

Temp. Coef.: to ±5 ppm/°C

Load Life (Full load for 1000 hr @ 125°C): 0.2% maximum change

Ladder Networks

Full Scale Accuracy: 10 bits or less, better than ±¼ least significant bit. More than 10 bits, better than ±½ least significant bit.

Frequency Response: Less than 100 nanosecond rise time or settling time

Temp. Coef.: Less than 10 ppm/°C

Temperature Range: −65°C to +175°C

ALLEN-BRADLEY
QUALITY ELECTRONIC COMPONENTS

EC 682


N.C. C. N.O.

Basic Switches? Go where you can pick from the whole blooming family.

You won't miss out on the latest in basic switches when you come to MICRO SWITCH. Here you can make your selection from the world's largest family. Thousands of subtle variations help you meet any combination of requirements—size, weight, circuitry, electrical capacity, actuation, termination and environmental resistance.

For example, there are switches especially sealed to do the job in highly contaminated environments; switches that operate efficiently at temperatures as severe as +1000° or −320°F; electrical loads from milliamp to 25 amps, 125 vac, or 10 amps, 125 vdc. A large number meet military specifications.

But you can expect much more when you come to MICRO SWITCH. For instance, extra assurance of consistent quality throughout a large quantity run. Or the certainty that a switch will deliver precise operating characteristics throughout a long life. Perhaps what's essential to you is the convenience of local distributors with complete selections on the shelf—or, on the other hand, world-wide availability! If on-time deliveries are critical to you, you'll be interested in our computer-controlled ordering, inventory and production control system. Finally, should you have special design problems, our engineering field service—the largest in the industry—specializes in coming up with the right solutions.

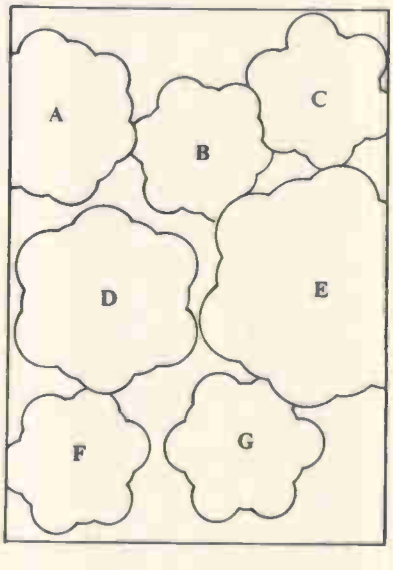
Shown at left and described below are just a few members of our ever-blooming family of basic switches. For additional information, call a Branch Office or Distributor (Yellow Pages, "Switches, Electric"). Or write for Catalogs 50 and 52.

A. Type V3 Basic Switches—Small, versatile precision switches. Over 500 standard designs, including many actuator and terminal variations. Operating force as low as 10 grams, differential travel as small as .002 inch. Rating up to 15 amps 125 vac. SPDT, SPNO or SPNC. Temperature range up to 600° F. Military listed. Case size 1.09 x .62 x .40 inch.

B. Subminiature Basic Switches—Precision operation with minimum space and weight. Variety of actuators, terminals and characteristics. Silver or gold contacts, and bifurcated contact design for reliable low energy operation. Military listed. Type SM: Case size .78 x .35 x .25 inch, up to 10 amps 125 vac. Type ISX: Case size .50 x .35 x .20 inch, 7 amps 125 vac.

C. Sealed Basic Switches—Small switches for reliable military/aerospace use and other applications requiring environmental protection. Types XE and SE are classed watertight (Symbol 3, MIL-S-8805), with a corrosion-resistant metal housing, molded silicone rubber plunger seal, and terminals encased in epoxy resin. Types HM and HS feature true hermetic sealing (Symbol 5, MIL-S-8805), with metal-to-metal and glass-to-metal fusion. Solder or leadwire termination.

D. Special Circuitry Basic Switches—Simplify circuit design and eliminate extra wiring. Type "DT": DPDT. Type TB: 2-Ckt and 4-Ckt Double-Break. Type MN: 2-Ckt Double-Break. Also dual SPDT assemblies, make-before-break, pulse operation, and sequential action types.



E. Standard Basic Switches—The maximum in precise operation, accurate repeatability, long life and high electrical capacity. Thousands of proven designs available. Variety of actuators and terminals. Case size: 1.94 x .95 x .68 inch. SPDT, SPNO or SPNC. Momentary or maintained contact. Type Z: 15 amps; Type A: 20 amps; Type M: 22 amps; Type E: 25 amps; each at 125 vac. Type MT: 10 amps 125 vdc.

F. High Temperature Basic Switches—Type HT switches withstand +1,000°F and −321°F. Available with panel-mount push-plunger or roller-plunger, or side-mount with auxiliary actuators. Corrosion and shock resistant.

G. Glass-Enclosed Switches—Hermetically sealed contacts for extra reliability and long life. Modern automatic equipment assures product uniformity in large quantity production. Type AS mercury switches: low force, tilt operation; SPST, SPDT, or 2-Ckt; rating up to 70 amps 30 vac; variety of operating characteristics. Type CS miniature reed switches: Form A or Form C; outstanding long life/high capacity combination—up to 100,000,000 cycles at 10 watts; and high reliability on micro-volt or micro-ampere circuits.

MICRO SWITCH

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A DIVISION OF HONEYWELL

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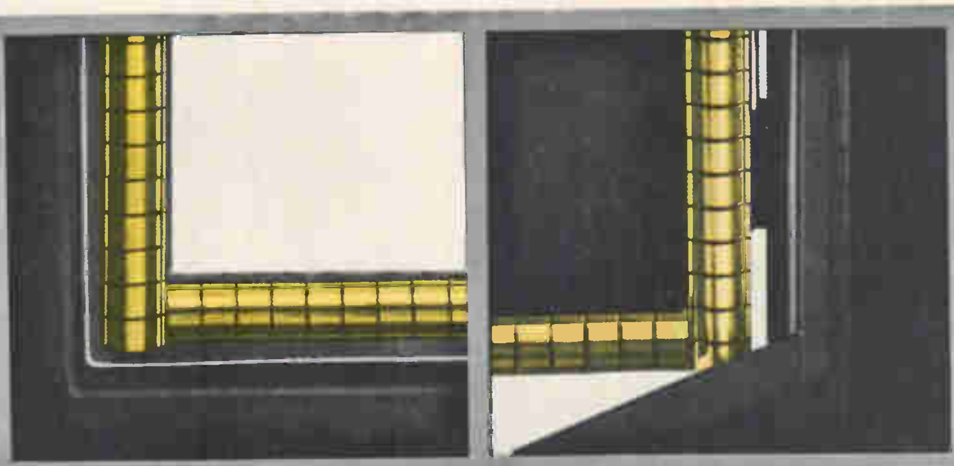
Sticky RFI problems?

sticky fingers®

attach with self-adhesive, shield RFI better than anything else!

Panel-type enclosure openings can be shielded quickly using STICKY FINGERS strip. Strip forms own corner.



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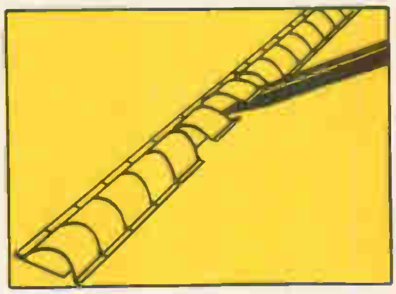

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Editorial comment

A case of self-deception

The electronics industry is perennially hopeful of converting the technology and management techniques learned while working on military and space contracts to civilian programs in such fields of public interest as rapid transit, air and water pollution, urban renewal, and air and ground traffic control. But though defense programs such as the missile development effort are unsurpassed in size and funding, the transfer of benefits to civilian areas has been less than overwhelming and often downright disappointing.

Sometimes the relationship between successful Government-sponsored projects and civilian fallout is tenuous indeed. Critics of the frustrating pace of technology diffusion argue that Japan, West Germany, and Sweden have accomplished as much in some civilian sectors as the U.S. without benefit of our vast aerospace programs.

In truth we are deceiving ourselves to expect the rapid and efficient diffusion of electronics/aerospace technology to broad civilian areas. Some technology just doesn't "transfer" well. When the Battelle Memorial Institute studied the attempts of aerospace businesses to diversify, it found that shifting into nonmilitary Government markets was generally much easier for such firms than tackling commercial-industrial or consumer markets.

The hardware needed for military gear and the hardware applicable to consumer products often differ so radically that the direct transfer of technology becomes an exercise in futility. Moreover, the technological content of some civilian programs seems so small that neither project managers nor vendors will invest in developing the possibilities.

Further complications stem from a poor understanding of the mechanisms of technology transfer and diffusion. Karl Harr Jr., president of the Aerospace Industries Association, emphasizes the years of lag time between the use of a new idea in advanced systems and its appearance in products on the commercial market. Even for those technological developments that seem eminently transferable, lag time is a limitation. The Air Force is proposing the use of synchronous satellites for communications, navigation, and identification [Electronics, Aug. 19, p. 33] and is aiming to get such a system in operation in five to 10 years. Could such a system be extended to handle commercial air traffic control? One Air Force official thinks it could, but that it might take up to 20 years.

The transfer of software has been more successful than the transfer of hardware, so that lists of conversions stress projects involving systems engineering and managerial methodology rather than devices, circuits, and systems. A good many of these projects involve systems modeling by computer. For example, TRW uses computer programs to weigh such factors as vehicle configurations, route selections, terminal locations, and system costs in its studies of transportation requirements for the Northeast Corridor. Aerojet-General has simulated the criminal justice system for the State of California, and North American Rockwell proposes the development of simulation models to continue its study of California's transportation problems.

Fortunately, there are cases in which hardware-oriented technology that's been nurtured by Government dollars can be directly applied to civilian needs. Those that come immediately to mind are in the field of medicine. For example, North American Rockwell is developing remote patient-monitoring systems that use IC's in transmitters (an outgrowth of the Apollo program). Hamilton Standard has developed a way to relay electrocardiogram data in real time by telephone, and Martin-Marietta is applying lasers to surgery and diagnostics.

Ultimately, the payoff from Government-supported R&D should come in the greater transfer of hardware, or at least in the development of new hardware based on "hard" technology. We applaud studies by private research groups—the Rand Corp. and the Brookings Institution, for example—aimed at pinning down the factors involved in the transfer of technology. With better definition, the process might be speeded up, and, more important, extended to fields that don't currently benefit.

As of right now, though, there's little basis for optimism in the electronics industry about direct technological transfers.

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Electronics Newsletter

September 2, 1968

Air Force seeks most powerful pulse radar ever

The world's most powerful short-pulse radar is the goal of a $713,853 Air Force contract awarded to the Eimac division of Varian Associates, San Carlos, Calif. The ultrahigh power sought—perhaps 600 to 700 megawatts—and the ultrashort pulses—possibly only a few nanoseconds long—would boost range and target resolution far beyond today's levels.

Industry sources say development of the classified system will require major advances in both tube and power-supply designs. If the new designs succeed, the system will begin to push the bounds set by the theory of relativity. Though the tube will embody klystron design principles, its electrons will be accelerated at such speeds that they will gain significant mass as they near the speed of light.

A subcontractor, Ion Physics of Burlington, Mass., will develop a pulser capable of delivering several kiloampere pulses per second at potentials far above a megavolt. Such powers have never before been achieved in such short pulses.

The Air Force's Rome Air Development Center says the system should be operating by 1970-71 at the center's Floyd, N.Y., test facility.

LSI may get job in SST computer

Large-scale integration may find its way into the flight-control computer for the supersonic transport being built by Boeing. General Electric's Avionic Controls division, which is competing with Sperry Rand for the computer order, is buying 250-gate LSI circuits from Fairchild Semiconductor. The devices, which can perform a series of combinational logic functions, are in a MOS configuration on 80-by-80-mil chips.

GE paid Fairchild $12,000 to develop the arrays; it will pay $60 a chip for the first 100 and about $44 thereafter.

This purchase follows news that GE is negotiating with Fairchild to acquire medium-scale integrated devices for the electronic controls of the swiveling gunner's station in the Air Force's Cheyenne helicopter [Electronics, Aug. 5, p. 33].

Watkins-Johnson begins microwave transistor R&D

Watkins-Johnson, one of the major producers of traveling-wave tubes, has started in-house research on transistors for microwave amplifiers. Apparently the Palo Alto, Calif., firm sees the handwriting on the wall: except for very high-power needs, twt's will eventually be replaced by solid state components.

Although the R&D work is extensive, it's not far enough advanced to determine when or what commercial products will be available.

Navy sharpens new ship checkout

The Navy's going to write a new inspection procedure into future contracts for surface vessels. Under the scheme, tried for the first time on the aircraft carrier John F. Kennedy, crews will be installed aboard long before the ships are commissioned. This early exposure of operators to equipment makes for a more effective checkout, says the Navy, and improves equipment performance—including that of electronic gear—in builders' trials and acceptance tests.

Shipbuilders and electronics firms are generally less enthusiastic. They feel that these early shakedowns will force them to make many more revisions and adjustments than before, and will thus narrow profits.

Capital, technology get marriage broker

The latest to join a new trend in the electronics industry—the formation of companies specializing in marrying technology to capital—is Richard Petritz, former director of technology at the components group of Texas Instruments. He has joined Richard Hanschen to found a firm called New Business Resources in Dallas. Hanschen, a former marketing director and vice president at the TI group, will remain associated with the investment firm of Burnham & Co.

As Theodore Maiman has done in Los Angeles with Maiman Associates, the founders of New Business Resources plan to devote most of their efforts to helping people with sound technology find financial backing in return for a share of the resulting business. The company's officials will also act as consultants during the formative stages.

Maiman, inventor of the ruby laser and founder of the Korad Corp., left to form Maiman Associates when Korad was absorbed by Union Carbide. Petritz was director of TI's semiconductor research and development laboratory (a line function) for six years, before he was shifted to the technology directorship (a staff function).

He says the new firm was launched because he and Hanschen want to help bring about the fourth generation in electronics—the move to medium- and large-scale integration.

Philips wins FAA order

North American Philips is planning heavier marketing efforts in the U.S. for computerized message-switching equipment manufactured by Philips Telecommunications Industries of the Netherlands. The firm received a good start last month with the award by the FAA of a $5 million contract for a five-computer complex to handle weather and forecasting data at the Kansas City message-switching center. Last year, Philips got a $1.7 million contract for air traffic control message-switching equipment at the same facility.

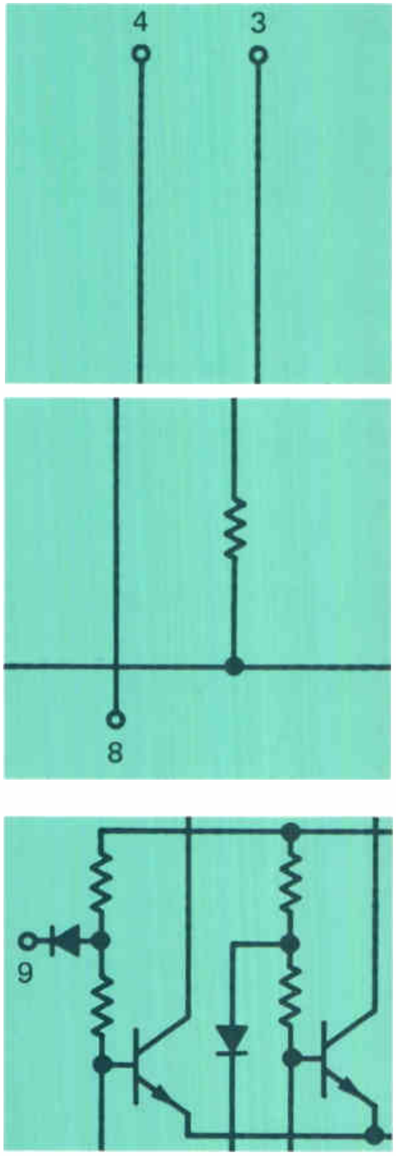
To avoid the "buy American" act provisions, the Dutch firm will buy at least 51% of the equipment and labor in the United States, including much of the peripheral equipment, assembly and programing.

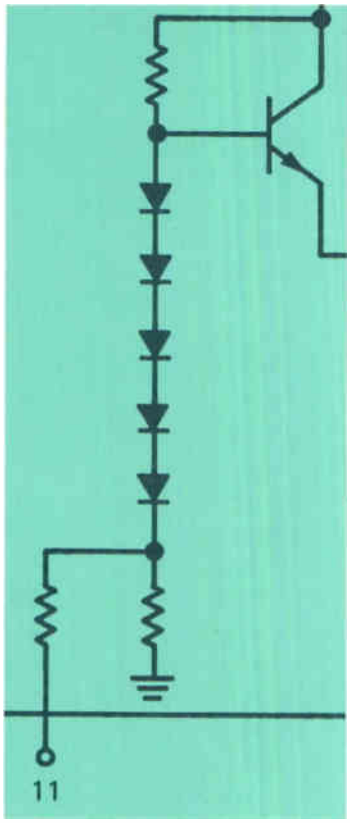
Motorola pushes memory work

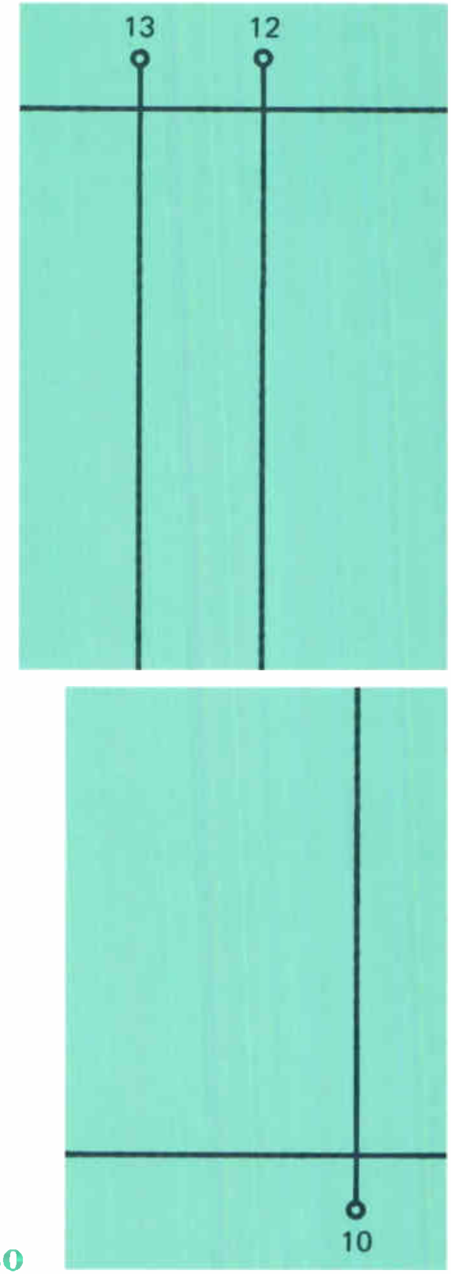
Officials at Motorola's Semiconductor Products division have ambitious plans for their fledgling semiconductor memory efforts. Wally Raisanen, newly named operations manager for metal oxide semiconductor and memory operations, says his group is working on a 4,000-bit memory module for main frame computer memories using hybrid large-scale integrated devices that will be faster (100-nanosecond cycle time) and cheaper (two to three cents per bit by the late 1970's) than magnetic memories. Motorola is working with two computer manufacturers now, and Raisanen foresees memories evolving into a $50 million per year business for the division in the 1970's.

Addenda

Corts (Conversion of Range Telemetry System) is finally on the way. An $11.5 million Air Force contract has been awarded to Service Technology, a subsidiary of LTV Aerospace, for the first phase, which runs to July 1969. The changeover, scheduled for completion by January 1970, will shift missile telemetery from the 225-260-megahertz vhf band to the 1,435-1,540-Mhz and 2,200-2,300-Mhz regions of the uhf band. . . . The Navy Systems Command is looking for companies to build and equip a satellite system for low-frequency air-to-ground communications.







½ μsec Memories With ½ The I/Cs

Dual-Channel Sense Amp, MC1541, Also Offers Six Performance Improvements

Two input channels on the new MC1541F make it possible to reduce by as much as one-half the number of I/C sense amp packages required for 0.5 μsec core memory applications. Basically, a dual-gated sense amplifier (with differential input amplifiers), the MC1541 also features these unusual performance features:

1. Either one of the two input amplifiers can be gated "on" to provide signal detection without interference from unwanted signals.
2. Precise threshold voltage is obtained without the designer having to provide a precision external reference.
3. Pins 12 and 13 let the designer look at the amplified pulse after the gain stage to accurately set strobe pulse position.
4. The two input channels drive a single DTL output stage. Each of the two channels and the strobe input can be gated with DTL and TTL levels.
5. For greater accuracy, the MC1541 provides an extremely tight threshold range with a 6 mV maximum spread.
6. Latch capability, with improved performance, is available by using two external cross-coupled gates.

In addition to the full-temperature-range ceramic flat pack, competitively-priced at $18.00 (100-up), this new circuit will soon be available also in the dual in-line ceramic package. Later, 0 to +75° versions will be available in ceramic flat and dual in-line packages.

For more complete details, turn page: ⇨

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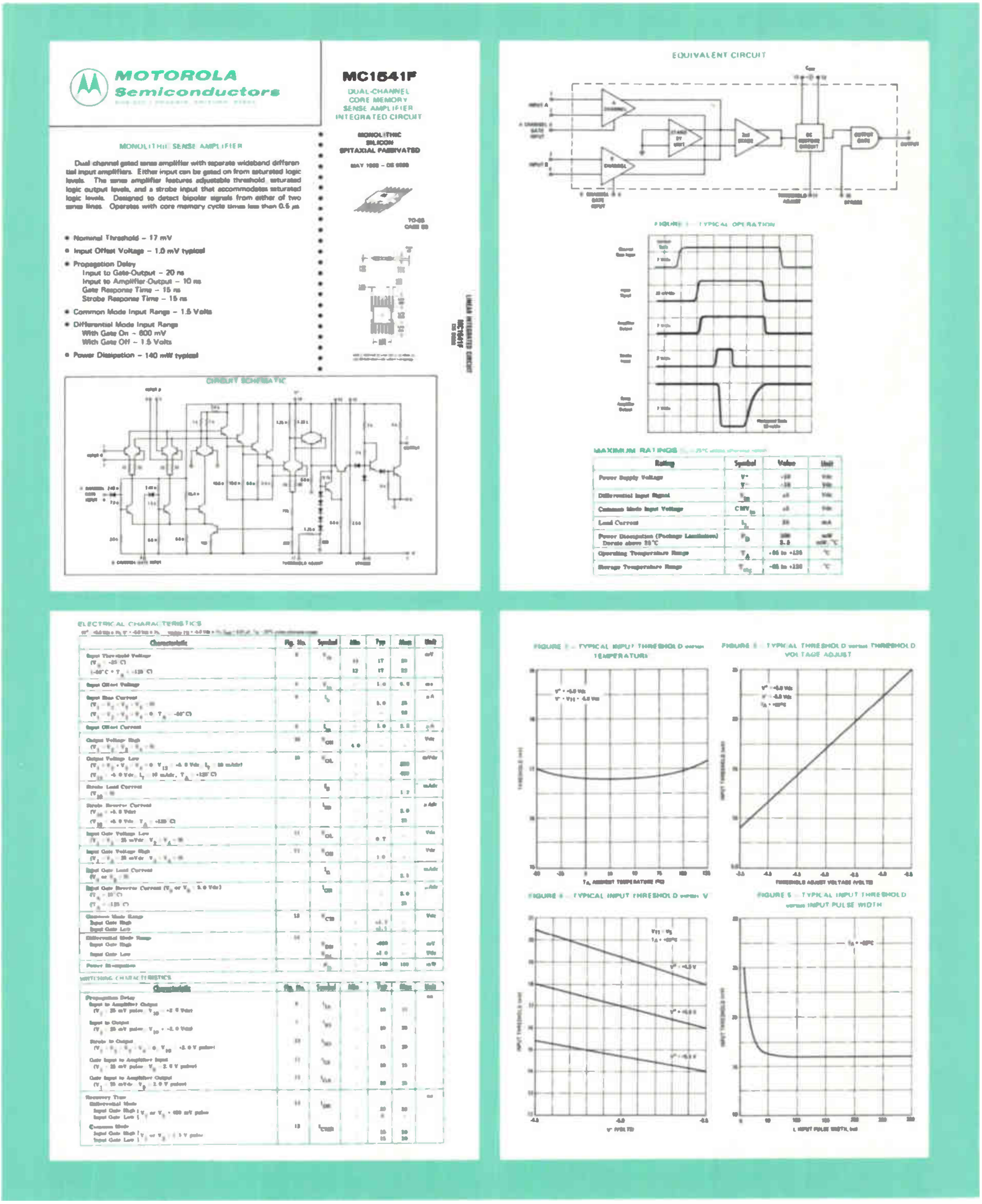

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Electronics Review

Volume 41
Number 18

Advanced technology

First of a series

In the five years since J.B. Gunn of IBM demonstrated that a chunk of gallium arsenide could directly generate milliwatts of microwave energy, output of such diodes has inched up steadily. Most recently, Gunn diodes in the limited space-charge accumulation mode have generated about 100 watts. But researchers have generally given up hope of substantially boosting the output of a single Gunn device much beyond that. And practical efforts to cascade the devices met with little success: parallel operation resulted in too sharp a drop in impedance and series operation just wasn't found to be practical.

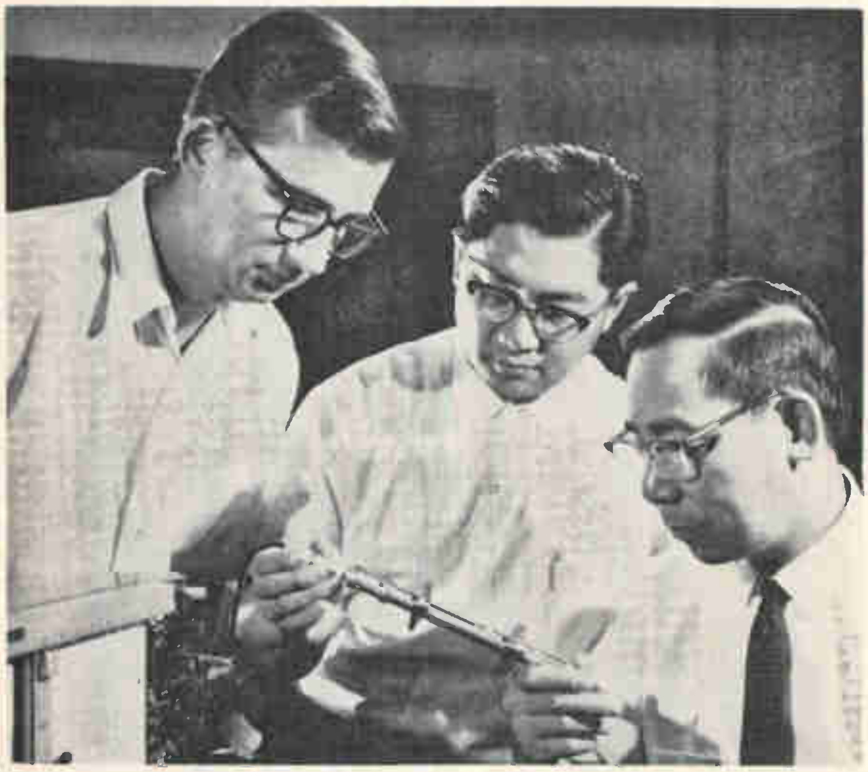
However, in a private showing in June, three scientists at General Electric's research center in Schenectady, N.Y., startled their colleagues with the disclosure that they could link four diodes in series.

No limit? "And if we can do it with four diodes, we can probably do it with hundreds," says one of the three scientists, Paul J. Shaver. The others on the GE team are SePuan Yu and Wirojana Tantraporn.

This means there's a distinct possibility of building solid state microwave transmitters that generate thousands of watts—and maybe even more.

Naturally, the trio had to do more than just bond the four diodes to get them to operate in series. Until now, microwave scientists have generally agreed that the reason series operation was impossible was that one member of the chain tended to capture most of the applied voltage, leaving but a trickle for the rest. And although connecting them in parallel was not difficult, the resultant impedance drop left the circuit nearly useless as a transmitter.

Last year, however, a British researcher, J.E. Carroll, showed that there was a way—albeit very complex and cumbersome—to connect the diodes in series. By connecting the Gunn diodes one-half wavelength apart he could get them to contribute equally to the total output. But the spacings—from a fraction of an inch to several



Together. Gunn-effect diodes (right) are linked in series to produce high-power microwave signals. GE developers, from left, Paul J. Shaver, Wirojana Tantraporn, and SePuan Yu, have already linked as many as four diodes.

inches—made the microwave component impractical as a piece of hardware.

Computer help. The GE team turned to a computer for help in understanding the voltage-capturing mechanism. By simulating the details of the electron-transporting properties of cascaded diodes, they could manipulate several variables in both the composition of the diodes and the geometry in which they were connected.

They found that three conditions were necessary to get the diodes to work together:

- The diodes must be similar in doping content to within 20%—relatively easy to control in manufacturing.
- The operating frequency of the microwave circuit must be somewhat higher than the Gunn frequency.
- The impedance of the circuit must exceed a certain minimum.

"What makes the direct series connection particularly attractive," explains Shaver, "is that the characteristics of the group of diodes are fundamentally the same as a single diode."

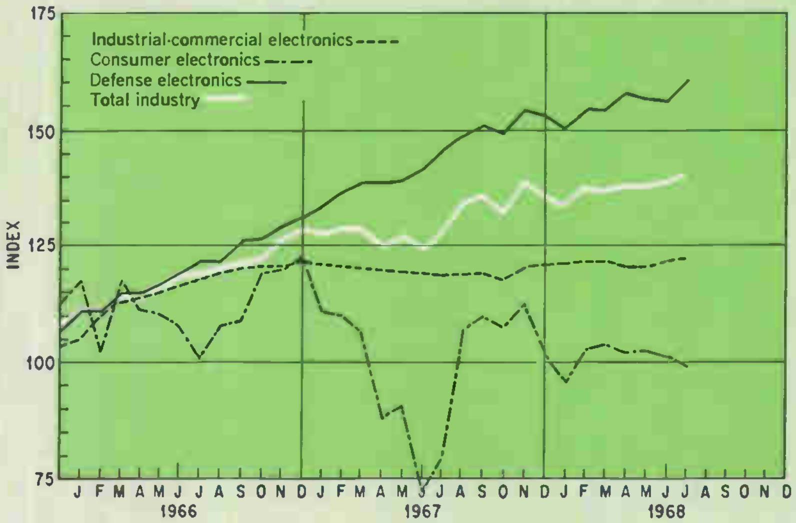
Further, he says, it's possible to tailor the combination to the needs of the circuit. For example, the demonstration model contains four diodes; two are arranged in parallel in combination with two in series. "In this way," notes Shaver, "we were able to select our impedance."

The GE team does acknowledge an inherent limit to the size of a diode series chain: it can be no longer than the wavelength of the microwave signal it produces. "But," cautions Shaver, "we've yet to hook up more than four diodes. We're still looking for the problems."

By November the team expects to link as many as 12 diodes in series.

Electronics Index of Activity

September 2, 1968



Segment Of Industry	July 1968	June 1968*	July 1967
Consumer electronics	99.7	102.0	79.5
Defense electronics	160.4	156.1	145.2
Industrial-commercial electronics	122.8	122.5	118.9
Total industry	139.0	137.1	126.2

Electronics production rose in July to 139.0, up 1.9 points from June and 12.8 points from the year-earlier level. The defense index posted the sharpest gain, advancing 4.3 points in the month and 15.2 points in the year. Industrial-commercial output inched 0.3 point ahead of the June figure and 3.9 points ahead of July 1967. The only decline was recorded in the consumer index, which slipped 2.3 points from the previous month. However, it was up 20.2 points from a year before.

Indexes chart pace of production volume for total industry and each segment. The base period, equal to 100, is the average of 1965 monthly output for each of the three parts of the industry. Index numbers are expressed as a percentage of the base period. Data is seasonally adjusted.
*Revised

Companies

The dust settles

Act Two of the Motorola-Fairchild management switch took place mostly behind the scenes. The Semiconductor Products division of Motorola, stunned at first by the departure of general manager C. Lester Hogan and seven other key executives [Electronics, Aug. 19, p. 45], reacted like a man who was hit by a truck but found to his surprise that he could get up and walk away from the accident. The Fairchild Semiconductor division, on the other hand, was like a mail-order bride discovering that married life doesn't necessarily begin with a honeymoon.

Although Motorola leaked word that the whole package had been sealed and delivered on the Friday afternoon that Hogan announced his resignation, no one at Fairchild expected to see such a large contingent from Phoenix quite so soon. Hogan and his team arrived in Mountain View, Calif., the following Monday morning (Aug. 12), and by that night, to no one's surprise, Fairchild general manager Thomas H. Bay had resigned.

Takeover. "Hogan is bringing in his own boys; I can understand his reasons, but I can't be a part of it," Bay said. "He doesn' t know if any of our guys are any good or not, but he's replacing them anyway." Bay was referring to Hogan's immediate assumption of the role of acting general manager of the Semiconductor division (in addition to the presidency of the parent corporation), and the appointment of his Motorola colleagues as "group directors" in charge of Fairchild's various manufacturing and support operations. In effect, Hogan inserted a whole layer of top management between himself and the previous top echelon.

The only survivor of the reorganization was Jerry Sanders, who cut short a Hawaiian vacation and confounded the experts by emerging from a conference with Hogan as group director of marketing, with a raise in pay. Otherwise, John Sentous, who had been in charge of discrete devices, found himself reporting to newcomer Wilfred Corrigan; and John Megarian, the integrated-circuit manager, was placed under Eugene Blanchette. Of the other newcomers, Leo F. Dwork became corporate director of research and development, with direct responsibility for L. John Kabell's semiconductor R&D facility; Thomas Hinkelman became a corporate planning director; George Scalise took over as head of manufacturing services; Andrew Procassini became group director of quality assurance and reliability; and William Lehner, who designed and built Motorola's automated assembly lines, was named head of equipment engineering and facilities.

Mixed reception. Reaction to the shakeup was mixed. Marketing men seemed delighted at the prospect of new manufacturing vigor, but at the same time they were sympathetic about their colleagues' plight. On the manufacturing side, there was some resentment at the swiftness of the takeover. No one, apparently, was mad enough to leave immediately, however.

In Phoenix, meanwhile, there was bitterness toward Hogan for taking so many top executives with him, but also expressions of confidence in the new team (see story on p. 14).

Motorola leaked the claim that Fairchild had made a fantastic offer to Hogan: an interest-free loan to buy 90,000 shares of Fairchild stock at $60 a share and another huge block at $10 a share, plus $250,000 in cash for "moving expenses." The others who left reportedly got interest-free loans to buy 12,000 to 15,000 shares at $60 each. Hogan's Fairchild salary was reported to be $120,000, and his aides' $50,000 to $60,000. "They've set a new pay scale," said one observer.

Motorola also denied rumors that Hogan had been locked out of his office after resigning.

No secrets. Everyone was painfully aware that Hogan and his colleagues knew every detail of Motorola's manufacturing techniques, profit rates, yields, and marketing plans. Officially, however, this factor was discounted. "That only serves to calibrate them as to how far behind Fairchild is," said Motorola's new general manager, Stephen L. Levy. But neither he nor any other Motorola executive would comment on the possibility of a damage suit against Fairchild.

To stop further "defections" (the term is Motorola's) after Hogan's move, the company immediately raised some salaries and offered promises of bonuses. To stop rumors and avert panic, it took quick action to inform its employees, down to the production-worker level, of exactly what had happened. To allay customers' fears (and get a line on customer reaction), it called its major ones; and Levy went on a special trip to address a distributors' meeting in California.

Initial results were heartening. As expected, there were a few resignations—Fairchild picked up two production people, including transistor specialist Gregory Rayes, Signetics lured away at least two employees, and Walter Seelbach, integrated-circuit R&D manager, resigned—but in general the precautionary moves apparently held the line.

No retreat. Customer reaction was so good that Thomas H. Connors, Motorola's vice president in charge of marketing, was positively jaunty. "We haven't reset our goals," he said. "My first inclination was to pull back, and that was Steve Levy's, too. But Fairchild has an empty wagon, across the board. If they don't have quality problems they have low yields, both in transistors and IC's." (One outsider says that Motorola's yields are four times higher than Fairchild's.)

As far as orders, Connors says: "I don't see any dent in the bookings curve, and as far as I can see, we'll have a record fourth quarter. From a bookings standpoint, the year is already over."

One of Hogan's first moves at Fairchild will be to try to fill that "empty wagon" by reversing a recent company decision to cut back on power transistors and silicon controlled rectifiers for the industrial-commercial market. The next step may affect processing; one source says a couple of minor adjustments in Fairchild procedures—improved wafer cleaning and the use of a glass layer to protect metalization—would quadruple yields immediately.

Hogan won't comment on that, but he does say that he expects quick results. "We have the technology, facilities, backlog, and personnel, to make a dramatic improvement in the next six to 12 months, and I'm fully confident that we will," he says.

Instrumentation

Light tuner

A diode laser that can be electronically tuned over 50 gigahertz has been developed by a team at the Massachusetts Institute of Technology. The diode's center frequency can be shifted from 6.5 microns (red) to 28 (infrared) by altering its chemical makeup. Because of the device's wide range and frequency stability—better than three parts in a billion—the MIT team believes the diode laser will have wide application in instrumentation.

The developers, E. David Hinkley, Theodore C. Harman, and Charles Freed, say the laser is made of single crystals of the mixed semiconductor lead-tin telluride, formed by vapor deposition from lead telluride and tin telluride seed crystals. The proportion of the two seed crystals determines the energy gap of the diode—or the center frequency.

Frequency finding. The diode is

tuned by varying the current through it. A few thousandths of a second are required for an output frequency shift of several gigahertz, but the tuning rate can be speeded somewhat by placing a magnetic solenoid around the diode.

In one application, the diode laser can be used to accurately measure the output frequency of another laser. The outputs of the known and unknown lasers are mixed, and the diode laser is tuned until a measurable heterodyne signal is obtained. The wavelength of the unknown laser can then be easily calculated by measuring the tuning current, because the current is related to the diode laser's output frequency.

Such a measurement can be particularly handy in tracking a satellite with a laser. Since the satellite's motion will cause a doppler shift in the laser's frequency, the diode laser could be used as a local oscillator, analogous to superheterodyne radio receivers.

Oceanology

Underwater guide

Since radio beacons situated near or between airports help planes fix their position through triangulation, why couldn't a similar system aid submarines? The increasing number of commercial and oceanographic subs navigating along or above the continental shelf has created a need for an underwater equivalent of the omni beacon—a need the Submarine Signal division of the Raytheon Co. hopes to fill.

The division has developed a system that can give a submarine commander his bearing and range, and without triangulation; only a single benchmark beacon is needed to navigate accurately within an area several miles in diameter.

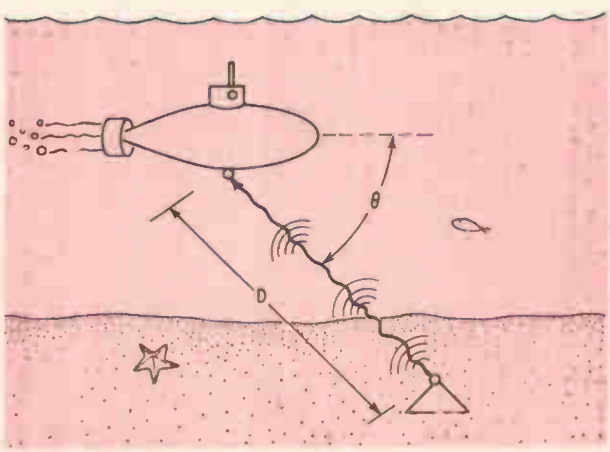
Tests of a breadboard model were to have begun late last month in Rhode Island's Narragansett Bay. This initial model will have a three-mile range, but later versions should be able to supply range and bearing data from as far away as 10 miles, says Gilbert N. Fain, designer of the system.

Clocking the run. A battery-powered bottom beacon will ping every 3 seconds at about 8.33 kilohertz. The timing of the pings is closely controlled by a low-drift crystal oscillator clock. Aboard the sub there will be an oscillator synchronized to the one at the beacon, making it possible to measure the travel time of the ping's sound wave as it moves at about a mile per second from beacon to ship. So accurate are the two oscillator clocks that range error should be only about 5 feet, according to Raytheon.

To determine bearing, a cylindrical piezoelectric transducer with four electrodes inside and a common electrode outside will be mounted aboard the sub. The two pair of electrodes are arbitrarily designated north-south and east-west, and the sensitivity pattern of each pair is shaped like a figure eight, with maximum receptivity along one axis and almost a total null for signals at right angles to this axis.

Full sweep. Fixing a submarine's position thus involves simply rotating the pairs of acoustic rabbit ears to find the direction from which the pings are coming.

Units will probably first be tested aboard research subs and then be installed on geophysical research and exploration vessels—perhaps to aid in the search for underwater natural resources such as oil.



Beep. Single underwater beacon can provide navigation data to submarine. Unit gives range and bearing data without triangulation. Range of present design is three miles, and plans are to extend that to 10 miles.

Integrated electronics

Opening the gates

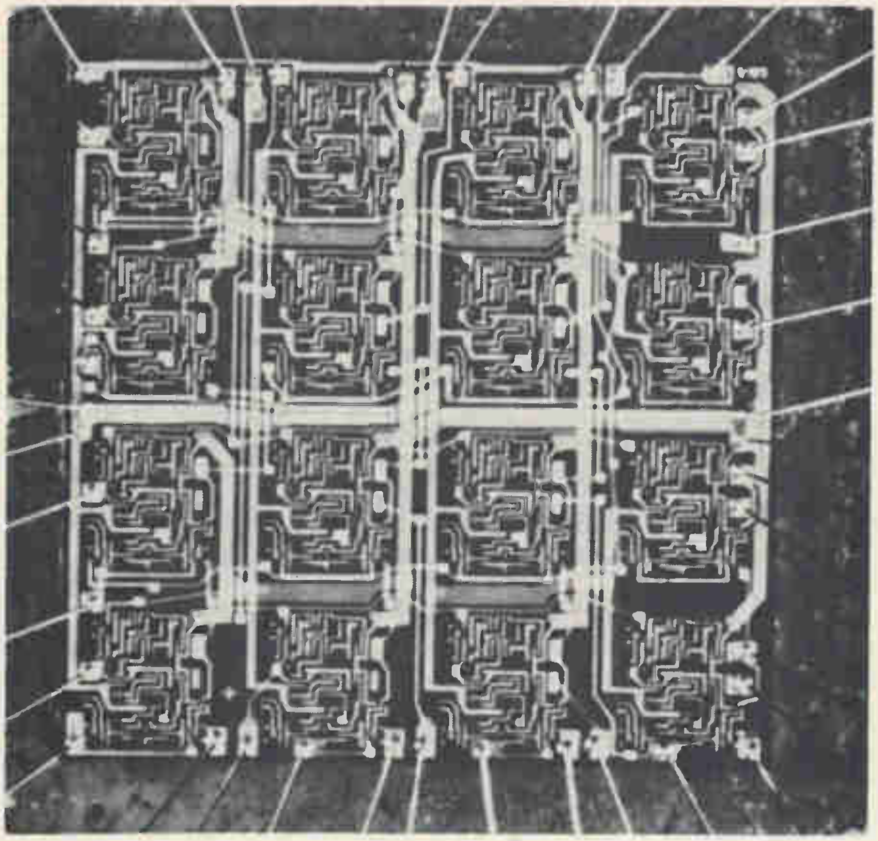
Fairchild Semiconductor made a big splash with its 96-gate large-scale integrated circuit when it introduced it this summer [Electronics, July 22, p. 121]. But the record for the commercially available circuit with the most gates won't stay with Fairchild long. Both Westinghouse's Molecular Electronics division and Texas Instruments are getting into the act, with 120- and 174-gate LSI circuits, respectively.

Westinghouse has a series of semicustom bipolar transistor-transistor-logic arrays, the largest of which will have 120 gates. And TI has delivered TTL bipolar arrays with 174 equivalent gates to two West Coast firms and says it can now deliver similar customized arrays to others on two months' notice.

More to come. TI's arrays which use discretionary-wiring techniques, consist of flip-flops plus one-, three-, five-, and seven-input TTL gates in TI's standard series 54 logic configurations. The propagation delay at the gate is 15 nanoseconds, and the power dissipation is 10 milliwatts per gate.

The array is on a single 1.25-inch silicon wafer. The 174 gates are interconnected with three layers of metalization separated by insulating layers of silicon dioxide.

Glenn Penisten, a vice president, said TI expects to produce within 18 months LSI devices using 2-inch



Upward. Record for the largest number of gates on a commercially available chip, held since this summer by Fairchild with a 96-gate device, went briefly to Westinghouse with a 120-gate device, above. Now Texas Instruments has a 174-gate circuit.

silicon wafers that will reach the level of 500 equivalent gates.

Also, he said, emitter-coupled logic circuits are now being designed into the cell library.

Made to order. Developed originally under a proprietary contract with a computer house, the Westinghouse WM500 series will soon be introduced for adder circuits, storage registers, and other applications. The basic unit of the series is a cell with three to five gates whose intraconnections can be made to order. The series will come in any combination, from three-by-three to four-by-six cell variations, with a five-by-five (125-gate) array coming later.

Regardless of size, the same basic cell diffusion pattern prevails. Westinghouse chooses to partially customize the circuit on the first layer of the two-layer metalization process. An interconnect pattern is superimposed on the photographic plate along with the standard cell pattern. The second-layer metalization, over dielectric glass, completes the customization.

Westinghouse uses the fixed-pattern master slice method—excluding redundancy in production and discretionary-wiring problems—which puts 800 standard cells on a single silicon wafer. This would give 40 four-by-four arrays, assuming a 100% yield. For any one such array to be good, however, all 16 grouped cells have to be functional.

"To make LSI pay you have to have high yields," comments O. Robert Ryerson, an engineer on the project. "Our way is to have somewhat loose tolerances to ensure a high yield at the photochemistry steps."

Consequently, Westinghouse uses large dies, which it believes don't slow up the circuit with TTL logic. The basic cell is 37 mils square, making the four-by-six array 148 by 222 mils (Fairchild's 96-gate 4700 measures 145 mils square). Right now, the division figures that's as large as it can go before silicon defects begin to reduce the yield measurably.

Space electronics

Speculative proposal

In the solemn jargon of the Pentagon and the space agency, an RFP, or request for proposal, announces an intention to buy equipment or services based on competitive bidding. Recently the Communications Satellite Corp., acting for the International Telecommunications Consortium, issued a long-awaited RFP for an aeronautical services satellite—but the RFP included a monumental catch.

It read: "The issuance of this RFP should not be understood as implying a decision by the ICSC (Interim Committee for Satellite Communications) to proceed with an aeronautical communications satellite program."

No one is happy with this state of affairs except, of course, Comsat. One FAA official said the situation was clearly an imposition on bidders who might have to lay out as much as half a million dollars to develop a proposal. He added that "privately" the potential bidders were upset with the arrangement.

No comment. Of the four potential bidders, Philco-Ford and Hughes Aircraft, plan to bid, while the Space Vehicles division of TRW Systems intends to go in as a subcontractor with another company, and Lockheed Missiles and Space won't bid at all. All four refused to comment publicly on the unorthodox RFP.

The reason for the disclaimer is lack of cash. Says an insider: "We're still not exactly sure how attractive this concept is to potential users and we are still not sure how the bill will be paid."

Heading the list of potential users are the airlines, which are represented by the Air Transport Association. Frank C. White, manager of communications and data processing for the ATA, says, "Comsat tells us that the cost of the satellite could go as low as a million dollars per channel per year."

Again no comment. He explains

in earlier talks about such a
lite with Comsat, the costs
nated were in the neighbor-
l of $4 million to $5 million per
nel per year. Meanwhile, Com-
efuses to comment on the cost
e satellite, indicating only that
ould be less than $4 million.
proposed, either two or three
lites would be purchased. The
would be a very-high-fre-
cy communications satellite
four channels. Eventually the
lite would also provide naviga-
l services. It would be spin-
lized and in a synchronous
torial orbit. The technical var-
ns in the bids will be exam-
closely but the future of the
lite rests on the ability of
o-Ford and Hughes to keep
ost down.

lical electronics

rt watch

ugh effective in monitoring
activity, the electrocardio-
can't measure the amount of
l pumped by the muscle.
t the only way to take such a
urement is to implant cathe-
into the heart—a potentially
erous procedure with critically
tients. A physiology professor
an undergraduate degree in
ical engineering, however, has
oped an electronic technique
easure the blood flow.

n't say why. The professor,
William G. Kubicek of the Uni-
y of Minnesota Medical
ol, passes a small current
gh the patient's body and then
ures the slight drop in imped-
of the current each time the
pumps. It's this change in
dance, Kubicek has discov-
that's related to the amount
od flow. But just why this is
e doctor is unsure.
is month Kubicek will deliver
f his instruments to Dr. Chris-
Barnard, the South African
transplant specialist. A de-
in the blood flow, Kubicek

rejection reaction by the body.

Developed under Air Force and NASA contracts, the impedance cardiograph is also being tested at 12 medical centers across the country. Four instruments miniaturized to the size of two cigarette packages by Space Labs of Van Nuys, Calif., have been delivered to NASA.

The experimental instrument measures the drop in resistance between two external electrodes while 4 to 5 milliamperes of 100-kilohertz current are sent through the body. The 25-ohm body resistance fluctuates about 0.1 ohm with the action of the left ventricle. And the amount of blood the heart is pumping can be derived from this small change.

Four strips. To take a reading, four Mylar-aluminum strips are taped to the patient. Two are placed on the neck and two on the body, one about five inches below the armpit and the fourth just above the waist. The top and bottom electrodes receive the current; the others are pickup electrodes connected to amplifiers.

Since such factors as the current and the distance between the electrodes are known, the change in impedance in the thoracic cavity between the middle electrodes can be measured.

Kubicek's instrument is a bulky 12-inch, 16-pound cube containing a differentiator, a digital voltmeter, and detector circuits designed by Robert Patterson, an electronics engineer on Kubicek's staff.

For the record

Firepower. The Navy's Poseidon ballistic missile and the Air Force's Minuteman 3 were successfully test-fired from Cape Kennedy last month. Both the two-stage Poseidon and the three-stage Minuteman are designed to carry the "multiple individually targetable re-entry vehicles" that contain up to 10 nuclear bombs in each warhead. This makes each missile es-

High power. By lan
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has pushed the power
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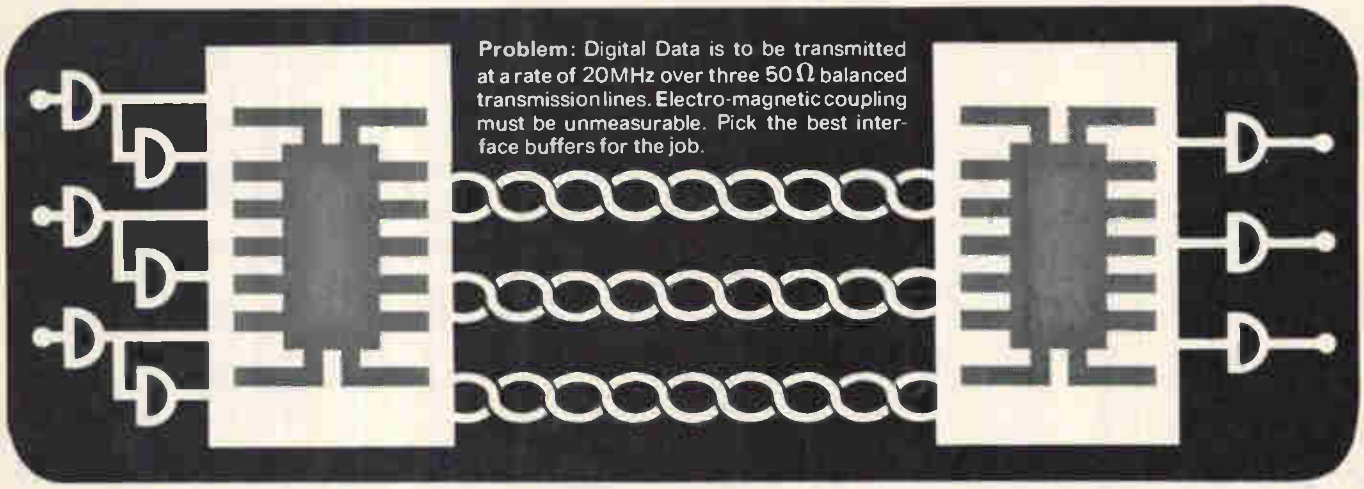
Pick the BEST IC for the job



the BEST Solution:

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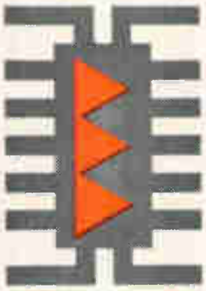

The best IC to use at the sending end is Radiation's dielectrically isolated RA-245. This line transmitter converts digital voltage pulses to current pulses. The high speed CML circuits assure data transfer rates in excess of 30MHz. Power dissipation is a constant, independent of data rate. The balanced system virtually eliminates the adverse effects of line capacity. Electro-magnetic coupling and susceptibility is greatly reduced.
RA-245 is available in both the TO-84 flatpack and the ceramic dual inline package. Three voltage-to-current converters are in each package. Power dissipation is negligible when converters are not being used. So use only one or all three. RA-245 is the Best IC for the job.

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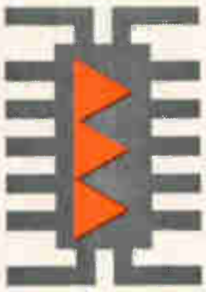

For best results, use Radiation's dielectrically isolated RA-246 at the receiving end. This 3-element buffer faithfully restores the current pulses to digital voltage pulses. The RA-246 current-to-voltage converter has built-in input terminations for balanced 50 Ω lines. Outputs from each element are suitable to drive all standard saturated logic circuits (such as DTL, TTL, etc.).
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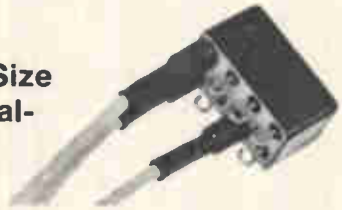
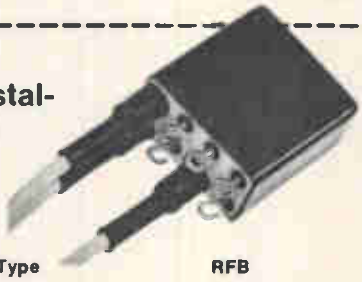


Relay Type	**RFK**
Size	.4 x .8 x .4 inch
Rated Contact Current	1.5 Amperes RF
Maximum Weight	0.37 Ounce (without terminations)

Crystal-Can



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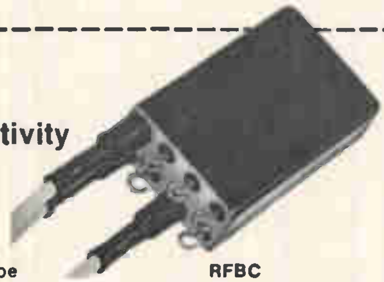

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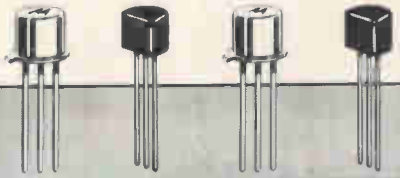

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Renowned for Minutes-To-Microseconds Timing Capability	February, 1967	2N4851 2N4852 2N4853	2.0 2.0 0.4 @ 25 V	0.56 0.70 0.70	0.75 0.85 0.85	100 100 50
Outstanding for Ultra-Accurate Industrial/Military Timing	May, 1967	2N3980	2.0 @ 25 V	0.68	0.82	10
Popular for 43-cent* Plastic Versatility	August, 1967	2N4870 2N4871	5.0 5.0 @ 25 V	0.56 0.70	0.75 0.85	1.0‡
Distinguished† For Reliable Timing, Triggering, Sensing Capability	November, 1967	2N4948 (JAN2N4948) 2N4949 (JAN2N4949)	2.0 1.0 @ 25 V	0.55 0.74	0.82 0.86	10
Specified For Wide Spec Choice At Low Cost	March, 1968	MU4891 MU4892 MU4893 MU4894	5.0 2.0 2.0 1.0 @ 25 V	0.55 0.51 0.55 0.74	0.82 0.69 0.82 0.86	10
Discovered for Lower-Than-Ever Voltage Operation in Long-Time-Delay Circuits	August, 1968	2N5431	4.0 @ 4 V	0.72	0.80	10

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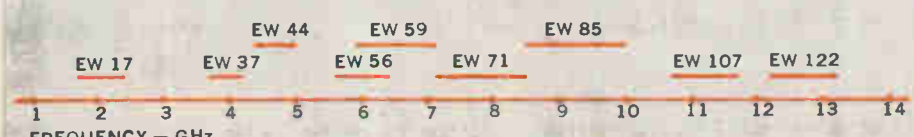

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Washington Newsletter

September 2, 1968

Missile sites to get new computer setup

The Air Force is planning to equip its Minuteman ICBM system with a new set of command and control computers. Details on the digital machines, which would be modular building blocks capable of handling several functions, will be spelled out at a bidders' briefing Sept. 5. On Oct. 21, the Space and Missile Systems Organization will issue a request for industry proposals for the initial phase of the program—the development of six prototype units. A production run of 1,080 machines over three years is planned.

To be located in the missile silos, these advanced computers wouldn't replace any equipment currently used in the Minuteman system. "There's nothing like it now," says a program official. The machines would monitor all the Minuteman systems and interlock the entire complex.

Among the specifications the Air Force will ask: a mean time between failure of 25,000 hours; a 32,000-bit, electrically alterable, random-access permanent memory with a 4,000-word temporary storage; access times of less than 500 nanoseconds to the permanent memory storage and no more than 2 microseconds to the temporary storage; and bi-directional serial data channels with a capacity of up to 100,000 bits per second.

The development contract is scheduled to be awarded next February, with delivery of the prototypes set for the following October.

FAA approves color for radar displays

The FAA is finally convinced that color-phosphor technology is here—for its air traffic control radar displays. The agency has set Sept. 3 as the date for industry proposals on a two-part development contract for prototype color-phosphor tubes. The contract would be awarded in November and tests might begin this winter.

About three years ago the FAA ruled out color radar displays—using a single layer and a triple electron gun—for lack of accuracy. But, even if accuracy had been adequate, the costs would have been prohibitive. Now the agency is convinced that the single gun, multilayer phosphor approach will work. Color-coded information on radar scopes would separate vital data from radar clutter and ease the job of the controllers.

First phase of the development effort will be experiments to prove feasibility. With feasibility established—and the FAA has no doubt about it—the contractor would build six prototype tubes for installation at the FAA's Atlantic City center and possibly at its Atlanta center. If the tests go well, color displays may be in all major terminals within two years. The rest of the FAA's 700 enroute and terminal radar displays would get the color tubes as the agency obtained funding.

NASA, FAA seek low-cost detectors to complement CAS

With work finally moving ahead towards flight tests next year of five competing collision-avoidance systems [Electronics, Aug. 5, p. 34], NASA and the FAA are now pressing for development of a complementary pilot warning indicator that would cost less than $2,000. Collision-avoidance systems (CAS) are expected to cost $40,000 to $50,000 and will be used en route by high-altitude, high-speed craft. The pilot warning indicator would be carried by slower planes flying at lower altitudes—general-aviation craft, feeder airlines' planes and the like—but it would also be used by jet airliners in terminal areas. Its range would be five miles.

Washington Newsletter

NASA's Electronics Research Center has asked for industry proposals for a prototype infrared sensor that could detect a plane's xenon strobe lights. And the agency's Langley Research Center is working on a radio-frequency doppler device.

The FAA—though it hasn't had the money to let a contract—has persuaded several companies to work in-house on pilot warning indicators. Two approaches are being studied—infrared detectors and lasers. In the latter scheme, all aircraft would carry laser-signal reflectors. **Out of all this work could come a decision standardizing on a single technique.**

NASA juggles funds; hopes 1970 budget will justify the risk

The space agency is playing a dangerous game with its fiscal 1969 budget. In shifting money away from some long-term programs to keep the more immediate ones fully funded, NASA is gambling that it will get enough money next year to put the neglected projects back on schedule. "There's a calculated risk in this kind of thing," concedes one NASA official. "It means we're going to have to really fight in the next budget to get the long-term programs going again."

An early case in point: the Mariner Mars 1973 program, originally down for $20 million this year, will now receive only $4 million to $6 million. The two spacecraft with their planet landers will be held to their present schedule, but unless there's a lot more money for the program in fiscal 1970, they'll have to go, at best, with far less sophisticated lander sensors than are now planned. On the other hand, NASA intends to allocate to the Mariner Mars 1971 project the full $18 million slated.

It's expected that this kind of budget juggling will be applied to other projects as NASA puts into effect its "interim operating plan" [Electronics, Aug. 19, p. 59].

Research cash asked for solid state

The latest addition to the litany of complaints about decreasing Government support for basic research will be in a report to be issued later this month by the National Academy of Sciences' solid state sciences group.

The report will warn that the level of Government support in solid state research "is actually critical with respect to both manpower and technology." Specifically, says the committee, research is most needed in ferromagnetism, superconductivity, dislocation theory, low-temperature physics, high-field transport phenomena, plasmas, and lattice dynamics.

ATS-E launch may be delayed

Launching of the fifth Applications Technology Satellite (ATS-E)—presently scheduled for next May—**would be delayed several months if the addition of a number of experiment packages is approved.**

Because ATS-D failed to achieve proper orbit last month, project officials would like to add some of the ATS-D experiments to ATS-E. One of them is the image orthicon camera with steerable optics.

Project officials are also awaiting approval to add an L-band transponder [Electronics, July 22, p. 53]. Also being considered is a piggyback satellite called Camsat. **The outlook for adding the L-band transponder is still bright, but somewhat dimmer for Camsat**, a Hughes Aircraft proposal that would cost as much as $10 million. It would carry three cameras—black and white, infrared, and color—capable of simultaneous transmission. A final decision will be made on Camsat and the L-band transponder in the next few weeks, while the go-ahead on adding ATS-D experiments is expected shortly.

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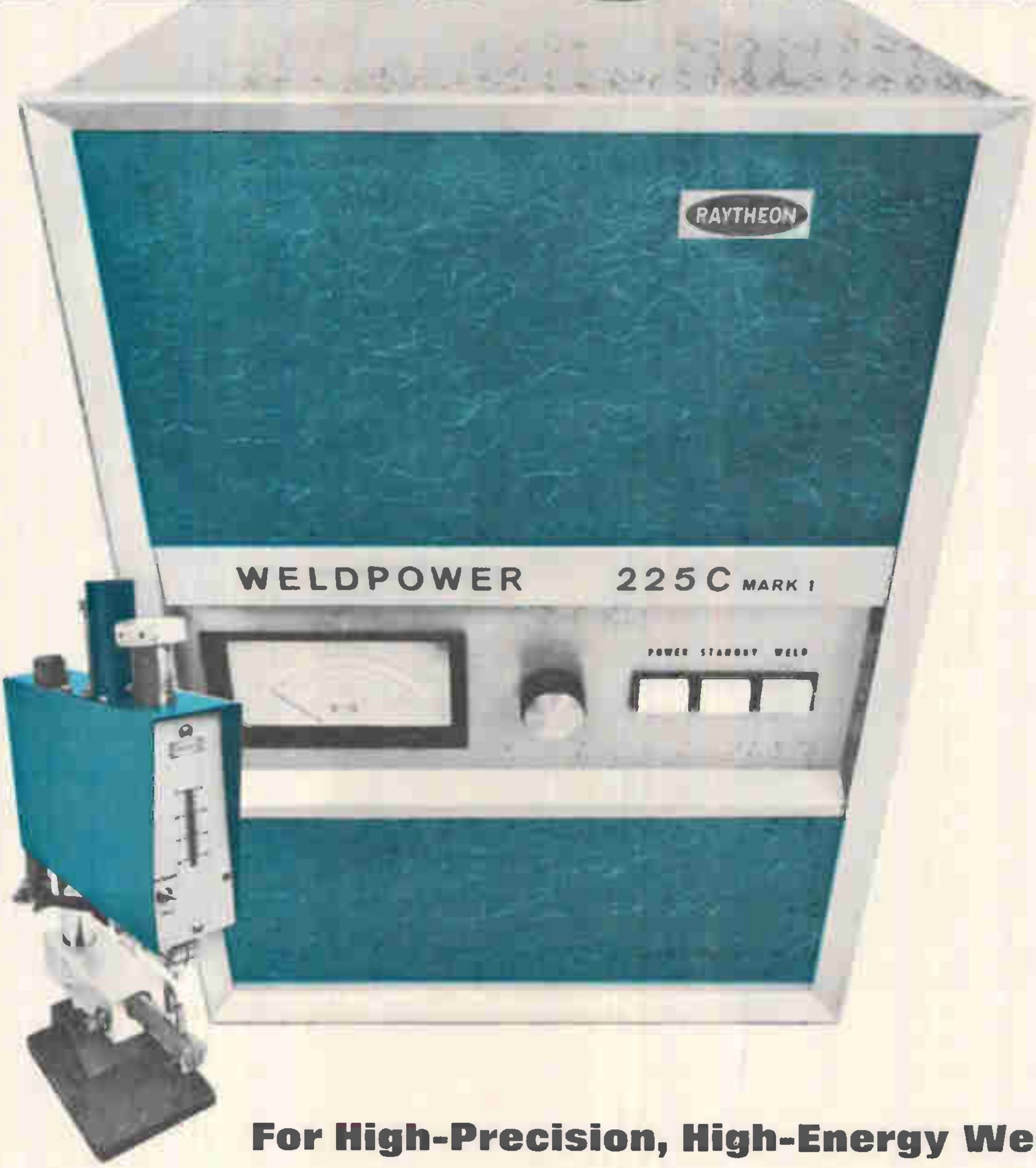

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The new R-Series welding heads, ideal companions for the 225C Mark I, offer adjustable electrode forces from 2 to 60 pounds, high acceleration for high-speed production and repeatability proven through thousands of hours of endurance testing. Additional features include a firing indicator, adjustable external override and a precisely calibrated pressure indicator.

Raytheon's coherent design concept provides wide-range flexibility for both the Mark I and the R-Series. For example, the 225C Mark I is not only compatible with R-Series heads but with other Raytheon heads as well (Q-, O-, J and JA Series, to name a few).

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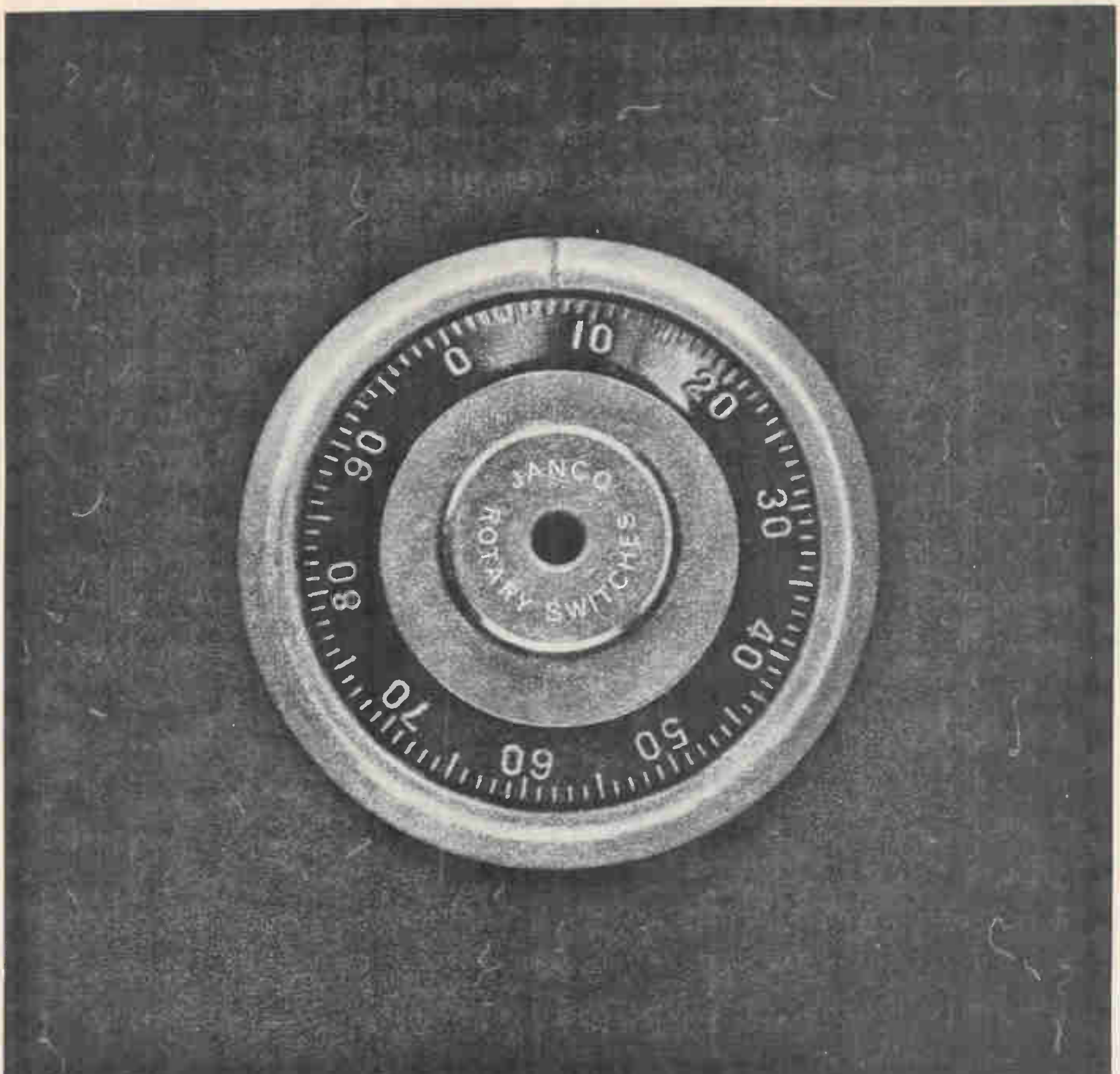

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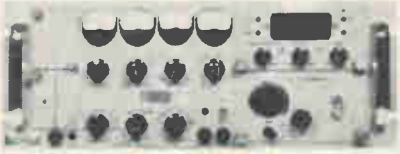

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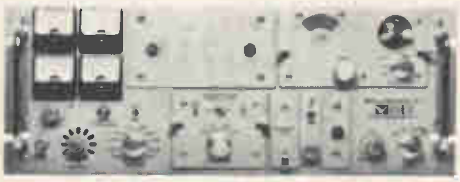

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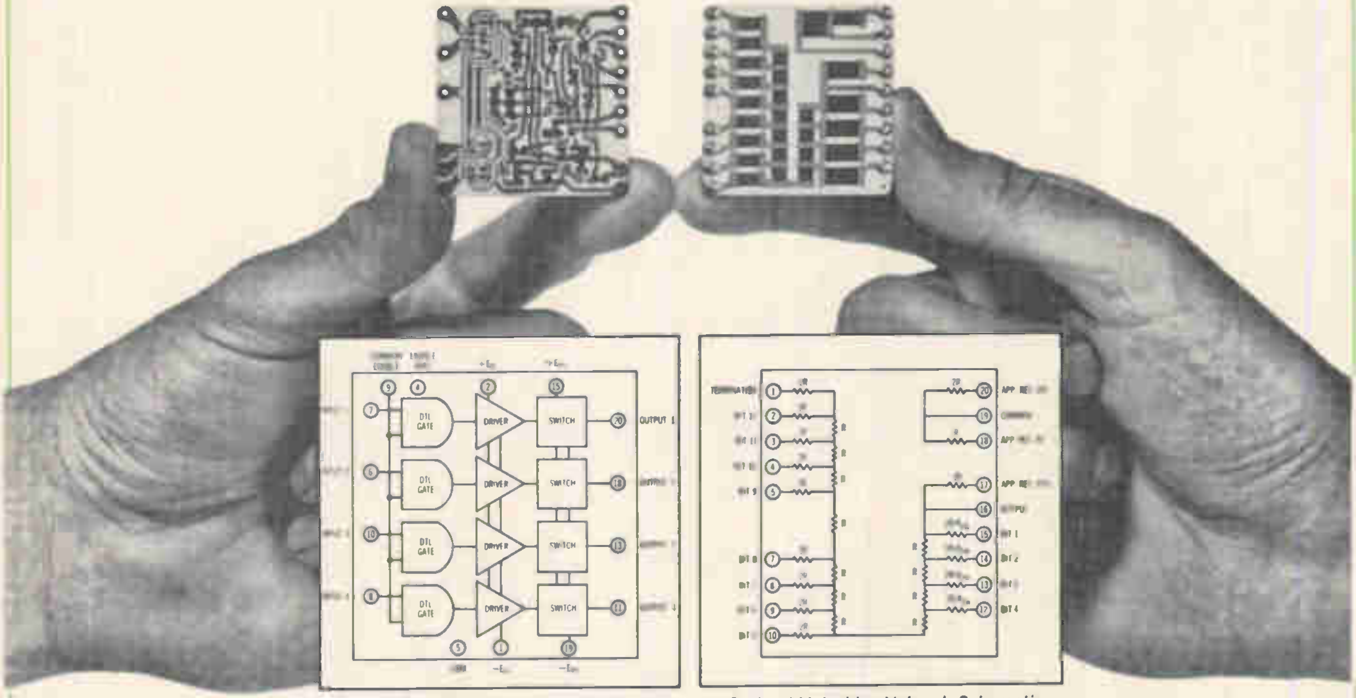

Model 841 Ladder Switch Block Diagram

Series 811 Ladder Network Schematic

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September 2, 1968 | **Highlights of this issue**

Technical Articles

Charts simplify Fourier analysis page 62

A Fourier analysis of a pulse train can help determine where high-frequency noise is coming from, but such analysis takes a long time. Some relief can be found in handbooks that contain equations defining the characteristics of common pulse shapes, but using these equations isn't a simple analytical method. However, the need for very detailed Fourier analysis can be eliminated by using generalized charts. By listing actual values for a given pulse, the charts provide a straight-line approximation of an equivalent broadband spectrum.

Solid state diode display page 74

A practical version of the solid state display —more convenient and longer lasting than phosphor-type electroluminescent lamps— has emerged in the form of an array of gallium-arsenide-phosphide light-emitting diodes. Not only is this numerical display compatible with integrated circuits, but the decoding and driving circuit, an LSI chip, is packaged in the same compact module as are the diodes, 28 of which form each matrix.

Active filters part 3 page 82

Negative-impedance converters can be used to design active filters that have a smaller spread of capacitance values and fewer network elements than active filters made with a gyrator. They offer the engineer many design alternatives for synthesizing a network from its transfer equations. Only a few transistors are needed to build an NIC, which can give filters very high Q's at very low frequencies.

A look at phased-array radar page 94

Any system that promises to handle more than one job, especially in an aircraft, is sure to be the object of heavy R&D activity; such is the case with phased-array radar. As this survey indicates, the pace of present efforts points to the development in the near future of airborne systems that will search, track, and map with a single antenna.

Coming

High-power lasers

The kickoff of a series on new laser applications and advances in laser capabilities will feature an article on generating short-duration pulses and another on the use of narrow-pulse lasers in an optical communications terminal.

Charts simplify prediction of noise from periodic pulses

Families of broadband spectra for six common pulse shapes make it easy to determine high-frequency interference by eliminating the need for Fourier calculations

By Robert B. Cowdell
Genisco Technology Corp., Compton, Calif.

Experienced engineers know that pulses with a low repetition rate can generate high-frequency interference, but circuit designers who aren't familiar with this phenomenon might be baffled until they recall their hours in school studying Fourier analysis. What such analysis offers, of course, is a way to convert waveshapes stated as a function of time (pulses) to waveshapes stated as a function of frequency (spectra).

Specifically, engineers will recall that by using Fourier analysis any periodic nonsinusoidal waveform can be represented by an infinite series of sinusoidal spectral lines at harmonic multiples of the pulse frequency. Spectral lines at high frequency and with enough energy can cause interference in related or nearby circuits by conduction or radiation coupling.

However, Fourier analysis of a pulse takes more time than most engineers can spare. Some relief can be found in handbooks that contain equations defining the frequency characteristics of common pulse shapes. But these equations aren't quite adequate either as simple analytical methods or as explanations of how a pulse's parameters affect harmonic content.

The need for Fourier analysis can be eliminated, however, by using the generalized charts on pages 64, 65, and 66. These charts make it easy to find the broadband spectrum for six pulse shapes—trapezoid wave, full- and half-wave rectified sine wave, Gaussian wave, clipped sawtooth, sawtooth, and fractional sine wave. Only values of pulse parameters—such as amplitude, rate, width, and rise—are needed. The charts cover a wide range of these parameters, so using actual values for a given pulse can very rapidly yield the straight-line approximation of an equivalent broadband spectrum.

Noisy trapezoid

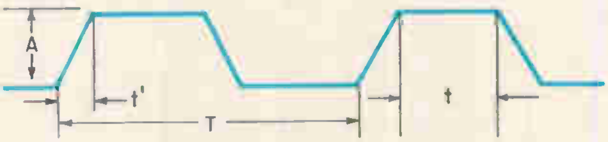
To see how these charts were obtained, consider the so-called square wave. Actually, this pulse is shaped like a trapezoid, because of the finite rise (and fall) time of the pulse. The rise time must be considered in a Fourier analysis because it creates the higher harmonics in the frequency spectrum. In this trapezoidal pulse, of amplitude A,

$$T \geq 2\,(t + t')$$

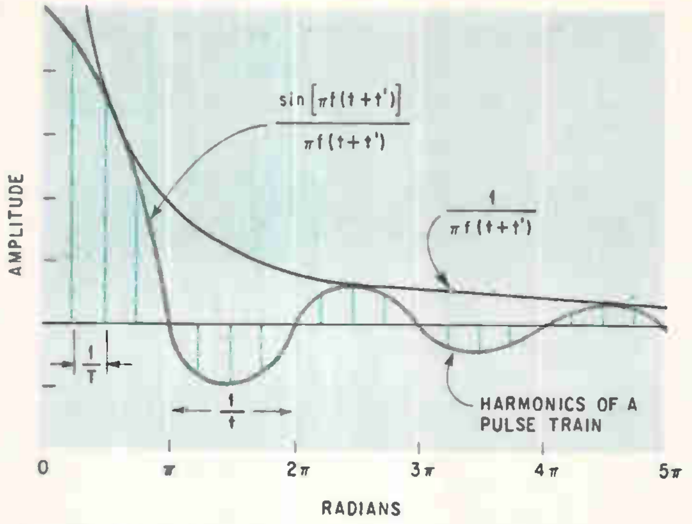
where T is the pulse repetition rate, t the pulse width, and t′ the rise time.

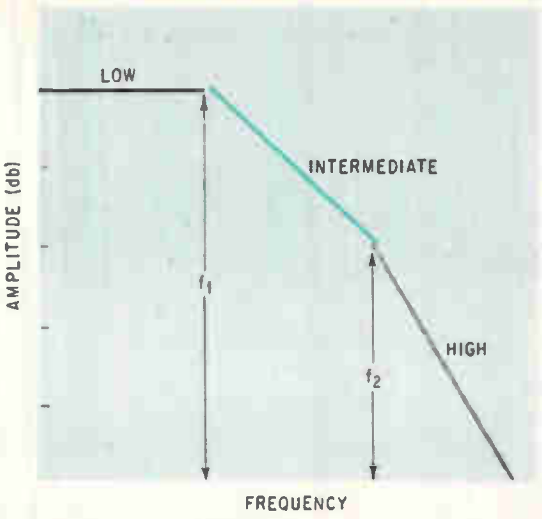
By Fourier analysis, the amplitude at the frequency of the nth harmonic, A_n, of the trapezoidal pulse is

$$A_n = \frac{2A\,(t + t')}{T} \cdot \frac{\sin\left[\pi f\,(t + t')\right]}{\pi f\,(t + t')} \cdot \frac{\sin \pi f t'}{\pi f t'}$$



Trapezoidal pulse. A steep rise time, t′, creates high harmonics with large amplitudes.





Spectral to broadband. The envelope of the maximum spectral lines, color, define the broadband spectrum, the black line. For convenience, the spectrum—approximated by three straight-line segments—is replotted in decibels and log frequency, right.

where $f = n/T$ is the frequency of the nth harmonic.

The figure above, at the left, shows one way of looking at the spectral response of the trapezoidal pulse. The colored vertical lines represent the harmonics of the pulse repetition rate. The amplitude of each such spectral line depends on the pulse shape; some lines, grouped in cusps, have negative amplitude.

If the frequency spectrum resulting from the pulse were scanned with a narrowband tunable receiver, the receiver would indeed show a peak output at each harmonic and no output at frequencies in between.

Broadband spectrum

The gray curve in the figure forms the envelope of the amplitude of the harmonics of the pulse train, including the harmonics that have negative amplitudes. The envelope of the maximum amplitudes of the harmonics, however, is more useful. To get this curve, shown in solid black in the figure, the cusps of the negative-amplitude harmonics are inverted to make them positive. This can be done with impunity; the receiver's detection circuit does the same thing anyway.

The black envelope yields more understanding of broadband characteristics of the frequency spectrum generated by a pulse. From a design and interpretation viewpoint, however, such an envelope is difficult to use and is somewhat unrelated to the physical significance of the broadband concept. It's more useful to plot amplitude and frequency on a logarithmic basis.

Accordingly, replotting the black curve results in a broadband spectrum like that shown at the right of the above figure.

The characteristics of the broadband spectrum can be developed mathematically. The number of harmonic spectral lines falling within a finite bandwidth is equal to the bandwidth (Δf) divided by the spacing, F, of the lines, where $F = 1/T$. The total interference, $V(\Delta f)$, falling in this bandwidth and caused by the "square" wave's harmonics, is equal to the average amplitude of the lines, A_n, times the number of lines within the bandwidth, $(\Delta f/F)$, where V and A are in volts. Thus, for the trapezoidal pulse

$$V(\Delta f) = A_n (\Delta f/F) = \frac{2A(t+t')}{T} \cdot \frac{\sin[\pi f(t+t')]\,\Delta f}{\pi f(t+t')\,F} \cdot \frac{\sin \pi f t'}{\pi f t'}$$

Conventionally, the interference is specified relative to microvolts above 1 μvolt per megahertz. Thus, the preceding equation is divided by the bandwidth, so that

$$\frac{V(\Delta f)}{\Delta f} = 2 \times 10^6 A(t+t') \cdot \frac{\sin[\pi f(t+t')]}{\pi f(t+t')} \cdot \frac{\sin \pi f t'}{\pi f t'} \frac{\mu V}{\text{Mhz}}$$

where A is volts, t and t′ microseconds, and f megahertz.

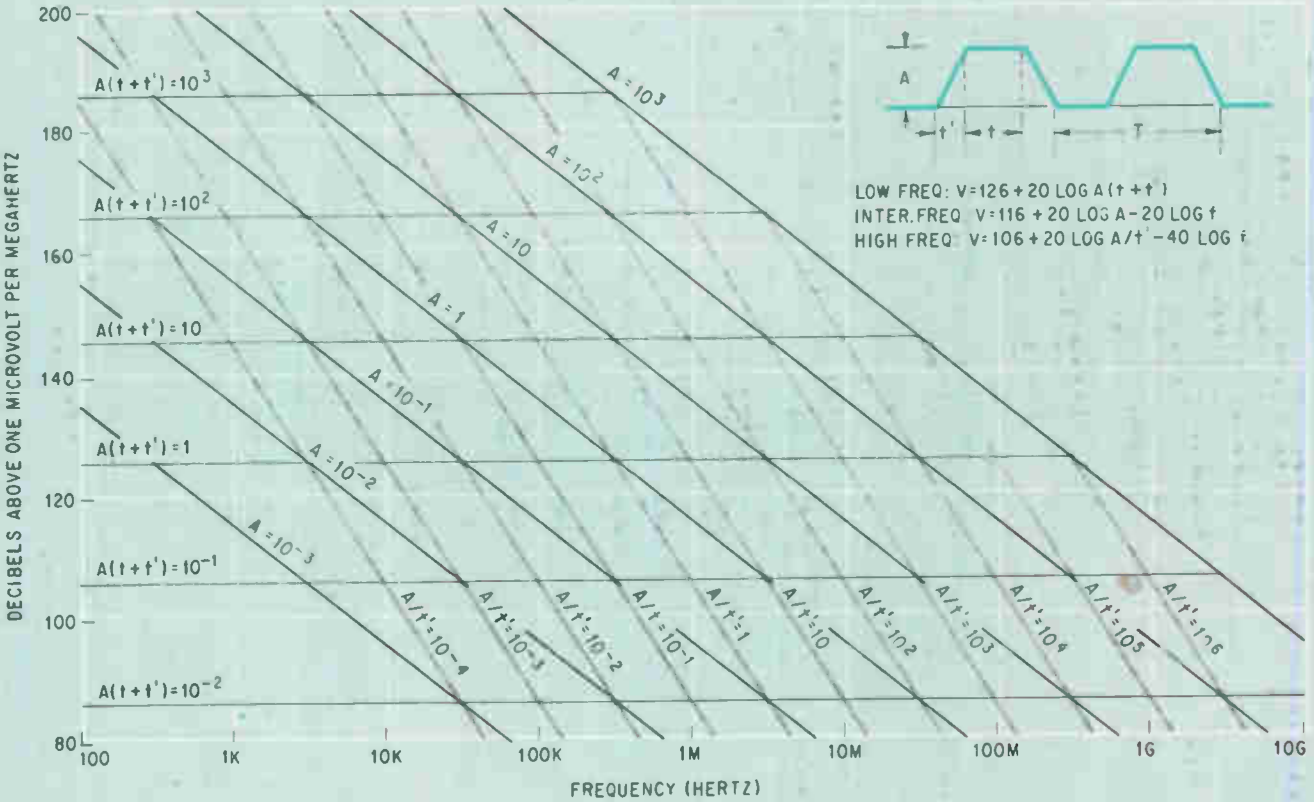
The governing equation

For convenience, however, this equation is converted so it's given in decibels above 1 μvolt per megahertz. Taking 20 times the logarithm results in

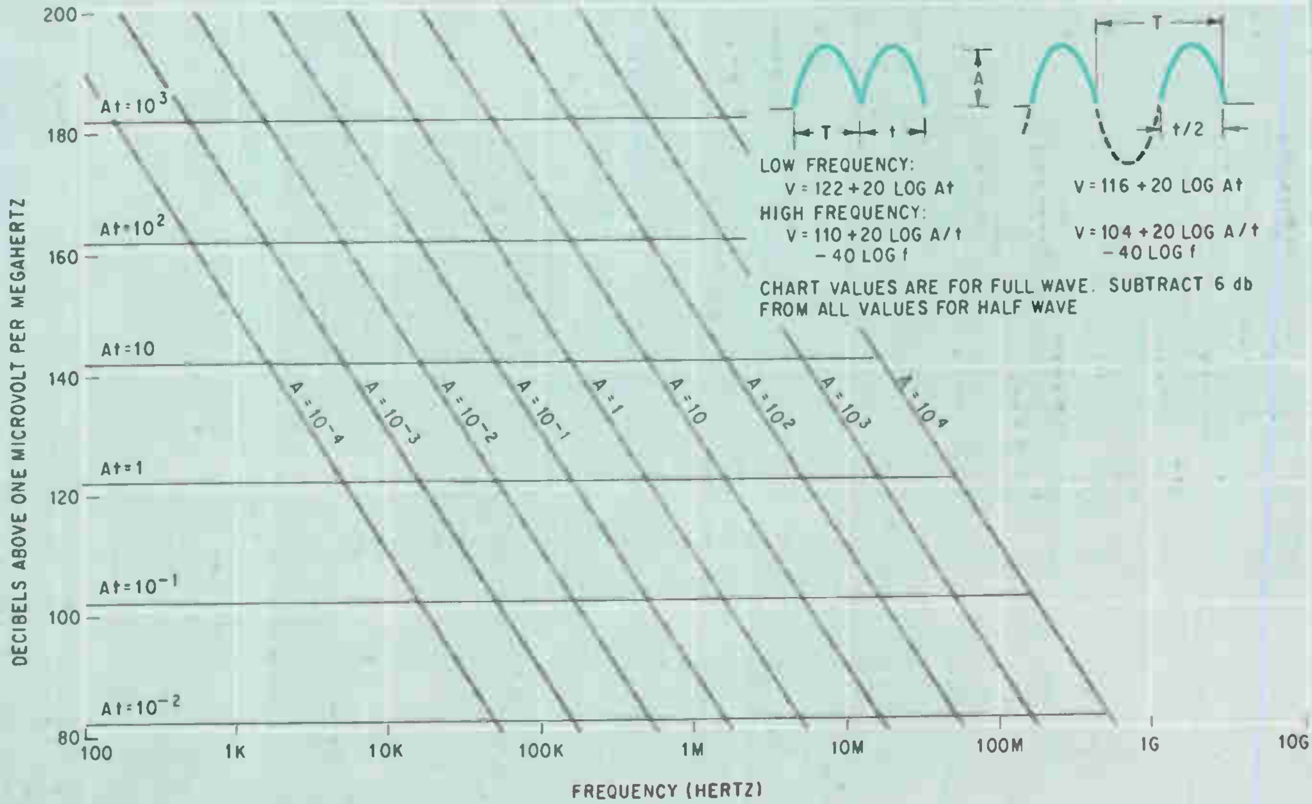
BROADBAND CONDUCTED

Trapezoidal pulse

Legend: A in volts; t and t' in microseconds; f in megahertz.



Full- or half-wave rectified sine wave



$$V \text{ (db above } 1\mu V/\text{Mhz)} = 126 + 20 \log A (t + t') + 20 \log \frac{\sin [\pi f (t + t')]}{\pi f (t + t')} + 20 \log \frac{\sin \pi f t'}{\pi f t'}$$

This equation can be used to plot the broadband spectrum of a trapezoidal pulse train directly from knowledge of the time characteristics of the pulse.

The amplitude can be calculated at each harmonic, but such a tedious procedure isn't necessary. An excellent approximation of the broadband spectrum can be made simply by developing three straight-line segments to represent the spectrum, as shown in the right figure on page 63. Indeed, taking the asymptotic linearization of the actual response is common engineering practice in frequency-response analysis.

One segment is for the low-frequency region, another the intermediate-frequency region, and the third the high-frequency region.

At low frequencies, ($f < 100$ hertz)

$$\sin [\pi f (t + t')] = \pi f (t + t')$$

and

$$\sin \pi f t' = \pi f t'$$

so the last two terms in the governing equation equal zero. Thus the low-frequency line segment, which is horizontal, is given by

$$V \text{ (db above } 1\mu V/\text{Mhz)} = 126 + 20 \log A (t + t')$$

and extends out to the first break frequency

$$f_1 = \frac{1}{\pi (t + t')}$$

At intermediate frequencies, $\sin \pi f t'$ still equals $\pi f t'$ because of the small value of t'. Therefore, the last term of the governing equation drops out. At these frequencies, however,

$$\sin [\pi f t (t + t')]$$

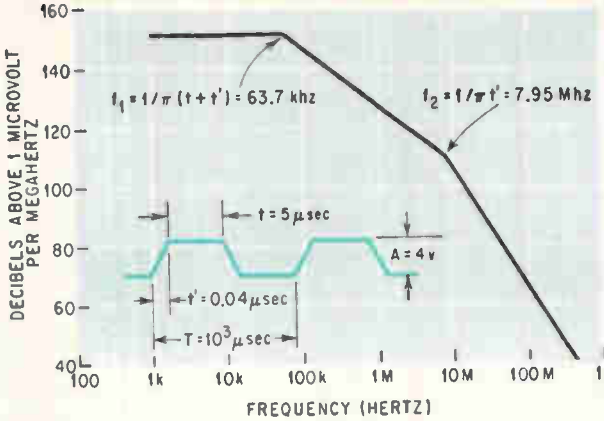
can be set equal to 1; this is valid because only the maximum harmonic in each cusp is of interest in determining the broadband spectrum. Therefore, at middle frequencies, the governing equation reduces to

$$V \text{ (db above } 1\mu V/\text{Mhz)} = 116 + 20 \log A - 20 \log f$$

This second line segment starts at the first break frequency and slopes off at —20 decibels per decade to the second break frequency

$$f_2 = \frac{1}{\pi t'}$$

At high frequencies, $\sin \pi f t'$ can be set equal to 1, so the equation becomes



For example. Spectrum of a specified pulse, above, can be found rapidly using the trapezoid chart on page 64.

$$V \text{ (db above } 1\mu V/\text{Mhz)} = 106 + 20 \log (A/t') - 40 \log f$$

That is, the third line segment starts at the second break frequency and slopes off at —40 db per decade.

The first break frequency is found by setting the right-hand terms of the low- and intermediate-frequency equations equal to each other and solving for f_1. Similarly, f_2 is found by equating the intermediate- and high-frequency equations.

Using the equations for each region and a range of values for each parameter, line segments can be plotted to make a general chart that can be used to obtain the broadband spectrum of any trapezoidal pulse. Such a chart appears at the top of page 64. Procedures similar to those for analyzing the trapezoidal pulse result in charts for other types of pulse shapes. These procedures aren't carried out here, but the useful results for five other pulse shapes are charted on pages 64, 65, and 66.

Sketching a spectrum

Use of the charts is simple and can be demonstrated by drawing the broadband spectrum, shown above, for a typical trapezoidal pulse. Consider a 1,000-hertz (2,000-baud) "square wave" used for data transmission. It has an amplitude, A, of 4 volts, a repetition rate, T, of 1,000 μseconds, a pulse width, t, of 5 μsec and a rise time, t', of 0.04 μsec. The three segments defining the spectrum in the chart on the top of page 64 are $A (t + t')$, A, and A/t'. For this example, the values are

$$A = 4$$
$$A (t + t') = 4 (5 + 0.04) = 20.16$$
$$A/t' = 4/0.04 = 100$$

Enter the chart at the db value corresponding to 20.16. The db value for $A (t + t') = 10$ is already plotted as 146 db. Then the value for $A (t + t') = 20.16$ can be found from $20 \log (20.16/10) = 6$ db, so the 6 db are added to 146. Thus the chart is

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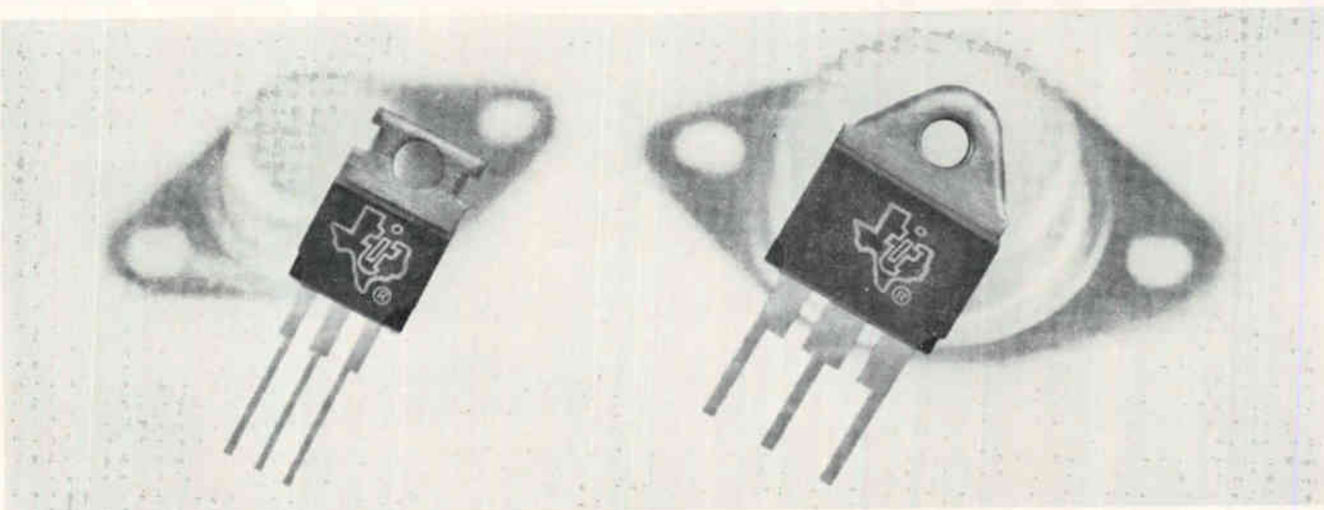

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TIP29A	TIP30A	60	1	TO-66	40-200 @ 200mA	30W
TIP31	TIP32	40	3	TO-66	20-100 @ 1A	40W
TIP31A	TIP32A	60	3	TO-66	20-100 @ 1A	40W
TIP33	TIP34	40	10	TO-3	12-125 @ 3A	80W
TIP33A	TIP34A	60	10	TO-3	12-125 @ 3A	80W
TIP35	TIP36	40	25	TO-3	10-100 @ 15A	90W
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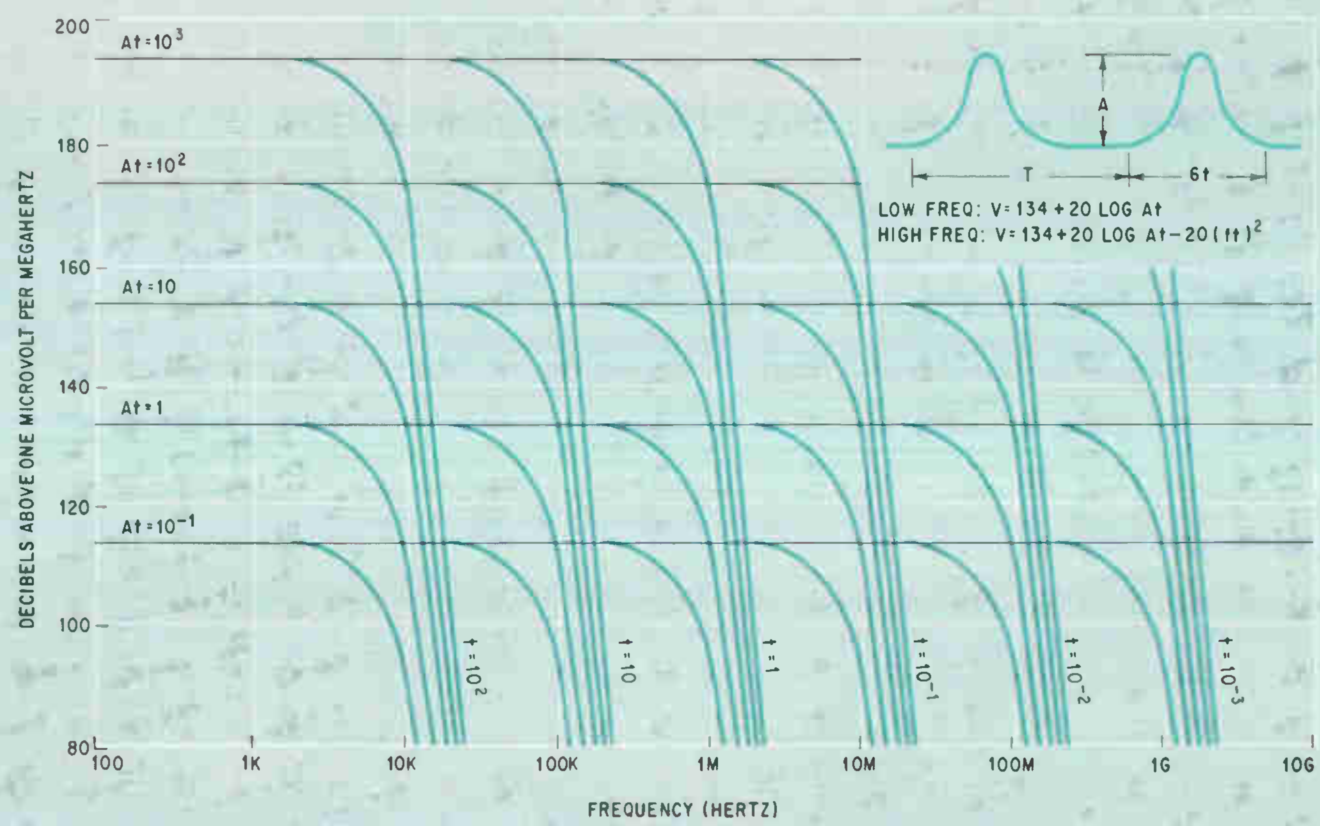
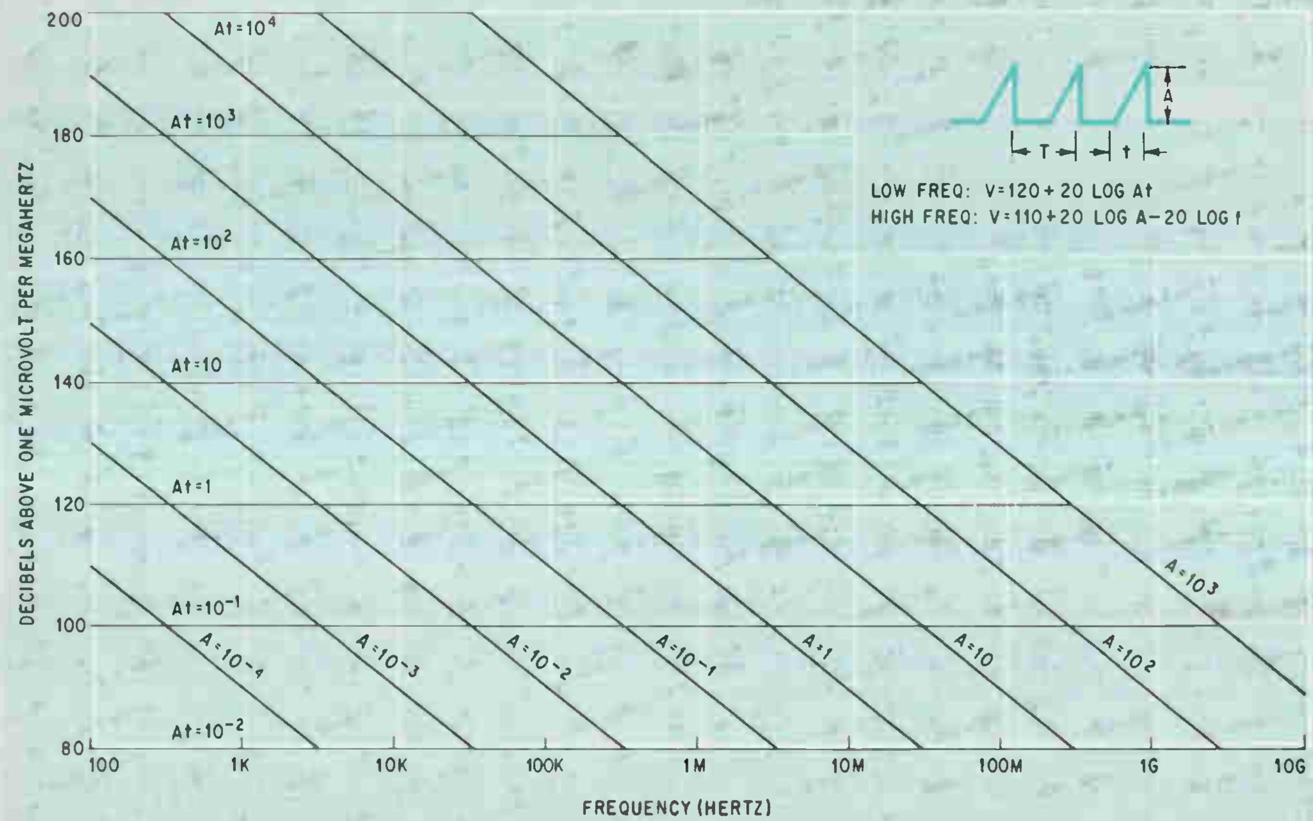
INTERFERENCE VOLTAGES FROM SIX COMMON PULSE SHAPES

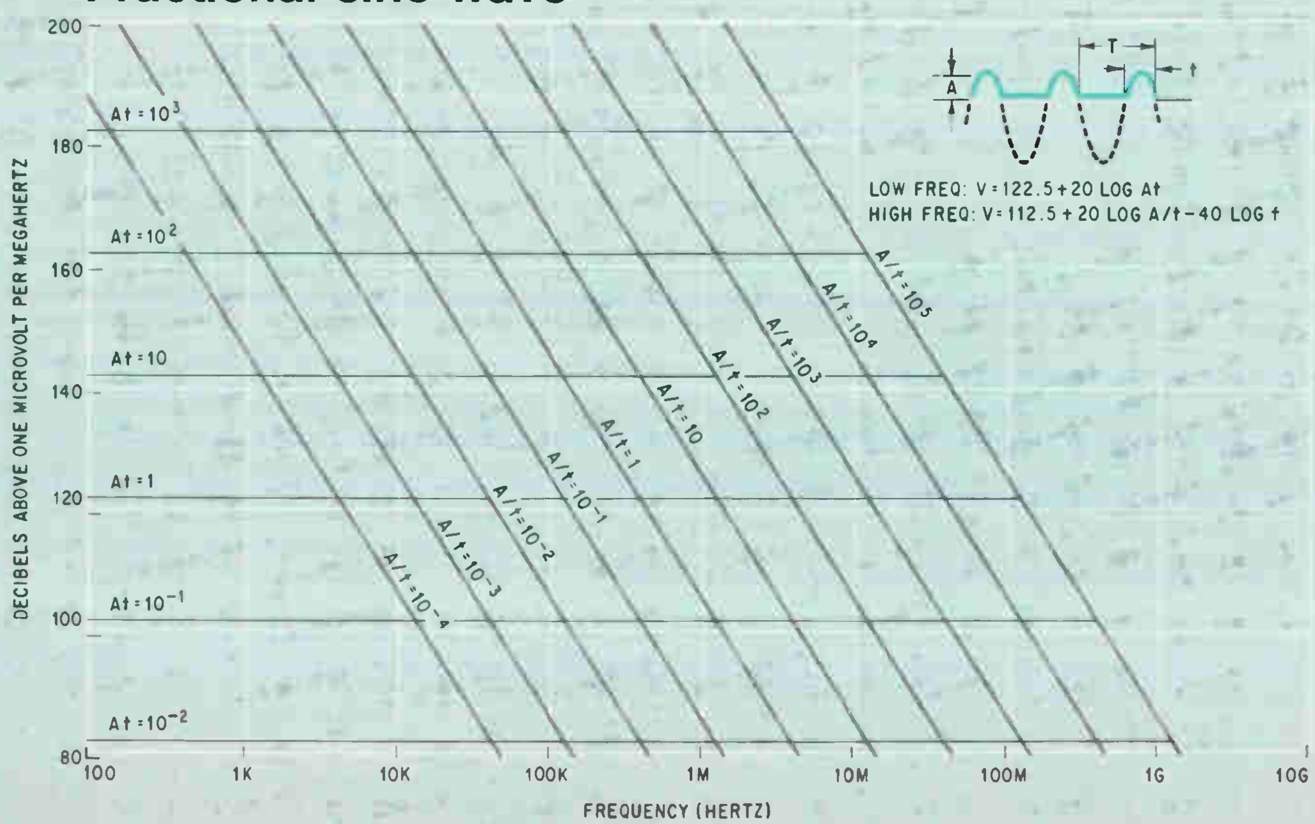
Gaussian waveform



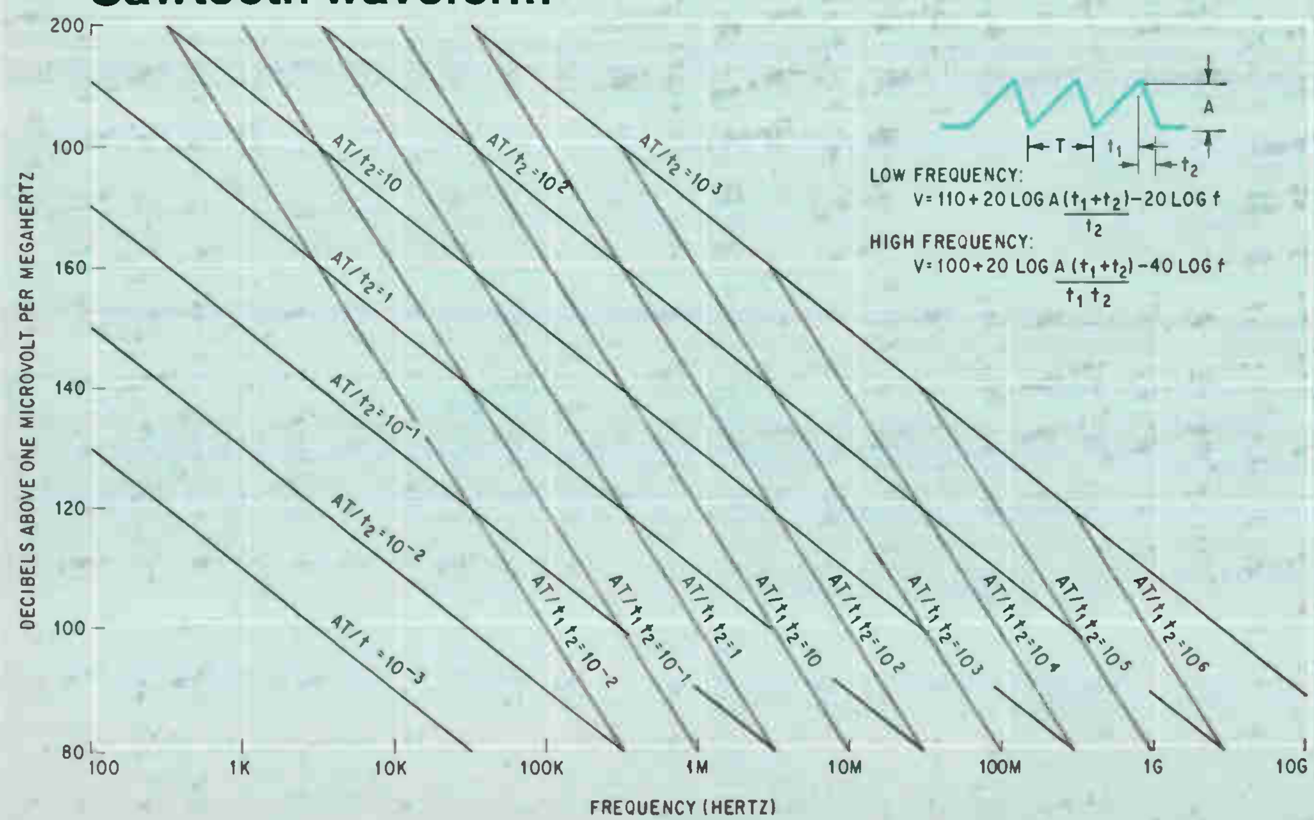
Clipped sawtooth waveform



Fractional sine wave



Sawtooth waveform



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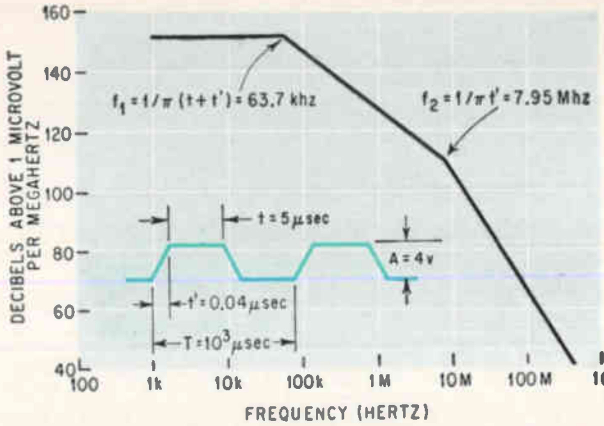

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Enter the chart at the db value corresponding to 20.16. The db value for $A (t + t') = 10$ is already plotted as 146 db. Then the value for $A (t + t') = 20.16$ can be found from $20 \log (20.16/10) = 6$ db, so the 6 db are added to 146. Thus the chart is entered at 152 db, and a horizontal line is drawn out until the first break frequency

$$f_1 = \frac{1}{\pi\,(t+t')} = \frac{1}{3.14\times(5.04)} = 63.7 \text{ khz}$$

The second segment (A = 4) then slopes off at —20 db per decade according to the intermediate-frequency equation until it intersects with the second break frequency

$$f_2 = \frac{1}{\pi t'} = \frac{1}{3.14 \times 0.04} = 7.95 \text{ Mhz}$$

The third segment slopes off from this break frequency at —40 db per decade according to the high-frequency equation.

Slower and shorter

The chart at the top of page 64 shows how pulse parameters affect frequency content. A change in the signal amplitude shifts the amplitude of the entire envelope by a factor of 20 log A. A change in pulse width, t, affects only the lower-frequency harmonics by a factor of 20 log t. A change in the repetition rate, T, does not affect the envelope's shape, but determines where the spectrum begins and succeeding harmonics. A change in rise time, t', affects only higher-frequency harmonics by a factor of —20 log t'. That is, making the rise time 10 times slower reduces the high-frequency interference by a factor of 20 db.

To sum up: the lower the pulse amplitude, the lower all harmonic amplitudes; the slower the rise time, the lower the high-frequency amplitudes; the shorter the pulse width, the lower the low-frequency amplitudes.

Narrow look

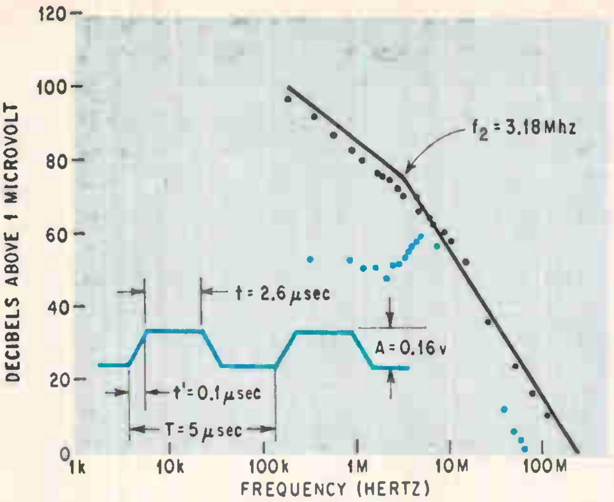
So far, only the broadband aspects of interference generated by pulses have been considered. If a receiver is to measure harmonics, its bandwidth determines whether the narrowband or broadband results are obtained. Narrowband means that only one harmonic is being measured at a time; broadband means that more than one harmonic is included and that the amplitude reading will therefore be the sum of the harmonics within the receiver bandwidth. Thus the bandwidth capabilities of a receiver, as well as its frequency range, must be taken into account when measuring interference.

A narrowband spectrum can be obtained easily; simply subtract 20 log T db from the entire broadband spectrum developed according to the previous procedures.

The two line segments in the figure above show just the intermediate- and high-frequency regions for a trapezoidal pulse obtained with the aid of the chart at the top of page 64. The dots represent measurements made with a narrowband receiver, one whose bandwidth is less than F = 1/T, where T is the pulse repetition rate. The black dots are measurements of maximum amplitude harmonics in each cusp, as noted in the figure on page 63. The colored dots are nonmaximum harmonics that exist when

$\sin\,[\pi f\,(t + t')]$

is not zero.



Narrowband spectrum. Harmonics for this pulse occur at 200-khz intervals. Line is calculated maximum-amplitude envelope; black dots show measured values. Colored dots are measured nonmaximum harmonics.

Field intensity

The six charts on pages 64, 65, and 66 apply to conducted interference. A very good estimate of radiation levels a foot from a circuit carrying the pulse waveform can be obtained by reducing the conducted levels by a factor of 22 db. This gives the electric field intensity levels in db above 1 μvolt per meter for narrowband signals and 1 μvolt per meter per megahertz for broadband signals. To obtain electric field levels at other distances, subtract an additional 20 log (distance in feet). Thus, at three feet, the level is (—22–20 log 3) (—22—10) = —33 db.

Finally, while the charts are given in voltage amplitudes, they apply just as well to current amplitudes. The amplitude is then interpreted as db above 1 μampere per megahertz.

To obtain the magnetic field strength generated by a small loop of current, first compute the current spectrum and add to it the factor

$$20 \log(NA/4\pi r^3)$$

where N is the number of loop turns, A the loop area in square meters, and r the distance from the loop in meters. This procedure will yield the decibels above 1 μampere-turn per megahertz per meter.

Circuit design

Designer's casebook

Inexpensive comparator reacts in 100 nanoseconds

By Richard Becker

University of Vermont

Inexpensive fast comparators are rare. But costs can be kept down by using heat sinks and emitter-follower configurations instead of such extra components as zener diodes.

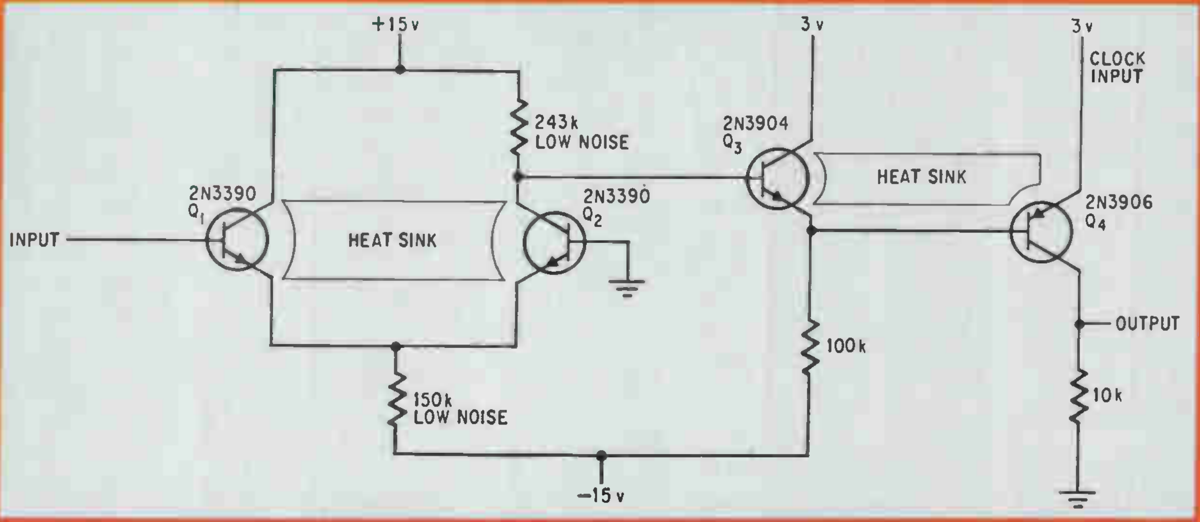
A comparator built in this way can detect and react to input changes in as little as 100 nanoseconds. Its output can be switched from logic 0 to 1 by less than 63 nanoamperes, and it's stable to less than 2 nanoamperes per degree C. It can be driven with a clock pulse for synchronous comparison when it becomes necessary.

With the input base at zero volts, each transistor in the differential amplifier draws 50 microamperes of collector current. In this output state of the pair, Q_1's collector rests at +3.6 volts and the emitter-follower output at +3 volts. Because these +3 volts are also the base of the output transistor, Q_4, it is turned off, thus providing a 0 signal. When Q_1's base goes negative, Q_2's collector goes to 0 and the emitter follower to —0.6 volt. This voltage saturates Q_4, providing a 1 signal. A 1-volt shift in the 3-volt supply causes less than 1.5% error in the comparison levels.

The differential-amplifier transistors, Q_1 and Q_2, are mounted on the same heat sink so temperature changes will affect the sensitive base-emitter voltages of the transistors equally. Q_3 and Q_4 don't have to be matched for beta. Their base-emitter voltages oppose each other, consequently, temperature changes which cause the V_{be} of Q_3 to change are nullified by an equal V_{be} change in Q_4 of opposite polarity. This is a fail-safe method of eliminating temperature caused errors.

Because of the comparator function of the transistors in the differential amplifier, their base-emitter voltages should be within a millivolt of each other. And to preserve linearity, their betas shouldn't vary more than 10% when the collector current is 50 microamperes.

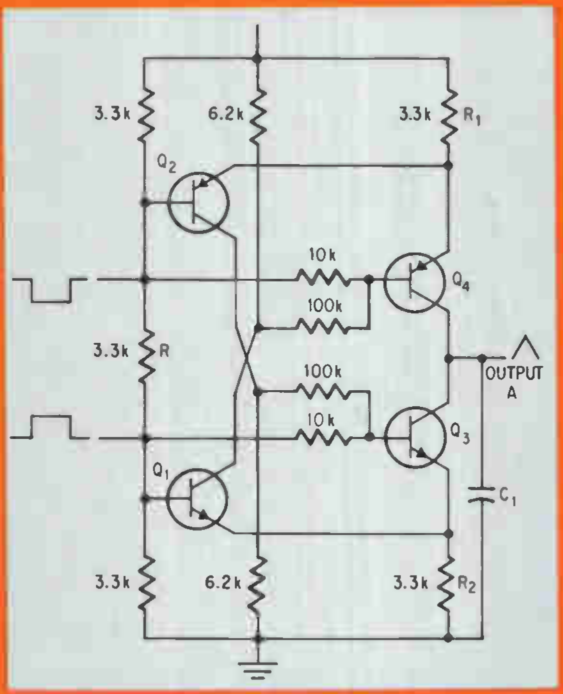
To prevent loading of the amplifier, Q_3 is connected in an emitter-follower configuration. This also enables the driver stage, Q_4, to operate an integrated-circuit gate.



Logical progression. A change in the input causes the differential amplifier's output to shift, moving the collector of the driver stage, Q_4, from ground to 3 volts. The heat sinks and transistor selection make the comparator insensitive to temperature and supply variations.

One capacitor makes IC a pulse-width modulator

By Otto Baade
Standard Telephones & Cables Ltd., London



Sawtooth. Changing of capacitor C_1 by Q_4's collector current forms the leading edge of the sawtooth.

Triangular-wave generators can be used for pulse-width modulation in audio amplifiers to provide greater output than conventional amplifiers. And integrated circuits can make this technique economical. Because it's difficult to put capacitors in IC's, a way to make an IC generator with only one capacitor should get an enthusiastic welcome. The generator described here produces two square waves in addition to the triangular ones.

With transistor Q_1 conducting, the voltage at the base of transistor Q_4 is more negative than that at Q_2's base, so Q_4 conducts. The constant collector of Q_4 charges capacitor C_1. The base voltage of Q_3 is more negative than that of Q_1, which conducts until Q_4 becomes saturated.

The current through resistor R_1 then flows through Q_2 instead of Q_4, causing Q_2 and Q_3 to conduct instead of Q_1 and Q_4. Capacitor C_1 is discharged by Q_3's collector current until Q_3 is saturated. The current is then switched back to Q_1 and Q_4.

Bridge and amplifier monitor d-c level

By John P. Budlong
Bedford Institute of Oceanography
Dartmouth, Nova Scotia

Small d-c signals with high source impedance can be difficult to measure, especially when the signals can vary either way from zero.

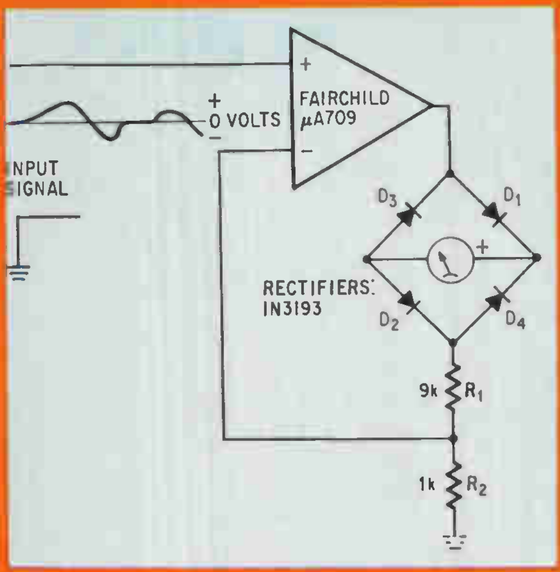
A circuit consisting of an operational amplifier, milliammeter, and bridge rectifier provides high input impedance and high sensitivity. The meter reads up-scale regardless of the input polarity, and calibration depends on only one component.

The circuit provides a sensitivity of 1 volt full scale. Assume a +1 volt signal applied to the amplifier's (+) input. Since the offset voltage between the amplifier's (+) and (−) inputs is very small (usually assumed to be zero), the voltage on the (−) input must also be +1 volt. The amplifier generates this voltage across R_2 by driving 1 milliampere through D_1, the meter, D_2, R_1, and R_2.

Resistor R_2 determines the calibration; its value is calculated by

$$R_2 = \frac{1\text{ v}}{1\text{ ma}} = 1\text{ kilohm}$$

R_1 provides meter protection and overload will not exceed 5%. To accurately measure a millivolt



Accurate both ways. Variations in a voltage level are given meter-driven capability by the operational amplifier signal, offset voltage—the small difference between the amplifier's (+) and (—) inputs—must be taken into account. A 100-microvolt offset will cause 1% error on a 10-mv range. Most types of amplifiers are adjustable to zero offset at a given time; the change in offset with time depends on the amplifier used.

The circuit can also be used to measure a-c voltage. The meter then indicates the average value of the rectified waveform. Root-mean-square readings can be obtained by reducing R_2 by 11%.

An earlier version of this article [Electronics, June 24, p. 99] contained some errors introduced in the editing process. Since a correction notice would require complicated explanations of the points involved, we are publishing the complete article in corrected form. Our apologies to the author and our readers.

Feedback circuit keeps motor's torque constant

By E.S. Busby

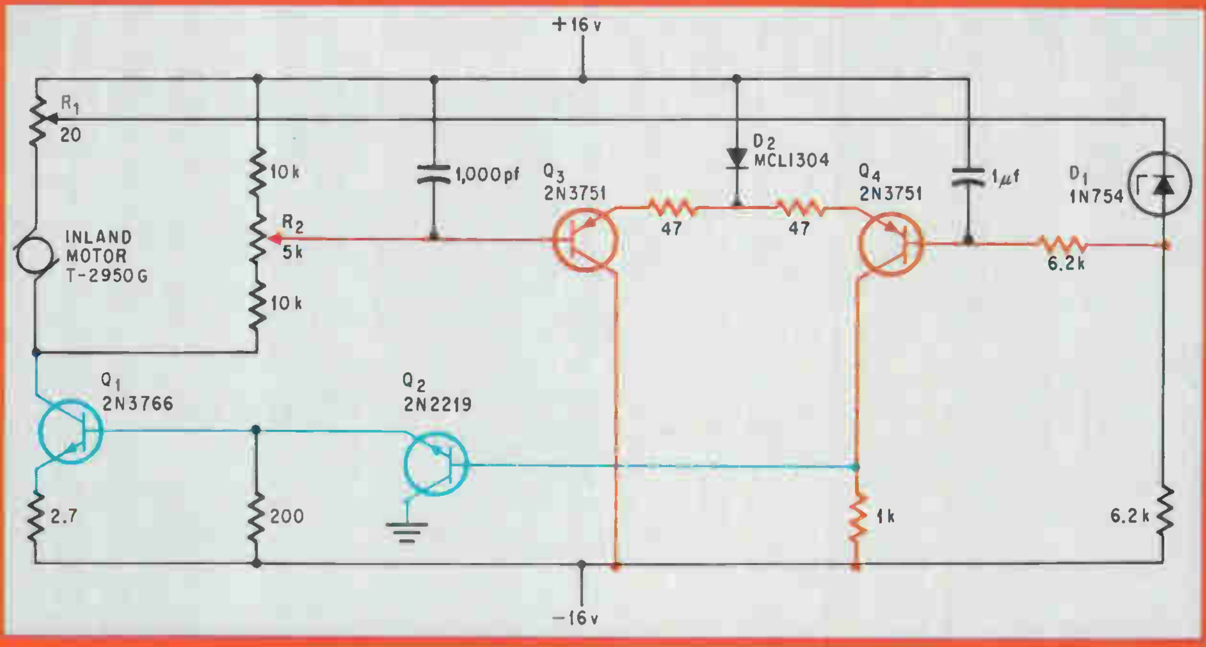
Ampex Corp., Redwood City, Calif.

The slope of torque versus speed of d-c motors can typically vary as much as 20% because of variations in the strength of the permanent magnet. In an application requiring close matching of the torque-speed slope to a part of the 1/torque characteristic required for a constant-speed, constant-tension tape drive, a feedback circuit can provide for the insertion of negative or positive adjustable resistance in series with the motor and for adjustment of motor voltage.

This nominal no-load motor voltage of 13.6 volts is supplied by comparing half the voltage across the motor and R_1 with a 6.8-volt zener diode in the differential amplifier composed of Q_3 and Q_4. The output of the amplifier drives Q_2 and Q_1, which are a constant voltage regulator. With potentiometer R_1 fully counterclockwise, the voltage is constant regardless of current, and 20 ohms are in series with the motor, reducing the slope of the torque-speed characteristic.

With the potentiometer fully clockwise, positive feedback equivalent to —40 ohms is introduced, making a total of —20 ohms in series with the motor and thus increasing the motor slope. With the potentiometer centered, positive feedback operates to make the —20 ohms cancel the +20 ohms.

To adjust for a slope, first set R_2 for the no-load speed indicated, then adjust R_1 for the proper torque with the motor stalled.



Sensitive feedback. Negative feedback placed in series by the combination of a zener diode and a comparator circuit keeps the necessary control on the d-c motor. The torque is adjusted with resistor R_1. Despite reel speed or the amount of tape on the reel the torque is constant.

Four-digit counter. Significant digit display without extra digits: $350.

Fairchild's 8040 counter provides a unique time base with five gate times in the frequency mode: 1msec through 10 sec. It's the only instrument in its price range that allows you to display the most significant digit for any frequency without buying extra digits. The 8040 time base is 60Hz line frequency with 0.1% stability. It offers 1 Megohm input. Its range is 10Hz to 2MHz. A fifth digit is optional. If you need a more sophisticated counter, we also have a five-digit, 30MHz instrument. It's called the 8050. It costs $695. It does a lot more than the 8040. Call for specs on both. Dial (408) 735-5201. Ask for Don Greening.

FAIRCHILD
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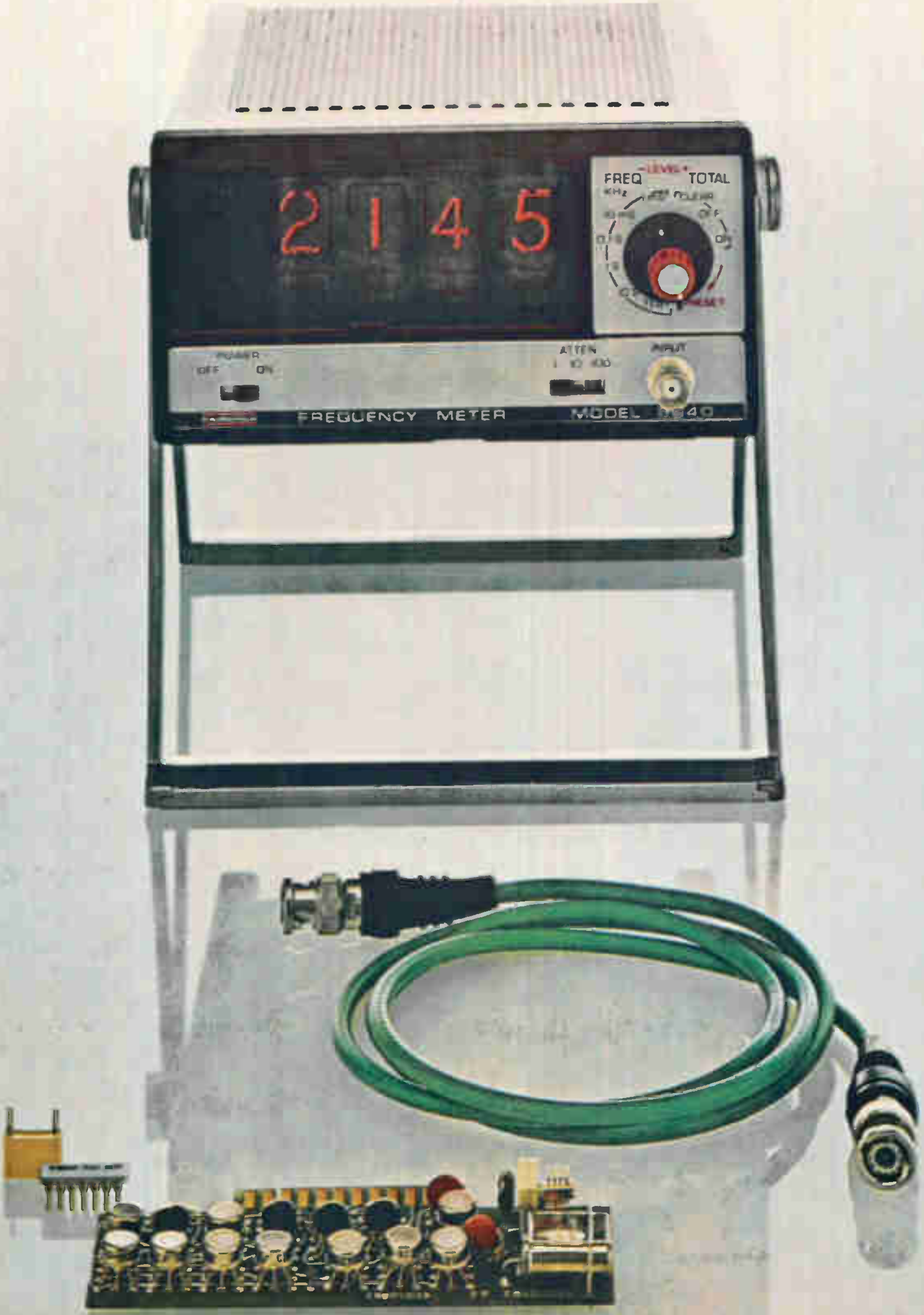


FAIRCHILD INSTRUMENTATION A Division of Fairchild Camera and Instrument Corporation 974 East Arques Avenue Sunnyvale California 94086 (408) 735-5201 TWX 910-339-9217

Solid state module makes for light reading

Bright, distinct numerals are displayed by this small, inexpensive unit, which uses a large-scale integrated circuit to decode binary commands and drive a matrix of light-emitting gallium-arsenide-phosphide diodes

By members of the technical staff

Solid State Laboratory, Hewlett-Packard Co., Palo Alto, Calif.

The need for a solid state display has been apparent for a long time. Phosphor-type electroluminescent devices were once thought to be the answer, but they've proven short-lived and dim, and require an awkward high-voltage and audiofrequency power supply. What's really needed is a semiconductor diode display compatible with integrated circuits.

It's now possible to build such displays—mass produce them, in fact—as a result of work at the Hewlett-Packard Co. on gallium-arsenide light emitters and large-scale IC's.

The display module is inexpensive and small and consumes little power. And it can directly translate, in less than a microsecond, internal machine states into intelligible symbols. The characters are readable in direct sunlight, and their brightness is adjustable; there's no parallax, flicker, or loss of definition.

One of the first uses of the solid state display will probably be in avionics equipment. The advantages of its employment in aircraft, spacecraft, and related ground support equipment are substantial—small size, readability, thinness, adjustable brightness, and electrical compatibility with IC's. Life span is important here, too—the half-life of the solid state display (the time required for a 50% drop in brightness) is apparently about 10,000 hours.

The interdisciplinary nature of the development of the solid state display is reflected in the contributors to this article. The materials aspects are explained by P. E. Greene and R. A. Burmeister, devices by R. J. Archer, E. E. Loebner, and D. Kerps, IC's by J. D. Barrett and J. E. Price, and engineering and manufacturing by H. D. Borden and G. B. Pighini. M. M. Atalla is director of the laboratory.

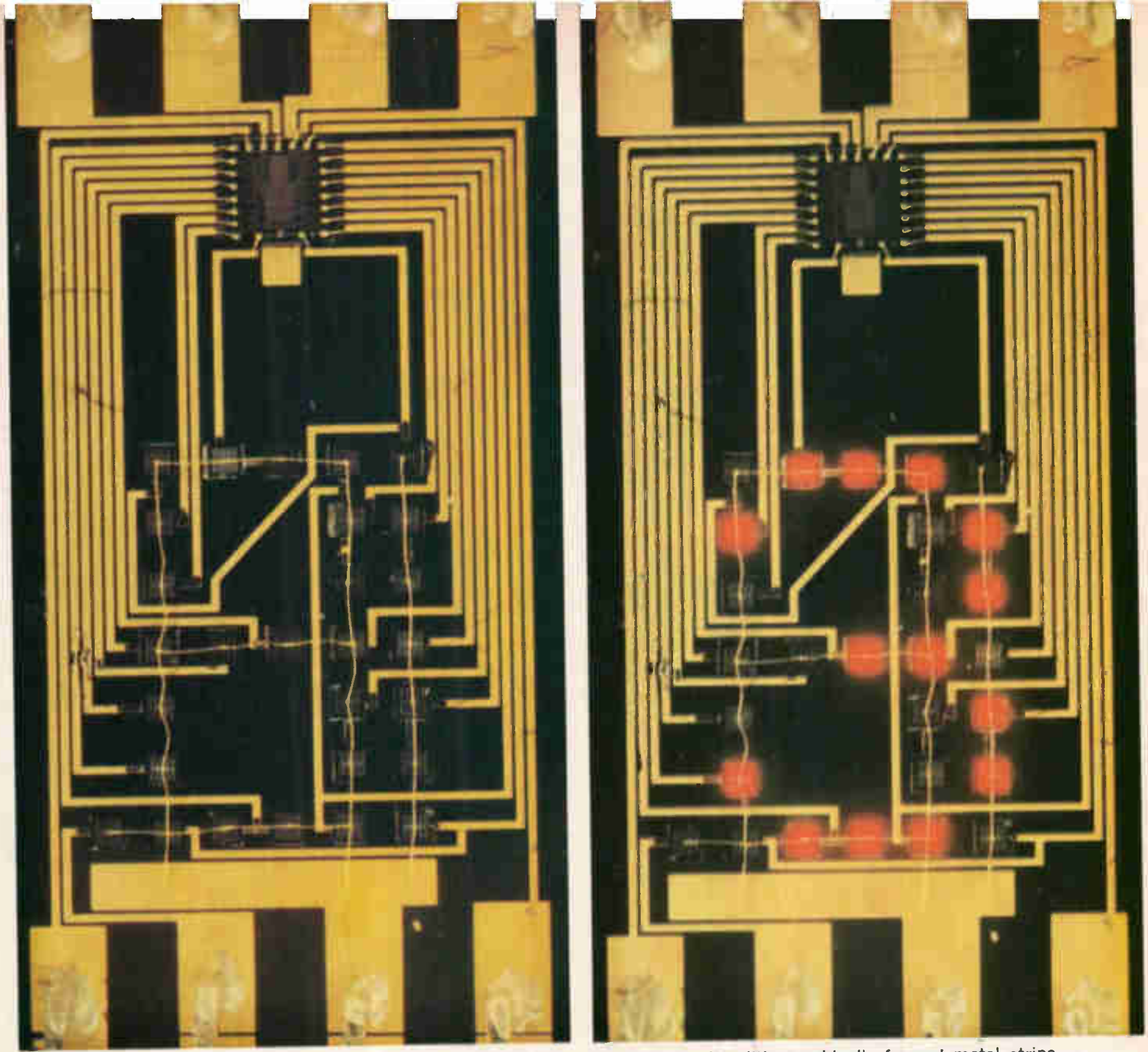
The new display is also suitable for commercial equipment. It can function as a readout for instruments or data-processing gear, for example. With its compactness and high image definition, the display is particularly suited to present telemetered or computer-generated data on situation status boards. And with its variable-intensity red light, it should find applications in darkrooms and in working areas where the personnel have to be dark-vision-adapted.

Efficiency's the thing

If there's a single key to Hewlett-Packard's solid state display, it's the ability to make a diode emit visible light efficiently. Although the integrated-circuit portion of the display is certainly state of the art—it contains some 400 circuit elements—it's the diode portion that's of special interest. The over-all display appears to be the first such to become commercially available [Electronics, July 22, p. 95].

Most of the research, development, and design work was financed by the company, but several important tasks were supported by outside organizations. Prominent among these are the Navy's former Bureau of Ships, now part of the Naval Electronic Systems Command, and the Tv Products division of the Corning Glass Works.

Efforts to increase the efficiency of light emitters started many years ago. By 1960, research on phosphor-dielectric-type electroluminescent devices had reached a plateau with three major problems still unsolved: light output was insufficient, operational life was limited, and there was no economical and



Bottoms up. Signals from a large-scale integrated circuit are conducted by photolithographically formed metal strips to the bottoms of the 28 light-emitting diodes. Wire at top of the diodes provides a common anode. IC determines which diodes light up by decoding the binary-coded-decimal input to the module.

Sharp definition. With a red glass cover, the IC and the metalization are not visible, and the diode display appears to float in space.

fast means of switching and addressing that was compatible with the high a-c voltages required by the devices. Theory was—and still is—vague and qualitative;[1,2] solvable problems couldn't be isolated. And as a result, progress had to be left to chance.

Hewlett-Packard then turned its attention to an older kind of electroluminescent device, the semiconductor injection diode. The theory of this device, which was moderately well understood even at that time, promised high efficiency and very high outputs. It also appeared possible to operate this device at the sort of low voltages compatible with semiconductor switching circuitry.[3]

But experiments had shown an extremely low efficiency at room temperature. Fortunately, it turned out that this inefficiency was only an apparent one, in gallium arsenide at least.[4] Photons were generated plentifully at room temperature, but they were absorbed by the material on their way from the diode junction to the surface. The inefficiency at room temperature was therefore a problem that could be overcome by improved design and better selection of materials.

Actually, there are three efficiencies that are useful in describing the performance of light-emitting diodes.

- External quantum efficiency—the number of photons emitted from the device for each electron.
- Internal quantum efficiency—the number of photons generated inside the device for each electron. This is computed from the external efficiency by accounting for all the optical absorption and scattering losses.
- Electroluminous yield—the number of lumens emitted per unit current, expressed in foot-lamberts per unit current density.

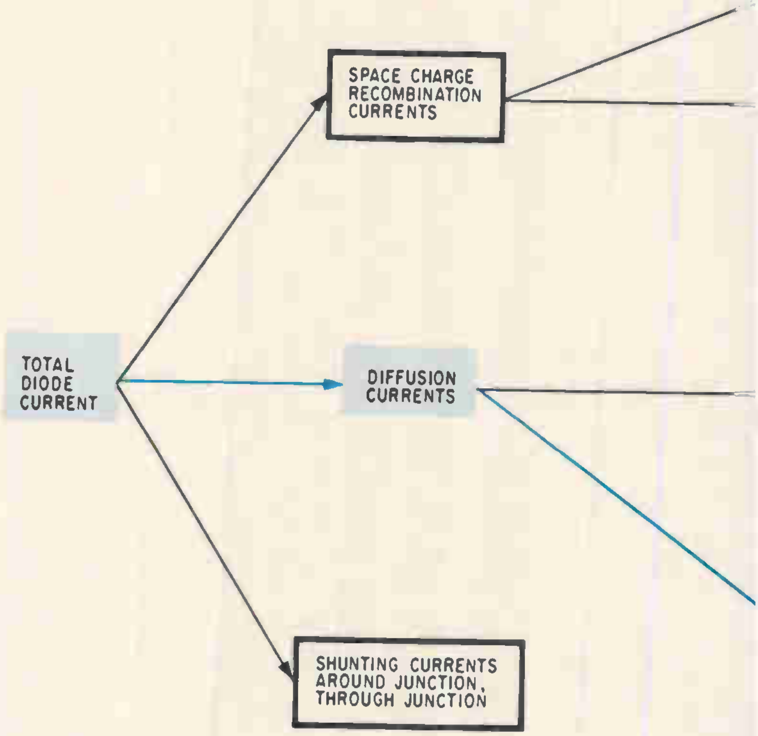
The physics of electroluminescent diodes is complex. In the case of the H-P display, the desired effect—photons emitted at energies compatible with the characteristics of the human eye—is only one of many possible injected carrier transitions, as shown at right. The quest for efficiency is thus a problem of channeling the sequence of physical events so that the strong near-edge luminescence branch of this family tree is favored.

Briefly, the sequence of events goes something like this:

- Externally applied energy is stored in excited electrons and holes in and around a p-n junction.
- This energy is disposed of by radiation of photons and other processes.
- The photons pass through the device and into the surrounding medium.

Where the transitions take place in the diode influences the number of photons generated and the quantity that escape from the device. For maximum efficiency, of course, both quantities should be as high as possible. In general, the transitions can take place on both sides of the p-n junction, in the space charge region, and at the electrodes.

The H-P diodes are designed to generate photons predominantly on the p side of the junction. Here



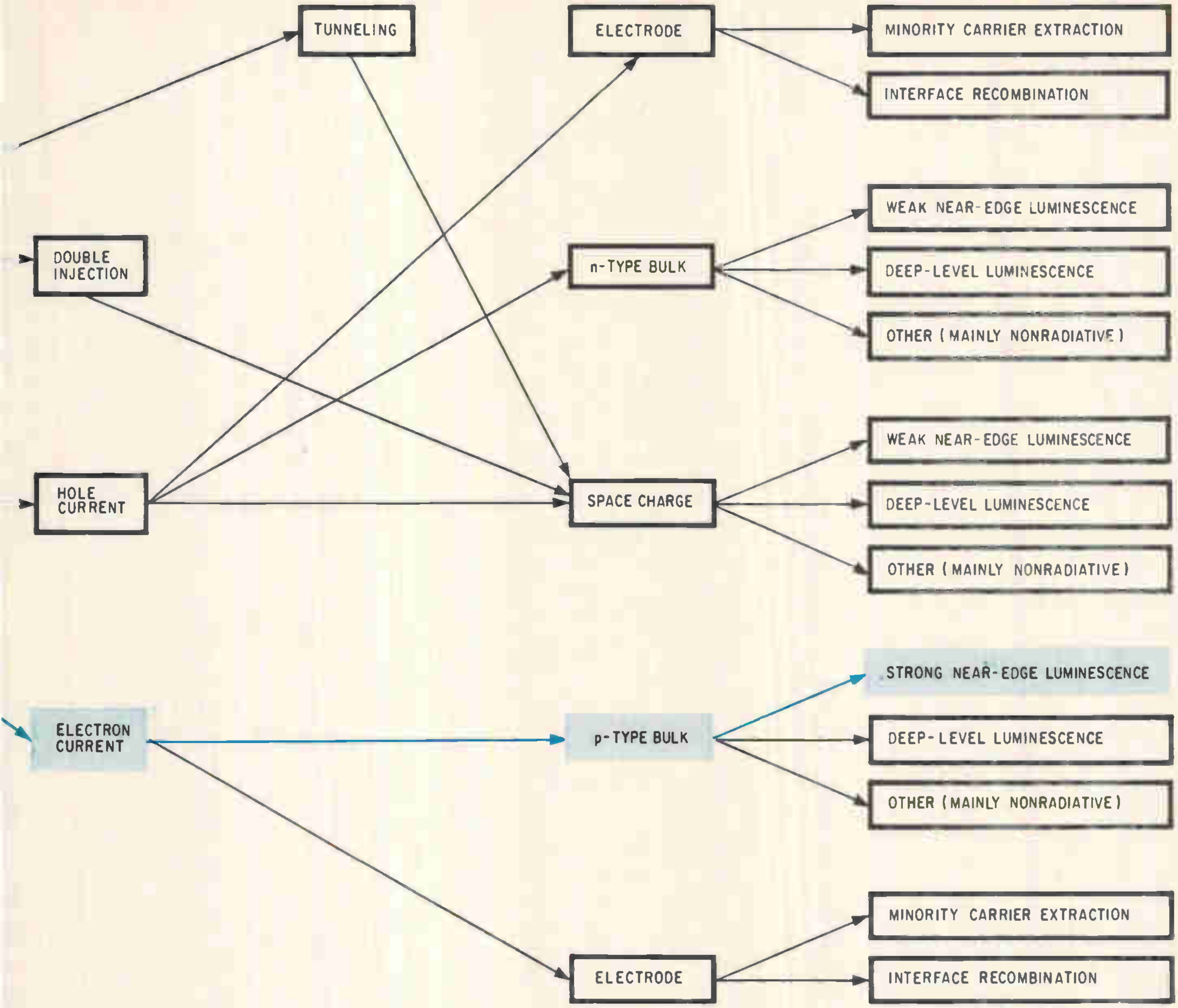
Genealogy of a photon. Many transitions of the injected carriers possible, but only one chain of them leads to the desired strong near-edge luminescence.

electrons, which have much higher mobility than holes, are injected more plentifully and tend to generate near-edge photons (that is, photons whose energy is near the band-gap energy).

Near-edge rather than deep-level luminescence was selected for the Hewlett-Packard diodes because its efficiency—power and luminous—is greater, it provides better definition, and it doesn't change color as the current varies.

The current density through the diode must be greater than 1 milliampere per square millimeter if a large fraction of the total diode current is to contribute to light emission. At a lower current density, the fraction of tunneling and space-charge recombination currents increases, and the current shunting the p-n junction entirely may become appreciable.

Optimizing the injection of electrons into the p side—by selecting the dopants and their profiles—is the main task in fabricating the diodes. If the



p-type dopant gradient is too steep, for example, or if the p-side electrode is too close, the electron may not suffer a shining termination of its existence, and efficiency may be too low.

Material questions

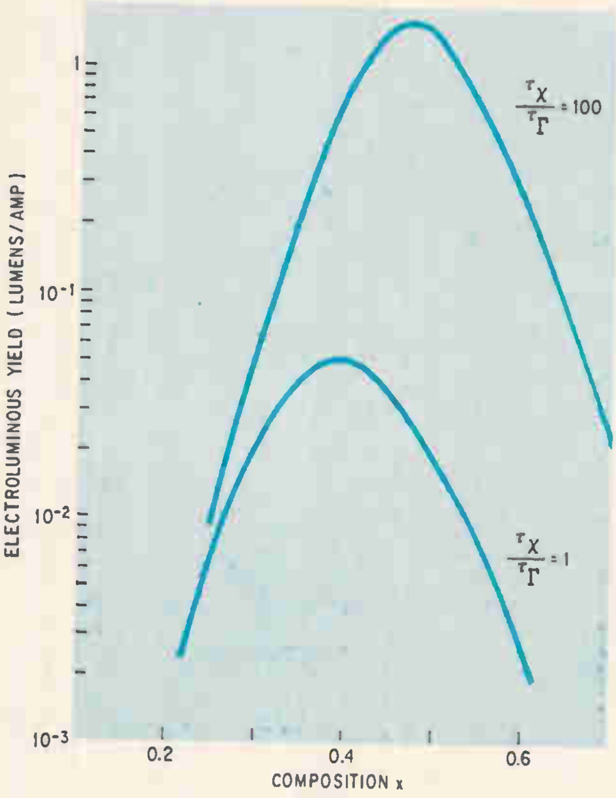
The choice of a semiconductor material for the diode hinges upon how closely the doping profile can be controlled—in other words, how carefully the positions of the various recombination zones can be controlled—and upon how strong the near-edge recombination is in comparison with all the other competing recombination mechanisms such as deep-level or nonradiative recombination.

Another important factor concerns whether the energy bandgap is larger than 1.85 electron volts, so that the radiation is sufficiently visible. There's only one practical material that satisfies these requirements now— a gallium-arsenide-phosphide [Ga(As,P)] alloy [Electronics, March 4, p. 105].

Gallium arsenide is amenable to device fabrication, but it emits in the infrared region. Gallium phosphide, though it can emit near-edge green light efficiently,[5] hasn't yet progressed to the manufacturing stage, technically or economically.

Gallium-arsenide-phosphide alloys have the formula $GaAs_{1-x}P_x$, where x can have any value from 0 to 1. These alloys have two conduction bands, described as Γ and X[6] in the Γ band, electrons are highly mobile and are characteristic of pure GaAs ($x = 0$). Electrons in the X band have a lower mobility and are characteristic of pure GaP ($x = 1$).

Hewlett-Packard researchers found that the luminous efficiency at room temperature is highest in an alloy composition in which the preponderance of electrons is in the X rather than Γ band. They developed methods of controlled synthesis for optimum material composition, and even more important, they developed a means of independently



Brighter, longer life. Increasing the lifetime τ of the X-type electrons boosts the electroluminous efficiency for a given proportion of phosphorus. Composition x of 0.4 corresponds to 20% of phosphorus.

increasing the lifetime of the dominant X electrons.[7,8] (For equal composition x, a long-lifetime alloy has much higher electroluminous efficiency, as shown at the top of the page).

The net result is that efficiency became a parameter subject to control during the synthesis of the diode material. This achievement is partly due to advances in the technology of growing materials, but also rests to a great extent on analytical and experimental work on the complex tradeoffs involved in electroluminescent p-n junctions.

H-P's manufacturing facility is equipped to make almost all the parts in the module. Initial production capacity is 1.5 million electroluminescent-diode elements a year. The company designed and built a vertical flow, r-f heated dual reactor system that can grow Ga(As,P) wafers up to 2 inches in diameter. This cold-wall vapor epitaxial system permits control of the phosphorus-to-arsenic ratio to within 1% throughout the epitaxial layer, and of the thickness to within a micron.[9] Because of this degree of control, the entire wafer is of sufficient quality for diode fabrication.

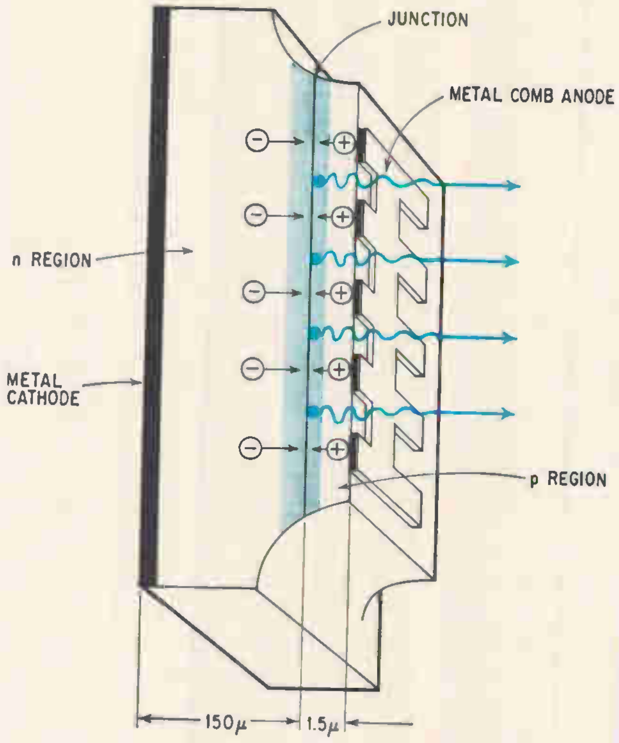
The net result of all the analysis, design, and development is a simple mesa structure, shown at right, in which a forward bias reduces the potential barrier between the n and p regions, allowing current to flow. Electrons are injected from the n region into the space charge layer and into the p region; there's a similar injection of holes from the p region. These excess carriers recombine, with as much as 10% of the recombination resulting in near-edge photons. Most of them are generated in a region only about a half-micron wide on the p side of the junction.

The nearness of the anode surface ensures high transmittance through the p region, but even so, about 98% of the photons are lost because of internal reflection—a result of the great difference in index of refraction between the semiconductor and the surrounding medium.

A bit more

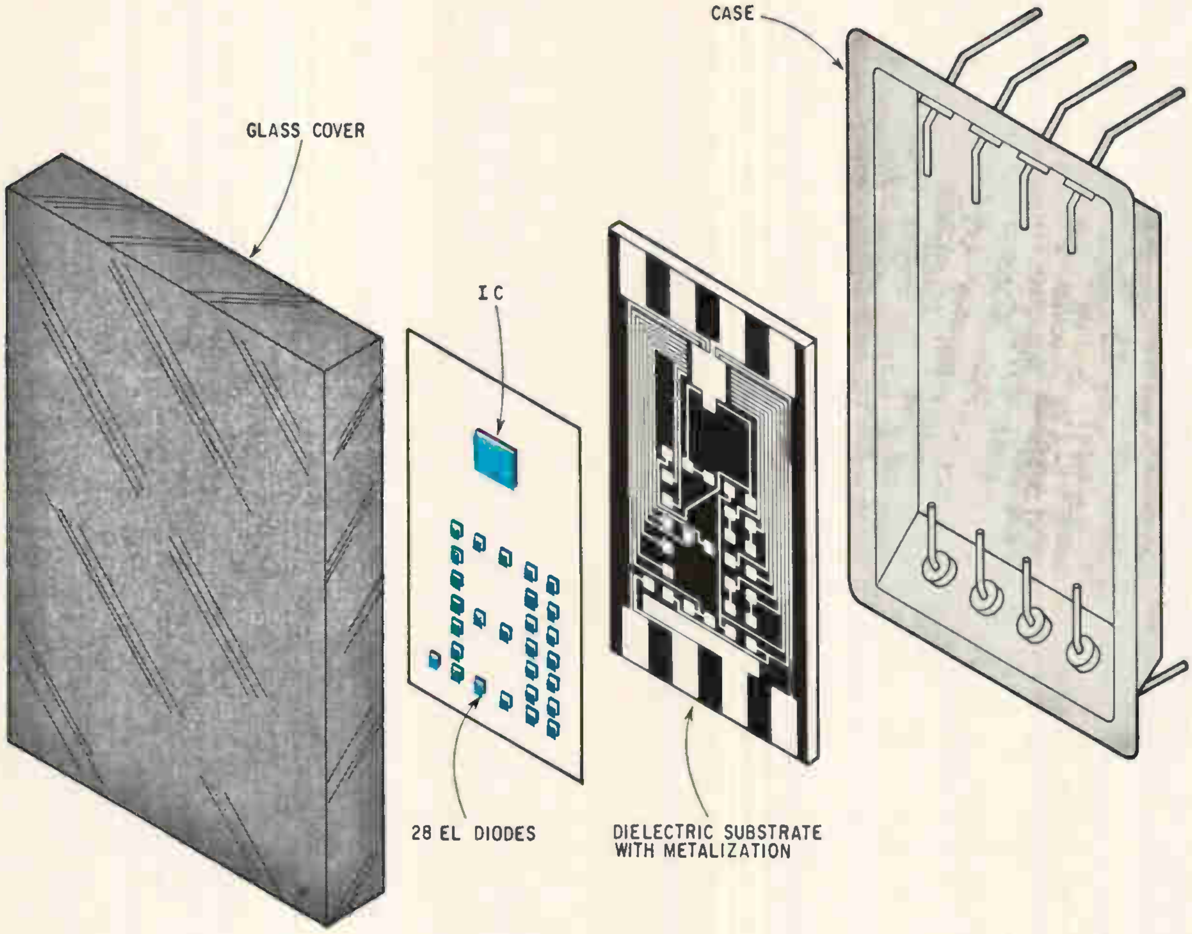
Although only four bits are needed to represent a decimal in machine language, or six bits to represent an alphanumeric symbol, humans need a greater quantity of bits to recognize the number. Because of this, the formats of electronic numeric planar displays produced by various manufacturers range from seven segments in a figure-eight arrangement to the more general matrix with 100 picture elements. This redundancy isn't wasted however. It makes the display easy to read and reduces the chance of error.

The electroluminescent diodes in H-P's system number 27, enough to make the display easily readable and to preclude ambiguity if one or two don't light. Further, they're compatible with the conventional five-by-seven matrix used in the ASCII



Anatomy of a diode. Each light emitter is a mesa diode. The light-emitting region (shaded) is a sheet approximately 0.5 to 1 micron thick and predominantly on the p side of the junction.

From bits to photons



Assembly. The diodes and IC are mounted on a substrate containing metalized conductive paths, placed in a metal case, and hermetically sealed with a glass cover.

H-P's new solid state display consists of 28 red-light-emitting, gallium-arsenide-phosphide diode chips and a monolithic silicon integrated circuit. These are assembled on a dielectric substrate in a flat package with a glass top. A metal-film pattern connects the IC to the diodes, and as many as three diode-IC modules have been incorporated in a single package, as shown on the cover.

The 28 diodes are arrayed in a five-by-seven matrix (not all positions are occupied by diodes). The characters 0 through 9 are generated by combinations of 27 diodes, while the remaining diode is used to indicate the decimal point. The cathode side of each diode is bonded to the substrate metalization. Light exits from the opposite side, which has a common anode connection. The metallic thin-film anode on the chip is digitated to assure uniform current density across the junction, and it's small in area to hold the loss of brightness to less than 25%.

The IC translates a machine-language input to drive the appropriate diode elements in the display. The input signals must be in standard 8-4-2-1 binary-coded-decimal logic at transistor-transistor-logic voltage levels (0 to 0.8 volt for binary 1, 2 to 5 volts for binary 0). A fifth input signal drives the decimal-point diode directly.

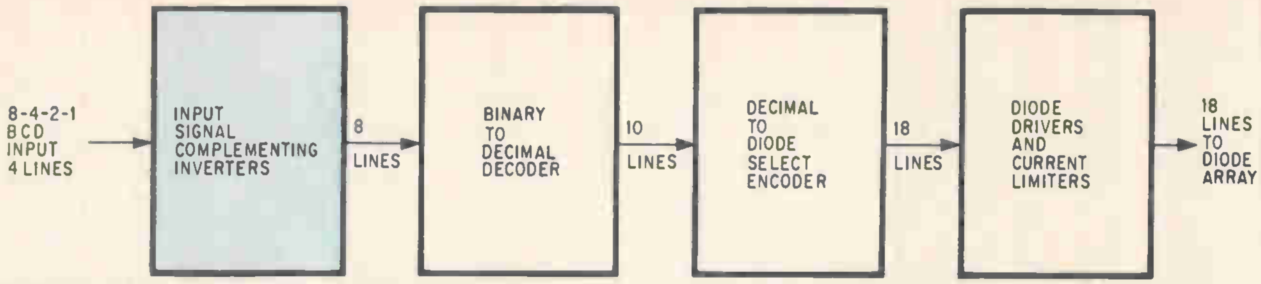
There are two power-supply connections—5 volts for the IC and a variable voltage to adjust the diodes' light output. Typical power dissipation is 150 milliwatts for the logic and 500 mw for the combined IC driver stages and electroluminescent diodes at the 50-foot-lambert output level.

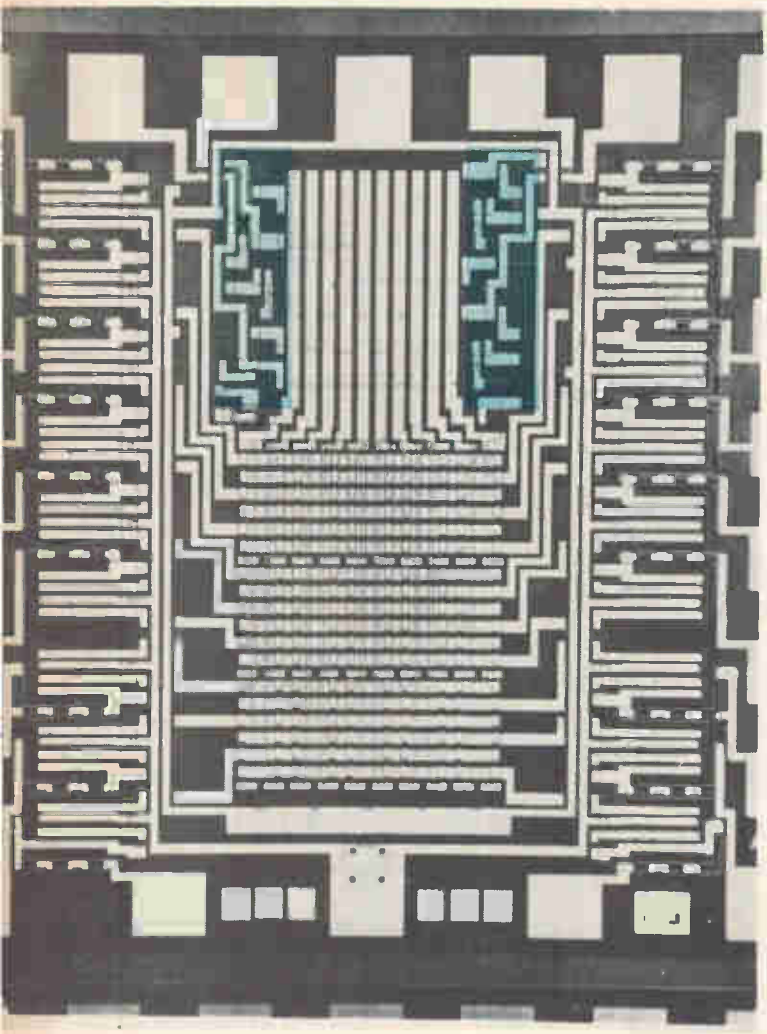
The luminous emittance of the diodes is adjustable between 5 and 50 foot-lamberts. Hue is of high purity and has a dominant wavelength to which the human eye is rather sensitive. The diodes have a response time of less than 1 microsecond.

The display can be viewed from an angle as much as 60° off the axis horizontally and from an even wider angle above and below. The numerical character is a quarter-inch in height but is subject to an interesting and unexplained effect: it appears bigger than it is. Most people estimate the height at ⅝ inch and no has guessed under 0.4 inch.

The package for a one-digit display is slightly more than 1 inch high, and is 0.57 inch wide and 0.162 inch thick. Density is 275 characters per square foot.

Hewlett-Packard estimates the initial cost of a one-digit display module at $50.





Two steps. The IC generates the appropriate display pattern by first decoding the BCD input to decimal signals, and then putting them into an 18-line diode-select code. The tinted regions on the IC indicate the complementing inverters. Between them is the binary-to-decimal decoder, and below this is the decimal-to-diode-select encoder. Diode drivers are on both sides.

alphanumeric code. The 27 diodes don't operate independently. Rather, they are grouped in 18 independently switchable sets to minimize the complexity of the decoder-driver circuit.

The IC chip performs four basic functions:

▪ Generating the complements of the four binary-coded-decimal inputs by sending the signals through inverter stages for a total of eight signals for the decoding stage.

▪ Decoding the original and complemented BCD signals into 10 mutually exclusive line signals. The output from this stage is a decimal version of the input to the module.

▪ Encoding the 10 signals into 18 output signals for diode groups to form the numerals 0 through 9.

▪ Amplifying the 18 output signals by means of current-limited drivers matched to the light-emitting diodes.

The use of a two-step translation—binary to decimal, then decimal to the eighteen-set code—may appear unnecessary at first glance. Why not translate directly from BCD to the diode-select code? Well, the two-step process does require more active elements on the chip, but it was adopted because it allows easy changes in machine code and symbol font; all that's necessary for such a change is to alter the interconnection pattern between the logic elements.

Each of the four input complementing inverters consists of an npn emitter follower coupled by way of a resistor network to the base of an inverting transistor with a grounded emitter. For the worst case, the input threshold is between 0.8 and 2 volts, a range compatible with transistor-transistor logic.

The binary-to-decimal decoder consists of 10 four-input common-collector pnp transistor AND gates. The eight input lines are low resistivity n+ diffused stripes insulated from the 10 decoder aluminum lines by a layer of silicon dioxide. Since only the base current of the pnp transistors flows through these diffused stripes, the voltage drop is at a minimum.

The decimal-to-driver-select encoder consists of 18 common-collector npn emitter-follower OR gates fabricated within a single isolation area. To minimize the voltage drop in the encoder base regions, n^+ stripes were diffused into (and shorted to) the base in several places. The decode and encode logic matrices are fabricated by selective etching through the silicon dioxide; unused transistors are left floating and don't participate in switching.

The 18 drivers are made up of resistor-divider input networks followed by common emitter npn inverters that drive pnp emitter followers (whose currents are routed through the substrate) in series with output-current-limiting resistors. The resistor values are so closely matched in an IC that the brightness of the individual diodes is also matched closely.

Handy. Small size of solid state unit can be a convenience, as in this experimental probe display, which puts measurement data at the operator's fingertips.

A significant departure in the IC's from industry practice is the use of a low-resistivity (p^+) substrate with a p-type epitaxial layer. This substrate can conduct the sum of the output currents and minimizes the current density in the aluminum metalization.

Glowing future

An early extension of the present technology will be the addition of alphabetic characters. Hewlett-Packard plans to introduce upper- and lower-case letter symbols—both Greek and English—to identify measuring units.

One of the most promising areas of development is that in which small display size is a distinct advantage. Solid state displays could be incorporated, for example, in such manual instruments as probes and micrometers, as shown above. Head-mounted displays are another good possibility; they could keep data within the field of vision regardless of where the observer is.

H-P expects a density of 50,000 to 250,000 characters per square foot in these future displays. With cost reductions limited only by the size of the market, and size reductions limited only by the human side of the man-machine interface, a glowing future seems in store for these displays.

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Active filters: part 3
Negative-impedance converters

These two-port devices are being used to produce transfer functions without inductors, and their strong advantages over gyrators include greater simplicity of network design and use

By Louis de Pian and Arnold Meltzer
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Given a transfer function, an engineer can apply classical synthesis techniques and develop a passive RLC combination that produces this equation. But ask him to achieve the same result without inductors, and he will have to rely on active-circuit devices. Two such devices are the gyrator [Electronics, June 10, p. 114] and the negative-impedance converter, or NIC.

An NIC is a two-port device operating on the principle that any impedance placed across one of its ports will appear as the negative of that impedance at the other port. For example, if the load were a resistor it would behave as a negative resistor at the input port.

This means that resistor-capacitor circuits coupled to NIC's can be built in integrated-circuit form and achieve Q's at low frequencies far greater than those possible with inductors.

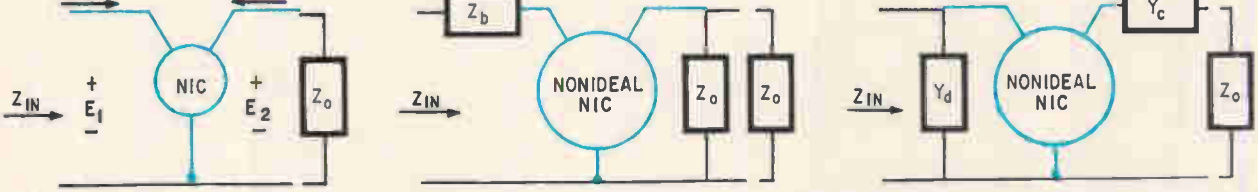
The NIC has several advantages over the gyrator. It can be used to design filters with a smaller spread of capacitance values and fewer network elements. There are more design procedures for NIC's. With simple networks, the poles and zeros can be shifted easily by adjusting the circuit components without any interaction. Thus, an exact transfer function is obtained simply by trimming the individual components. Finally, an NIC can be built with fewer transistors and with a wider bandwidth than is possible for a gyrator.

Understanding NIC properties

Because an NIC's input impedance is the negative of an impedance placed at its output terminals, its transfer matrix can be defined as

$$\begin{bmatrix} E_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} E_2 \\ -I_2 \end{bmatrix} \quad (1)$$

If a load Z_o is placed at the output, the input impedance is



Negative-impedance converters. By definition Z_{in} equals $-Z_o$ for an ideal NIC (left). When the negative-impedance converter is nonideal (center and right) impedances and admittances can be added to adjust the over-all behavior of the NIC, causing it to react as an ideal device. The added impedances Z_a and Z_b, and added admittances Y_c and Y_d cause the matrix element on the main diagonal of the G and H matrix to be zero.

$$Z_{in} = \frac{AZ_o + B}{CZ_o + D} \quad (2)$$

For Z_{in} to be equal to $-kZ_o$, B and C must be zero. Thus,

$$A = -Dk \quad (3)$$

This result is achieved with either of the following transfer matrices

$$[F] = \begin{bmatrix} -k & 0 \\ 0 & 1 \end{bmatrix} \quad (4a)$$

$$[F] = \begin{bmatrix} 1 & 0 \\ 0 & -1/k \end{bmatrix} \quad (4b)$$

Both of these yield

$$Z_{in} = -kZ_o \quad (5)$$

If an impedance transformation is realized from port 1 to port 2, the reciprocal impedance transformation is achieved from port 2 to port 1. Thus the designer can proceed once he is given the transfer impedance Z_{12} or Z_{21}.

For an ideal NIC, in which the input impedance is exactly the negative of the load impedance, k should be unity. Because equation 4a yields $E_2 = -(E_1)\ 1/k$, and $I_2 = -I_1$, the NIC for this system is said to invert the voltage while leaving the normal direction of current unchanged.

Alternate case

Conversely, because equation 4b produces $E_2 = E_1$, and $I_2 = k\ I_1$, this NIC inverts current; it reverses the current flow at one of the ports with respect to the flow that would normally be encountered in a purely passive device. For both types of NIC's, k is a positive constant that is called the gain of the NIC network.

In terms of the H and G matrix notations, the NIC can be expressed as

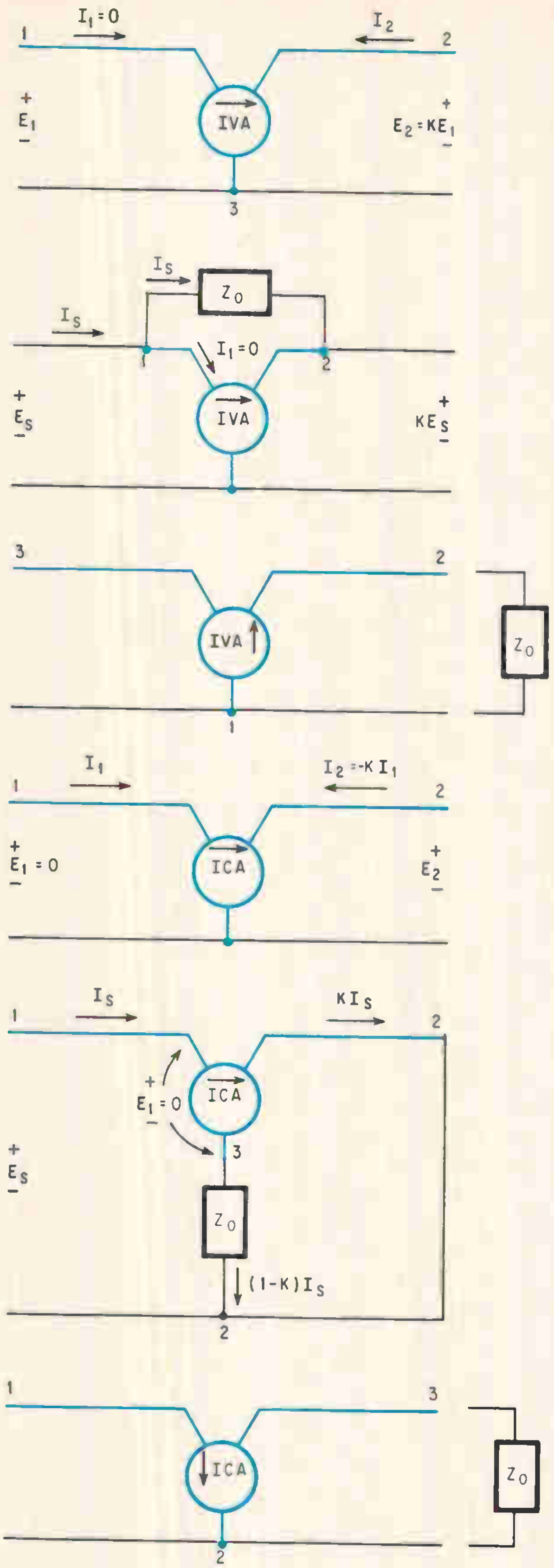
$$[H] = \begin{bmatrix} 0 & -k \\ -1 & 0 \end{bmatrix} \text{voltage inversion} \quad (6a)$$

$$[H] = \begin{bmatrix} 0 & 1 \\ k & 0 \end{bmatrix} \text{current inversion} \quad (6b)$$

$$[G] = \begin{bmatrix} 0 & -1 \\ -1/k & 0 \end{bmatrix} \text{voltage inversion} \quad (7a)$$

$$[G] = \begin{bmatrix} 0 & 1/k \\ 1 & 0 \end{bmatrix} \text{current inversion} \quad (7b)$$

The zero matrix element in equations 4, 6, and 7 is sometimes difficult to achieve. However, this requirement can be relaxed by adding input and output impedances, Z_b and Z_a, respectively, to an NIC that isn't ideal. Such a device will have G_{11}



Rotation helps. In the second and fourth drawings the load appears between terminals of an ideal voltage and current amplifier, IVA and ICA, respectively, without a common ground. Rotating the device as in the third and last drawings provides a common ground and doesn't change the NIC effect.

$\neq$ O, $G_{22} \neq$ O, and $G_{12}G_{21} \neq 1/k$. However, properly choosing Z_a and Z_b, can produce the effect of an ideal NIC. To have $Z_{in} = -k\,Z_O$ it is sufficient to have

$$Z_a = \frac{a}{G_{11}} \quad (8)$$

$$Z_b = b\,G_{22} \quad (9)$$

$$ab = 1 \quad (10)$$

$$G_{12}\,G_{21} = a + G_{11}\,G_{22} \quad (11)$$

$$a = \frac{1}{2k} + \sqrt{G_{11}\,G_{22} + \frac{1}{4k^2}} \quad (12)$$

If G_{11} = O, G_{22} = O then $a = 1/b = 1/k$, $Z_a = \infty$, Z_b = O, and $G_{12}\,G_{21} = 1/k$, thus satisfying equation 7.

Another possibility can be described with admittances. Here it is sufficient to set

$$Y_c = \frac{c}{H_{11}} \quad (13)$$

$$Y_d = d\,H_{22} \quad (14)$$

$$cd = 1 \quad (15)$$

$$H_{12}\,H_{21} = c + H_{11}\,H_{22} \quad (16)$$

$$c = \frac{1}{2k} + \sqrt{H_{11}\,H_{22} + \frac{1}{4k^2}} \quad (17)$$

The simplicity with which an NIC can be used to compensate for its own deviations from the ideal adds even more to its attractiveness.

Some simple configurations

The properties of voltage and current NIC's can be illustrated with an ideal voltage amplifier characterized by an infinite input impedance—making the input current I_1 equal to O—and a constant voltage gain K independent of the output current I_2. Its transfer matrix is

$$[F] = \begin{bmatrix} \frac{1}{K} & 0 \\ 0 & 0 \end{bmatrix} \quad (18)$$

If an impedance Z_o is placed between the output and input terminals, the input impedance will be

$$Z_{in} = \frac{E_s}{I_s} = \frac{E_s}{\frac{E_s\,(1-K)}{Z_o}} = \frac{Z_o}{1-K} \quad (19)$$

This indeed represents a voltage NIC with

$$k = \frac{1}{K-1} \quad (20)$$

If this ideal voltage amplifier is rotated clockwise by 90°, its new transfer matrix will be

$$[F] = \begin{bmatrix} \frac{-1}{(K-1)} & 0 \\ 0 & 1 \end{bmatrix} \quad (21)$$

which again characterizes a voltage NIC.

A similar result can be obtained with an ideal current amplifier whose characteristics are a zero input impedance—making E_1 = O—and a constant current gain K independent of E_2. Its transfer matrix is

$$[F] = \begin{bmatrix} 0 & 0 \\ 0 & \frac{1}{K} \end{bmatrix} \quad (22)$$

If an impedance Z_o is inserted in one leg, the input impedance will be

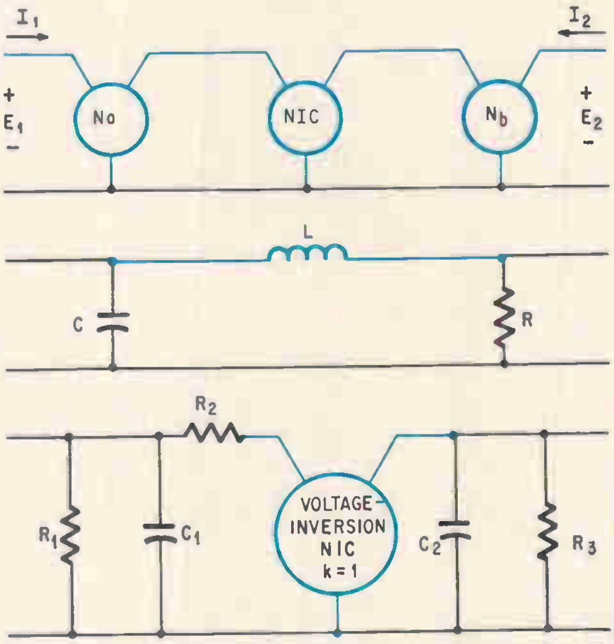
$$Z_{in} = \frac{E_s}{I_s} = \frac{(1-K)\,I_s\,Z_o}{I_s} = (1-K)\,Z_o \quad (23)$$

This is a current NIC with

$$k = K - 1 \quad (24)$$

Moreover, if the ideal current amplifier is rotated clockwise by 90° its new transfer is

$$[F] = \begin{bmatrix} 1 & 0 \\ 0 & \frac{-1}{(K-1)} \end{bmatrix} \quad (25)$$



Cascade. To design a low-pass filter using the Linvill technique, the engineer assumes an ideal NIC is flanked by an RC network N_a and N_b. Such a configuration, detailed in the bottom drawing, has the same effect as the RLC network, center, but without requiring an inductor. Cutoff frequency is approximately 20 kilohertz with the values in the text.

which again characterizes a current NIC.

Designing inductorless filters

In passive-network synthesis, all transfer functions are produced with specific combinations of resistors, capacitors, and inductors. In active-network synthesis, an active element replaces the inductor, and the transfer function is produced by a combination of R's, C's, and active elements, such as the NIC. Several engineers have developed design techniques for synthesizing a particular transfer function using NIC's. Three such techniques were developed by John G. Linvill, executive head of the electrical engineering department at Stanford University, T. Yanagisawa, and Jack M. Sipress supervisor at the Bell Telephone Laboratories. Features of these techniques are compared in the table on page 90. These techniques use only one NIC in combination with several RC networks.

In the Linvill technique, the engineer produces the transfer function with an RC network, N_a, in cascade with an NIC and another RC network, N_b. Either a voltage or current NIC can be used. With the voltage type, the over-all open-circuit transfer tionship is

$$Z_{21} = \left.\frac{E_2}{I_1}\right|_{I_2=0} = \frac{Z_{21a}\, Z_{21b}}{Z_{22a} - kZ_{11b}} \qquad (26)$$

where the subscripts a and b refer to networks N_a and N_b, and k is defined in equation 4 for the NIC. With a current-type NIC, the corresponding relationship is

$$Z_{21} = \frac{k\, Z_{21a}\, Z_{21b}}{k\, Z_{11b} - Z_{22a}} \qquad (27)$$

Either equation 26 or 27 may be used to design the filter network; the procedure is the same. As an example, consider the transfer impedance, Z_{21}, for a low-pass network:

$$Z_{21}(s) = \frac{K_o}{s^2 + K_1 s + K_2} = \frac{Z_{21a}\, Z_{21b}}{Z_{22a} - k\, Z_{11b}} = \frac{P/q}{Q/q}$$

where $P = K_o$, $Q = s^2 + K_1 s + K_2$, and the values of the K coefficients are $K_0 = 10^{12}$ ohms-sec^{-2}, $K_1 = 10^5$ sec^{-1} and $K_2 = 10^{10}$ sec^{-2}.

If this transfer function were to be produced with passive elements, the design would be an LC network loaded with a resistor, R, having the following parameters: $C = K_1/K_o$, $L = K_o/K_1 K_2$, $R = K_o/K_2$. For the numerical values given, C = 0.1 μf, L = 1 mh, and R = 100 ohms. With the Linvill technique the effect of the inductor is replaced as follows:

Step 1. Divide both numerator and denominator with an arbitrary polynomial q—as shown for Z_{21}—whose roots must be simple, real and negative, and whose order must equal that of P(s) and Q(s), whichever is higher.

$$q = M\,(s + \alpha_1)\,(s + \alpha_2)$$

where M, α_1 α_2 are arbitrary.

Step 2. Compare the result obtained in step 1 with equation 27 and set

$$Z_{21a}\, Z_{21b} = \frac{K_o}{M\,(s + \alpha_1)\,(s + \alpha_2)} = \frac{P}{q}$$

and

$$Z_{22a} - k\, Z_{11b} = \frac{s^2 + K_1 s + K_2}{M\,(s + \alpha_1)\,(s + \alpha_2)} = \frac{Q}{q}$$

Step 3. Expand Q/q into partial fractions. Thus,

$$\frac{s^2 + K_1 s + K_2}{M\,(s+\alpha_1)\,(s+\alpha_2)} = A_o + \frac{A_1}{s+\alpha_1} + \frac{A_2}{s+\alpha_2}$$

where

$$A_o = \frac{1}{M}$$

$$A_1 = \frac{1}{M}\,\frac{\alpha_1^2 - K_1\alpha_1 + K_2}{\alpha_2 - \alpha_1}$$

$$A_2 = -\frac{1}{M}\,\frac{\alpha_2^2 - K_1\alpha_2 + K_2}{\alpha_2 - \alpha_1}$$

Assume that the numerical values assigned to α_1 and α_2 make A_1 positive and A_2 negative. Assign the positive ones to Z_{22a} and the negative ones to $-kZ_{11b}$. Thus

$$Z_{22a} = A_o + \frac{A_1}{s + \alpha_1}$$

$$-k\, Z_{11b} = \frac{A_2}{s + \alpha_2}$$

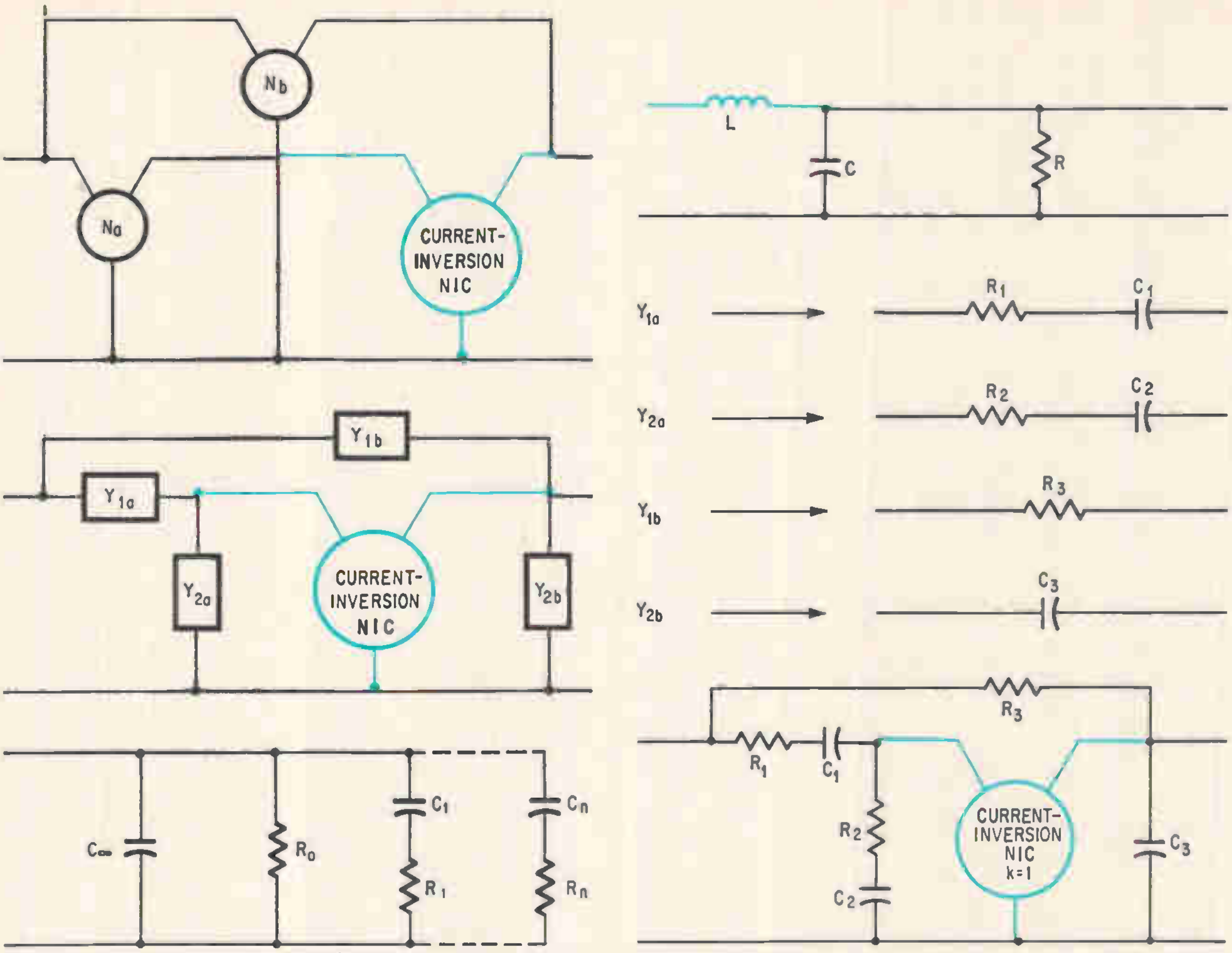
Step 4. Split P, which in this case is K_o, in a convenient manner to produce possible RC networks for N_a and N_b. Such a split gives

$$Z_{21a} = -K_o \frac{A_o}{A_2}\, \frac{1}{s + \alpha_1}, \quad Z_{21b} = K_o \frac{A_o}{A_1}\, \frac{1}{s + \alpha_2}$$

and

$$A_o = -\frac{A_1 A_2}{K_o}$$

Step 5. Having determined Z_{21a}, Z_{22a} for N_a and Z_{21b}, Z_{11b} for N_b, proceed with the conventional RC synthesis which will yield the network shown on



Bridging. A low-pass filter, designed by the Yanagisawa technique, has an RC network N_a cascaded to a current-inversion NIC and a bridged T, N_b. Networks N_a and N_b are replaced by admittances Y_{1a}, Y_{1b}, Y_{2a}, and Y_{2b}, which are achieved by RC combinations, bottom left and center right. Low-pass networks can be achieved with an RLC circuit but the inductor is undesirable since it can't be built in integrated-circuit form, has a low Q, and is bulky. Final design, bottom right, has a cutoff frequency of about 20 kilohertz.

page 84. For simplicity, the value of k for the NIC is set equal to unity. The element values are

$$R_1 = -\frac{K_o}{\alpha_1}\frac{A_o}{A_2}$$

$$R_2 = -K_o\frac{A_o}{A_1}\frac{A_o}{A_2} \qquad C_1 = -\frac{1}{K_o}\frac{A_2}{A_o}$$

$$R_3 = \frac{K_o}{\alpha_2}\frac{A_o}{A_1} \qquad C_2 = \frac{1}{K_o}\frac{A_1}{A_o}$$

For numerical simplicity assign $\alpha_1 = 10^5$ and $\alpha_2 = 1.1 \times 10^5$. This yields $A_1/A_0 = 10^6$ and $A_2/A_0 = -1.11 \times 10^6$, with

$$R_1 = \frac{10}{1.11}\text{ ohms} \qquad C_1 = 1.11\ \mu f$$

$$R_2 = \frac{1}{1.11}\text{ ohm} \qquad C_2 = 1\ \mu f$$

$$R_3 = \frac{10}{1.10}\text{ ohms} \qquad k = 1$$

The Yanagisawa technique

In Yanagisawa's method, the NIC is cascaded with an RC network; N_a, and the combination of N_a and NIC is parallel with an RC network N_b.

In this method, the product of two impedances isn't required, as it is in Linvill's technique (see equation 26). Moreover, Yanagisawa's technique is simpler because the resulting RC networks can be designed with one-ports rather than two-port networks. However, to apply this method the designer must use a current-inversion NIC.

The basic circuit is shown above at the top left, where both networks N_a and N_b consist of only RC elements. The over-all open-circuit voltage transfer function is

$$T = -\frac{Y_{21b} - k\,Y_{21a}}{Y_{22b} - k\,Y_{22a}}$$

If N_a and N_b are pi networks with the left shunt element missing, the over-all network takes the form shown in the drawing on page 86.

$$Y_{21a} = -Y_{1a}$$
$$Y_{22a} = Y_{1a} + Y_{2a}$$
$$Y_{21b} = -Y_{1b}$$
$$Y_{22b} = Y_{1b} + Y_{2b}$$

Now T can be written in the form

$$T = \frac{Y_{1b} - k\,Y_{1a}}{Y_{1b} - k\,Y_{1a} + Y_{2b} - k\,Y_{2a}} = \frac{P}{Q}$$

The Yanagisawa design procedure can be demonstrated with the transfer function for the following low-pass network.

$$T(s) = \frac{K_o}{s^2 + K_1 s + K_o}$$

where $P = K_o$, $Q = s^2 + K_1 s + K_o$, and the K values are $K_o = 10^{10}$ sec^{-2} and $K_1 = 10^5$ sec^{-1}. The classical passive synthesis can be achieved with an LC network loaded with R and having the following parameters

$L = R\,K_1/K_0$, and $C = (1/R)\,1/K_1$

with R arbitrary. This selection of values makes $R = 100$ ohms, $L = 1$ mh, and $C = 0.1\ \mu f$. The inductor is replaced as follows:

Step 1. Arbitrarily choose a polynomial q as outlined in the Linvill method, and divide numerator and denominator by q. Thus, $q = M\,(s + \alpha)$ where M and α are arbitrary.

Step. 2. Set

$$Y_{1b} - k\,Y_{1a} = \frac{K_o}{M\,(s + \alpha)}$$

$$Y_{2b} - k\,Y_{2a} = \frac{s^2 + K_1 s}{M\,(s + \alpha)}$$

Step 3. Expand P/q and (Q-P)/q into partial fractions. Thus,

$$\frac{K_o}{M\,(s + \alpha)} = A_o + \frac{A_1 s}{s + \alpha}$$

$$\frac{s^2 + K_1 s}{M\,(s + \alpha)} = B_\infty s + \frac{B_1 s}{s + \alpha}$$

where

$$A_o = \frac{K_o}{\alpha M}, \qquad A_1 = -\frac{K_o}{\alpha M}$$

$$B_\infty = \frac{1}{M}, \qquad B_1 = -\frac{\alpha - K_1}{M}$$

which gives (setting k-1 for simplicity)

$$Y_{1b} = A_o, \qquad Y_{1a} = -\frac{A_1 s}{s + \alpha}$$

$$Y_{2b} = B_\infty s, \qquad Y_{2a} = -\frac{B_1 s}{s + \alpha}$$

Step 4. The realizations of Y_{1b}, Y_{1a}, Y_{2b}, Y_{1b} are as shown on page 86, with the following parameters

$$R_1 = \frac{\alpha M}{K_o}$$

$$C_1 = \frac{K_o}{\alpha^2 M}$$

$$R_2 = \frac{M}{\alpha - K_1}$$

$$C_2 = \frac{1}{\alpha}\,\frac{\alpha - K_1}{M}$$

$$R_3 = \frac{\alpha M}{K_o}$$

$$C_3 = \frac{1}{M}$$

The over-all network is shown 1234567890. For numerical values, assume $\alpha = 1.1 \times 10^5$ sec^{-1} and $M = 10^6$ ohm-sec^{-1}.

This gives

$R_1 =$ 11 ohms	$C_1 = 1/1.21\ \mu f$
$R_2 =$ 100 ohms	$C_2 = 1/11\ \mu f$
$R_3 =$ 11 ohms	$C_3 = 1\ \mu f$

The Sipress technique

When two of a network's four short-circuit admittance parameters are specified—for example, Y_{11} and Y_{12} or Y_{12} and Y_{21}—the engineer can use the Sipress technique to design his network. If Y_{11} and Y_{12} are known, a voltage-inversion NIC must be used; if Y_{12} and Y_{21} are specified, a current-inversion NIC is used. For all cases, the basic circuit is the same, and the NIC is either of the voltage or current type, and N_a, N_b, N_c, and N_d are all RC networks.

To design an inductorless filter for this network, the y-admittance parameters of the over-all circuit must be known in terms of the individual RC components. These are as follows:

$$Y_{11} = Y_{11a} + Y_{11b} - \frac{(Y_{12a} + Y_{12b})(Y_{12b} - k\,Y_{12a})}{Y_{22b} + Y_{11d} - k\,Y_{22a} - k\,Y_{11c}}$$

$$Y_{22} = Y_{22c} + Y_{22d} - \frac{(Y_{12c} + Y_{12d})\,(Y_{12d} - k\,Y_{12c})}{Y_{22b} + Y_{11d} - k\,Y_{22a} - k\,Y_{11c}}$$

$$\underset{(V)}{Y_{12}} = -\frac{(Y_{12c} + Y_{12d})\,(Y_{12b} - k\,Y_{12a})}{Y_{22b} + Y_{11d} - k\,Y_{22a} - k\,Y_{11c}} = \underset{(I)}{Y_{21}}$$

$$\underset{(V)}{Y_{21}} = -\frac{(Y_{12a} + Y_{12b})\,(Y_{12d} - k\,Y_{12c})}{Y_{22b} + Y_{11d} - k\,Y_{22a} - k\,Y_{11c}} = \underset{(I)}{Y_{12}}$$

The left-hand side of Y_{12} and Y_{21} applies for voltage-inversion NIC's and the right-hand side for current types indicate by V and I

When Y_{21} is specified, the basic circuit can be simplified in the form shown at center right. This gives

$$Y_{11c} = -Y_{12c} = Y_{22c} = Y_c$$
$$Y_{11d} = -Y_{12d} = Y_{22d} = Y_d$$

and Y_{11} and Y_{21} are:

$$Y_{11} = Y_{11a}+Y_{11b}-\frac{(Y_{12a}+Y_{12b})(Y_{12b}-kY_{12a})}{Y_{22b}+Y_d-k\,Y_{22a}-k\,Y_c}$$

$$Y_{21} = -\frac{(Y_{12a}+Y_{12b})\,(k\,Y_c - Y_d)}{Y_{22b}+Y_d-k\,Y_{22a}-k\,Y_c}$$

A further modification of the circuit appears at bottom right. Here networks N_a and N_b are split into N'_a and N'_b, with Y_a and Y_b at their output terminals. This means

$$Y_{22a} = Y_{22a}' + Y_a$$
$$Y_{22b} = Y_{22b}' + Y_b$$

The design procedure is as follows, given:

$$Y_{11} = \frac{K_1}{s} = \frac{P_1}{Q}$$

$$Y_{21} = \frac{K_1}{\omega_o}\,\frac{(s-\omega_o)}{s} = \frac{P_2}{Q}$$

Find the network. Here, Y_{11} and Y_{21} have the same denominator polynomial, Q. The denominators of the given Y_{11} and Y_{21} can be made the same, if necessary, by multiplying with suitable surplus factors; for example, if $Y_{11} = P_1'/Q'$ and $Y_{21} = P_2''/Q''$, write

$$Y_{11} = P_1'\,F_1/Q'\,F_1, \quad Y_{21} = P_2''\,F_2/Q''\,F_2$$

such that

$$P_1 = P_1'\,F_1, \quad P_2 = P_2''\,F_2, \quad Q = Q'\,F_1 = Q'\,F_2$$

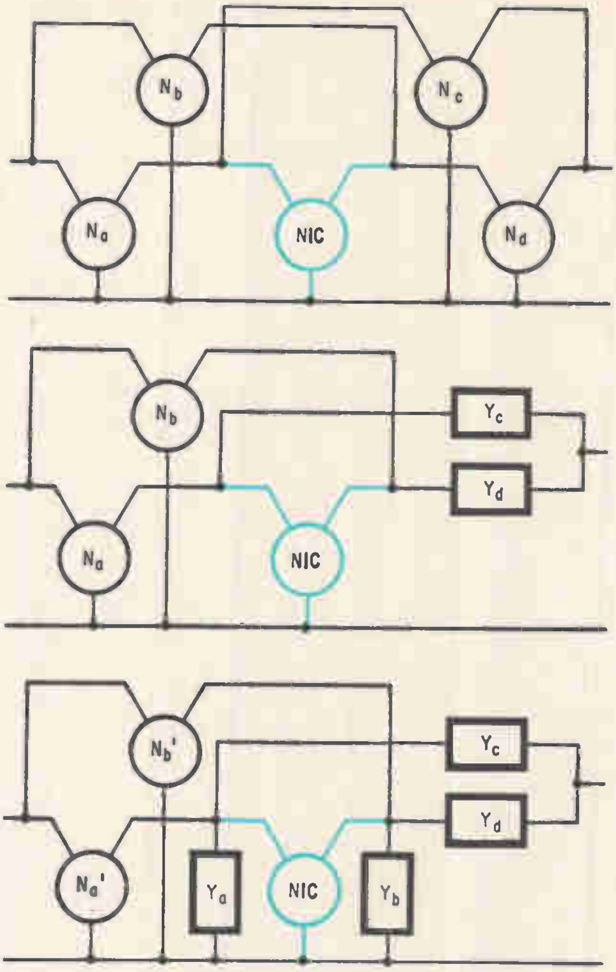
To simplify the calculation, let $K_o = K_1/\omega_o$ and $s = \omega_o$, which yields $Y_{11} = K_o/p$, $Y_{21} = K_o(p-1)/p$. This means that if the admittance of a capacitive element is found to be $Y = Kp = K_s/\omega_o$, the value of the capacitance is K/ω_o. The dimensionless variable p is used rather than s.

By inspection:

$$P_1 = K_o$$
$$P_2 = K_o\,(p-1)$$
$$Q = p$$

Step 1. Choose an RC admittance

$$Y_{RC}(s) = N_1\,\frac{r(s)}{q(s)}$$



Combining. In the Sipress technique, a basic Linvill configuration is combined with two bridged-T networks, N_b and N_c. Networks N_b and N_c are RC admittances Y_c and Y_d. Networks N_a and N_b are partially represented by RC admittances Y_a and Y_b and RC networks N_a' and N_b'.

The only restrictions here are that the order m of Y_{RC} must be equal to or larger than the degree of P_1, P_2, or Q, whichever is larger, and that $r(0) \neq 0$. N_1 is a constant. Thus,

$$m = 1$$
$$r(p) = p + \beta_1$$
$$q(p) = p + \beta_2$$

If $\beta_1 < \beta_2$ then r/q can be produced by an RC admittance. Let $\beta_1 = 1$, $\beta_2 = 4$ so that

$$r(p) = p + 1$$
$$q(p) = p + 4$$

Step 2. Choose two polynomials U(s) and V(s) such that U(s) has a degree m

$$U(s) = M_o\,(s+\alpha_1)\,(s+\alpha_2)\ldots(s+\alpha_m)$$

where $\alpha_1, \alpha_2, \ldots, \alpha_m$ are all distinct, real and positive, and M_o is any positive constant. The polynomial V(s) must be either the same degree as m or one less. Also choose a real constant M_1 such that

$$M_1N_1rQ - q\,P_1 = UV$$

Thus,

$$M_1N_1\,(p + 1)\,p - (p + 4)\,K_o = M_1N_1\,p^2 + (M_1N_1 - K_o)\,p - 4\,K_o$$

Choose $M_1N_1 = K_o$, giving

$$M_1 = \frac{K_o}{N_1}$$

so that

$$M_1N_1rQ - pP_1 = K_o\,(p + 2)\,(p - 2)$$

and therefore

$$U = K_o\,(p + 2)$$
$$V = (p - 2)$$

Step 3. Let

$$Y_{11a} + Y_{11b} = M_1\,Y_{RC}$$

$$= M_1\,N_1\,\frac{r}{q} = \frac{K_o\,(P + 1)}{(p + 4)}$$

Step 4. Separate Y_{11a} and Y_{11b} as follows:

$$Y_{11a} = M_a\,N_{1a}\,\frac{r_a}{q}$$

$$Y_{11b} = M_b\,N_{1b}\,\frac{r_b}{q}$$

The separation must be such that Y_{11a} and Y_{11b} are RC admittances and

$$M_a\,N_{1a}\,r_a + M_b\,N_{1b}\,r_b = M_1\,N_1\,r$$

$$M_aN_{1a}r_a + M_bN_{1b}r_b = K_o\,(p + 1)$$

$$r_a = p \qquad r_b = (p + \gamma_1)$$

Thus,

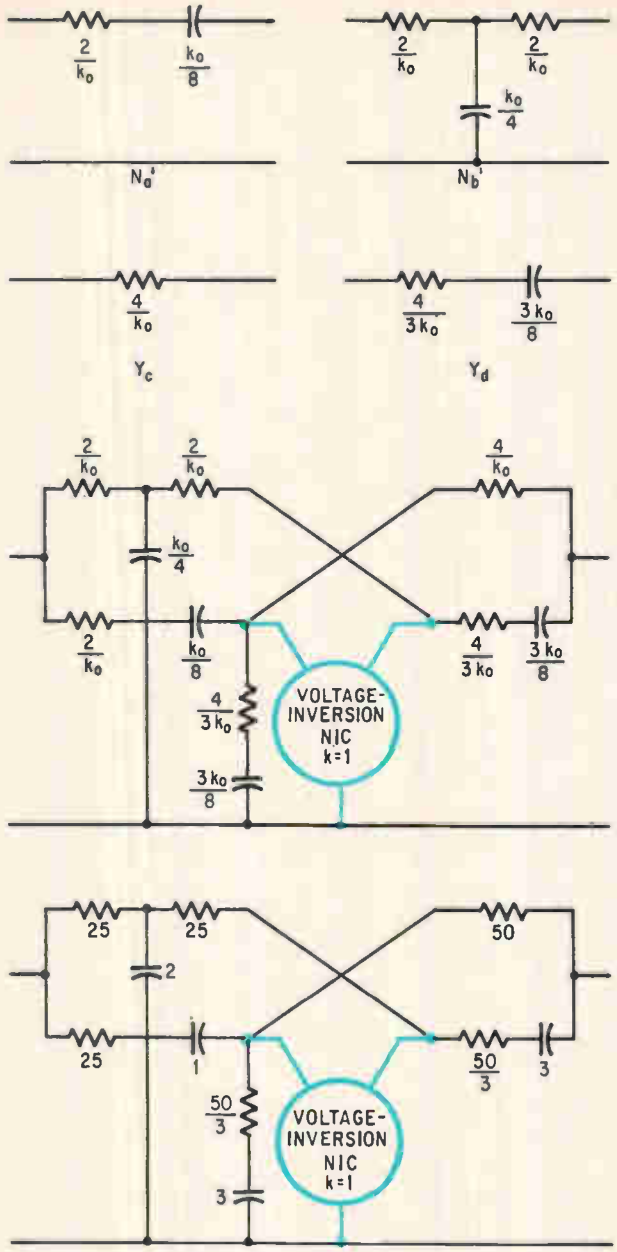
$$\gamma_1 > \beta_1, \quad \gamma_1 < \beta_2. \quad \text{Let } \gamma_1 = 2, \quad \text{so that}$$

$$r_a = p \qquad r_b = (p + 2)$$

and

$$M_aN_{1a}p + M_bN_{1b}\,(p + 2) = K_o\,(p + 1)$$

or, equating equal powers of p,



High-pass network. Two-port parameters for a high-pass, short-circuit current gain, $I_2/I_1 = Y_{21}/Y_{11}$ are used to design this NIC network. Values in center drawing are given in terms of k_o, final numerical values appear in bottom drawing.

$$M_aN_{1a} = \frac{K_o}{2}$$

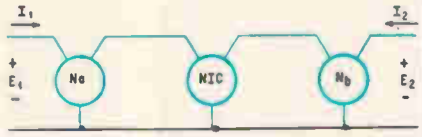
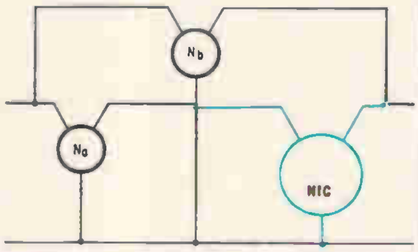
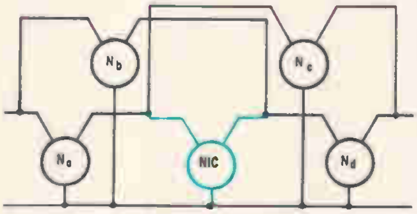
$$M_bN_{1b} = \frac{K_o}{2}$$

giving

$$Y_{11a} = \frac{K_o}{2}\,\frac{p}{(p + 4)}$$

$$Y_{11b} = \frac{K_o}{2}\,\frac{(p + 2)}{(p + 4)}$$

Comparing the three techniques

Basic circuit		Applicable NIC's	Applicable transfer function	Networks needed with NIC	Ease of Synthesis
Linvill		INIC or VNIC	Open-circuited impedance transfer functions	2 RC two-ports	Fair
Yanagisawa		INIC	Open-circuited voltage transfer functions	2 RC one-ports	Good
Sipress		INIC or VNIC	Resistance-terminated and open-circuited impedance-admittance, and voltage-transfer functions	2 RC two-ports and 2 RC one-ports	Poor

Linvill technique

Given: $Z_{21}(s) = \dfrac{P(s)}{Q(s)}$

Step 1. Divide Z_{21} by a polynomial q(s).

$$Z_{21} = \frac{Z_{21a}\, Z_{21b}}{Z_{22a} - kZ_{11b}} = \frac{P/q}{Q/q}$$

Step 2. Set $Z_{21a}\, Z_{21b} = P/q$

$$Z_{22a} - kZ_{11b} = Q/q$$

Step 3. Expand Q/q into partial fractions.

Step 4. Assign the positive terms to Z_{22} and the negative to $-kZ_{11b}$.

Step 5. Divide P into two factors, one for Z_{21a} and the other for Z_{21b}.

Step 6. Synthesize networks N_a and N_b.

Yanagisawa technique

Given: $T(s) = \dfrac{P(s)}{Q(s)}$

Step 1. Divide T(s) by a polynomial q(s).

$$T = \frac{Y_{1b} - kY_{1a}}{Y_{1b} - kY_{1a} + Y_{2b} - kY_{2a}} = \frac{P/q}{Q/q}$$

Step 2. Set $Y_{1b} - kY_{1a} = P/q$, and

$$Y_{2b} - kY_{2a} = (Q - P)/q$$

Step 3. Expand P/q and (Q-P)/q.

Step 4. Synthesize N_a and N_b

Sipress technique

Given: $Y_{11} = \dfrac{P_1}{Q}$, $\quad Y_{21} = \dfrac{P_2}{Q}$

Step 1. Choose an RC admittance

$$Y_{RC} = N_1 \frac{r(s)}{q(s)}$$

Step 2. Choose two polynomials U(s) and V(s)

$$U(s) = M_o\,(s + \alpha_1)\,(s + \alpha_2)\cdots(s + \alpha_m)$$

$$V(s) = (M_1N_1rQ - qP_1)/U$$

Step 3. Let $Y_{11a} + Y_{11b} = M_1Y_{RC} = M_1N_1r/q$

Step 4. Separate $Y_{11a} = M_aN_{1a}r_a/q$

$$Y_{11b} = M_bN_{1b}r_b/q;\ M_aN_{1a}r_a + M_bN_{1b}r_b = M_1N_1r$$

Step 5. Define $U_a = \dfrac{M_2U + kV}{1 + k}$

$$U_b = \frac{kM_2U - V}{1 + k};\ \ Y_{12a} = M_3U_a/q;\ \ Y_{12b} = -M_3U_b/q$$

Step 6. Form $Y_d - kY_c = M_3kP_2/U$

Step 7. Expand Y_d-kY_c into partial fractions.

Step 8. Assign positive A's to Y_d and negative ones to $-kY_c$.

Step 9. Form

$$kY_a - Y_b = kM_3(M_2M_3Q/q + P_2/U) - kY_{22a}' + Y_{22b}'$$

Step 10. Synthesize the networks

Step 5. Define

$$U_a = \frac{M_2 U + k V}{(1 + k)}$$

$$U_b = k \frac{M_2 U - V}{(1 + k)}$$

and subsequently

$$Y_{12a} = -M_3 \frac{U_a}{q}$$

$$Y_{12b} = -M_3 \frac{U_b}{q}$$

The choice of the constants M_2 and M_3 is arbitrary. If M_2 is large enough, networks N_a and N_b can be designed with ladder networks. For simplicity, let $k = 1$; Thus,

$$U_a = \tfrac{1}{2} (M_2K_o + 1) p + (M_2K_o - 1)$$

$$U_b = \tfrac{1}{2} (M_2K_o - 1) p + (M_2K_o + 1)$$

and therefore,

$$Y_{12a} = -\frac{M_3}{2} \frac{(M_2K_o+1) p+2 (M_2K_o-1)}{(p + 4)}$$

$$Y_{12b} = -\frac{M_3}{2} \frac{(M_2K_o-1) p+2 (M_2K_o+1)}{(p + 4)}$$

Choose

$$M_2 = 1/K_o$$

so that

$$Y_{12a} = -M_3 \frac{p}{(p + 4)}$$

$$Y_{12b} = -M_3 \frac{2}{(p + 4)}$$

now

$$M_3 = \frac{K_o}{2}$$

Thus,

$$Y_{11a} = \frac{K_o}{2} \frac{p}{(p + 4)}, \qquad Y_{12a} = -\frac{K_o}{2} \frac{p}{(p + 4)}$$

$$Y_{11b} = \frac{K_o}{2} \frac{(p + 2)}{(p + 4)}, \qquad Y_{12b} = -K_o \frac{1}{(p + 4)}$$

Networks N_a' and N_b' can now be designed by conventional synthesis and $Y_{22}'_a$ and Y_{22b}' determined. The result is given in the top drawings on page 89. From these networks

$$Y_{22a}' = Y_{11a} = \frac{K_o}{2} \frac{p}{(p + 4)}$$

$$Y_{22b}' = Y_{11b} = \frac{K_o}{2} \frac{(p + 2)}{(p + 4)}$$

Step 6. Find $Y_d - Y_c$.

$$Y_d - Y_c = \frac{K_o}{2} \frac{(p - 1)}{(p + 2)} M_3 k \frac{P_2}{U}$$

Step 7. Expand $Y_d - Y_c$ into partial fractions, and assign the positive A'_s to Y_d and the negative A'_s to $-kY_c$. Y_c and Y_d are determined in this fashion. Thus,

$$Y_d - Y_c = \frac{K_o}{2} \frac{(p-1)}{(p+2)} = \frac{K_o}{2} \left(A_\infty p + A_o + \frac{A_1 p}{(p+2)} \right)$$

with

$$A_\infty = 0$$

$$A_o = -\frac{1}{2}$$

$$A_1 = \frac{3}{2}$$

so that

$$Y_c = \frac{K_o}{4}$$

$$Y_d = \frac{3K_o}{4} \frac{p}{(p + 2)}$$

Their realization is on page 89, center drawing.

Step 8. Find Y_a, Y_b, and Y_d.

$$kY_a - Y_b = kM_3\left(M_2M_3 \frac{Q}{q} + \frac{p_2}{U}\right) - kY_{22a}' + Y_{22b}'$$

which can now be expanded in a manner similar to that of step 7, with the positive terms assigned to kY_a and the negative to $-Y_b$. In this fashion the complete network can be designed in this way. Thus,

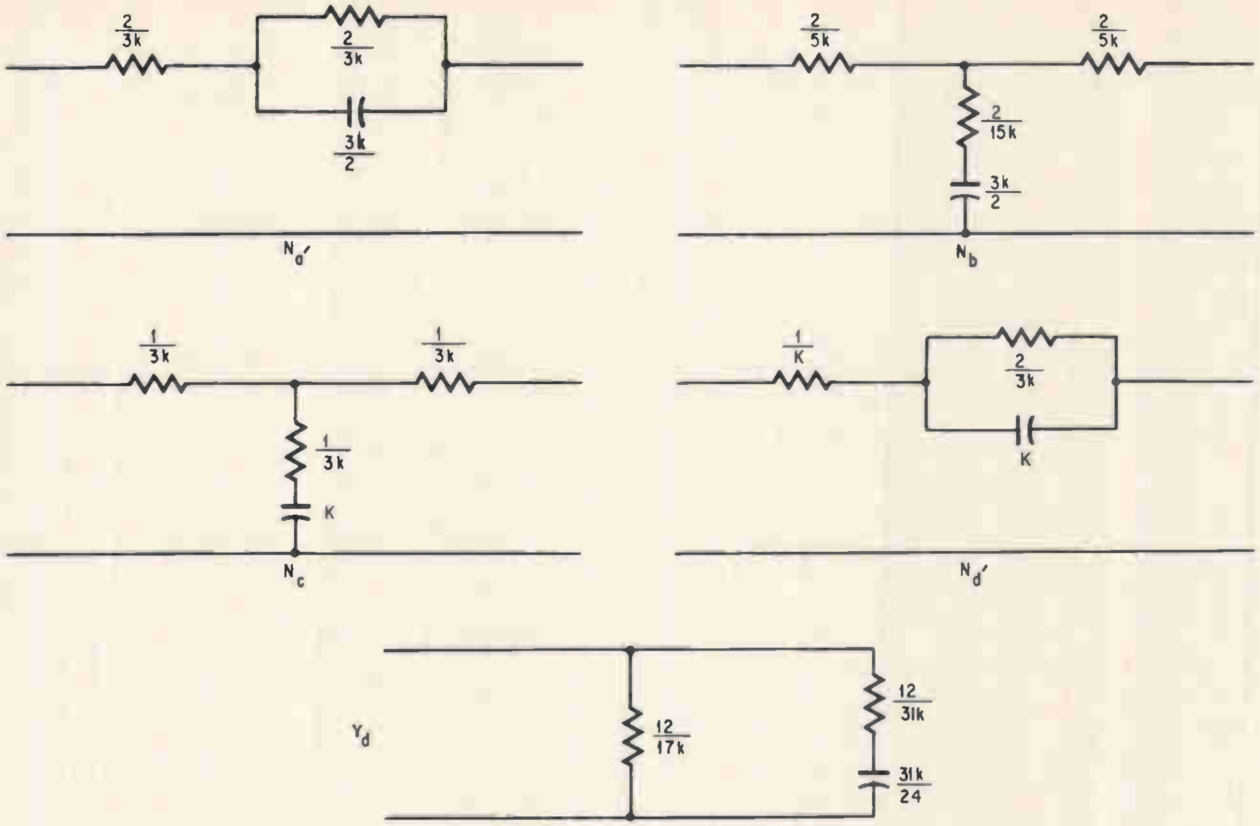
$$Y_a - Y_b = \frac{K_o}{4} + \frac{K_o}{2} \frac{(p-1)}{(p+2)} = \frac{3K_o}{4} \frac{p}{(p+2)}$$

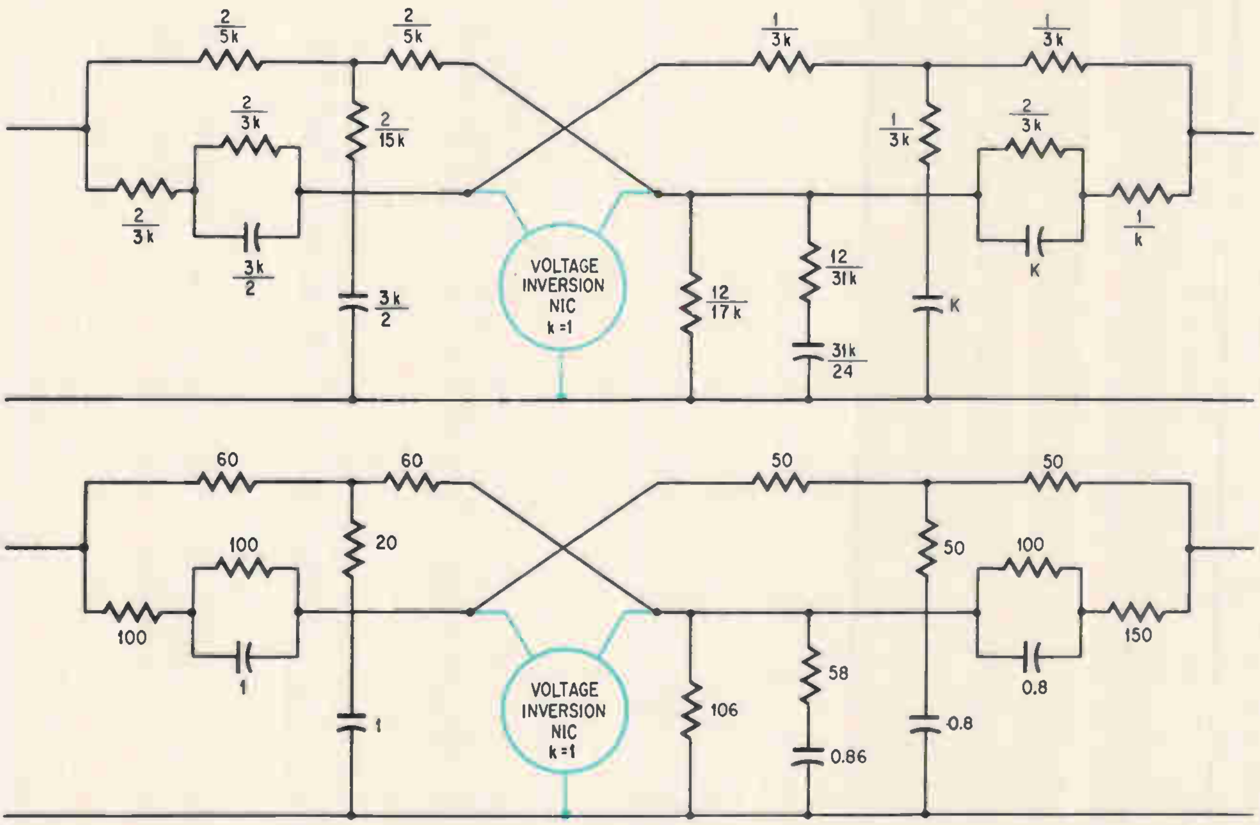
which gives

$$Y_a = \frac{3K_o}{4} \frac{p}{(p + 2)}$$

$$Y_b = 0$$

Thus, Y_a is the same as Y_d, and Y_b is an open circuit. The final network is on page 89, bottom





Alternate case. When parameters Y_{12} and Y_{21} are specified, the designer must use a voltage inversion NIC. Network is based on the example on the opposite page and all numerical values appear in bottom drawing.

drawing. Numerically $K_o = 8 \times 10^{-2}$ ohms^{-1} and $\omega_o = 10^4$ sec^{-1}.

When Y_{12} and Y_{21} are specified, a current NIC will be used and the circuit will be that shown on page 92.

To simplify the calculations, let $s = \omega_o p$ so that

$$Y_{12} = \frac{P_1}{Q} = \frac{k(s-w_o)}{(s+w_o)}$$

$$Y_{21} = \frac{P_2}{Q} + \frac{2kw_o}{(s+w_o)} \qquad (126)$$

Let m be the degree of P_1, P_2, or Q, whichever is greatest. If the parameters happen not to have the same denominator, surplus factors can be used as explained in the example for a voltage NIC.

By inspection,

$$Y_{12} = \frac{K(p-1)}{p+1}$$

$$Y_{21} = 2K\frac{1}{p+1}$$

Step 1. Choose a polynomial q (s) of degree m, with real, negative, distinct roots of the form

$$P_1 = K(p-1)$$

$$P_2 = 2K$$

$$Q = (p+1)$$

with M_1 a positive constant. Thus,

$$q = M_1(s+\alpha_1)(s+\alpha_2)\cdots(s+\alpha_m)$$

$$q = (p+2)$$

Step 2. Choose an arbitrary constant M_2 (if M_2 is large enough, the RC networks will be of the ladder type) and define the following polynomials:

$$U_a = \frac{M_2q+P_1}{(1+k)} \qquad U_b = \frac{kM_2q-P_1}{(1+k)}$$

$$U_c = \frac{M_2q+P_2}{(1+k)} \qquad U_d = \frac{kM_2q-P_2}{(1+k)}$$

For simplicity, let $k = 1$ and choose

$$M_2 = 2K$$

Thus,

$$U_a = \frac{3K}{2}(p+1) \qquad U_b = \frac{K}{2}(p+5)$$

$$U_c = K(p+3) \qquad U_d = K(p+1)$$

Step 3. Set

$$Y_{12a} = -\frac{U_a}{q} \qquad Y_{12b} = -\frac{U_b}{q}$$

$$Y_{12c} = -\frac{U_c}{q} \qquad Y_{12d} = -\frac{U_d}{q}$$

Thus,

$$Y_{12a} = -\frac{3K}{2}\frac{(p+1)}{(p+2)} \qquad Y_{12b} = -\frac{K}{2}\frac{(p+5)}{(p+2)}$$

$$Y_{12c} = -K\frac{(p+3)}{(p+2)} \qquad Y_{12d} = -K\frac{(p+1)}{(p+2)}$$

$$Y_{22b}+Y_{11d}-Y_{22a}-Y_{11c} = 2K\frac{(p+1)}{(p+2)}$$

Step 4. Networks N_a', N_b, N_c, N_d' are synthesized from the transfer admittances Y_{12}.

Step 5. The driving-point admittances are calculated from these networks as:

$$Y_{22a}' = \frac{3K}{2}\frac{(p+1)}{(p+2)} \qquad Y_{22b} = 2K\frac{(p+5/4)}{(p+2)}$$

$$Y_{11c} = 2K\frac{(p+2/3)}{(p+2)} \qquad Y_{11d}' = \frac{3K}{2}\frac{(p+1)}{(p+2)}$$

Step 6. From the networks N_a and N_d by adding the admittance Y_a to the output of N_a' and Y_d to the input of N_d'. This makes

$$Y_{22a} = Y_{22a}' + Y_a$$
$$Y_{11d} = Y_{11d}' + Y_d$$

$$Y_d - kY_a = M_2\frac{Q}{q} - Y_{22b} - Y_{11d}' + kY_{22a}' + kY_{11c}$$

yielding, $Y_d - Y_a = 4K\dfrac{(p+17/24)}{(p+2)}$

Step 7. Expand $Y_d - Y_a$ into partial fractions, so that

and assign the positive A's to Y_d and the negative A's to $-kY_a$. Y_d and Y_a can then be determined. For this example,

$$Y_d - Y_a = \frac{17K}{2} + \frac{31K}{2}\frac{p}{(p+2)}$$

which makes

$$Y_a = 0 \quad Y_d = \frac{17K}{2} + \frac{31K}{2}\frac{p}{(p+2)}$$

References

1. John G. Linvill, "A New RC Filter Employing Active Elements," Proc. National Electronics Conference, vol. 9, September 1953, pp 342-352, and "RC Active Filters", IRE, vol. 42, March 1954, pp 555-564.

2. T. Yanagisawa, "RC Active Networks Using Current-Inversion Type Negative Impedance Converters," IRE Trans. on circuit theory, vol. CT-4, No. 3, September 1967, pp. 140-144.

3. Jack M. Sipress, "Synthesis of Active RC Networks," IRE Trans. on circuit theory, vol. CT-8, September 1961, pp. 260-269.

Potential of phased-array radar spurs increasing R&D activity

More experimental models are due soon, but operational versions of these multifunction systems are still several years away; further in the future are arrays of solid state modules

By Alfred Rosenblatt
Avionics and space editor

"It's only a matter of time before antenna gimbals are placed in the Smithsonian," says Robert San Souci, president of the Emerson Electric Co.'s Electronics and Space division. His prediction of impending obsolescence for the bearings used to mechanically rotate radar antennas is based on the increasing pace of efforts—both military- and company-funded—to apply phased-array techniques to airborne radars.

About half a dozen phased-array systems will be turned on between now and early next year. And at least one is already being test-flown. However, problems involving weight and cost have yet to be overcome, and present estimates put the application of phased arrays at least four years away.

The prime advantage of this kind of antenna is its ability to perform a combination of tasks. With a multimode capability, a phased-array system could replace two or more conventional radars with dishes, and could handle such jobs as

- Air-to-air search, with tracking of multiple targets
- Air-to-air and air-to-ground weapons delivery
- Ground mapping
- Terrain following and avoidance
- Identification of aircraft and ground-beacon tracking

In a phased-array setup, the radar beam is shaped, positioned, and scanned electronically. Instead of a mechanically rotated dish, there's a flat array of electronically steerable radiating elements; the signal applied to each element is phase-shifted to shape the beam and position it in space. Scanning rates are fantastically high—up into the megahertz range.

Such electronic beam handling also lends itself to the development of radar systems capable of adapting to changes in mission conditions. It should be possible, for example, to vary the character of the signal that's transmitted—changing its pulse width, compression ratio, or power level—to match the threats faced by an aircraft. Such an array could also provide electronic countermeasures. Once energy from an enemy's radar was sensed, a high burst of jamming energy could be immediately pulsed in his direction.

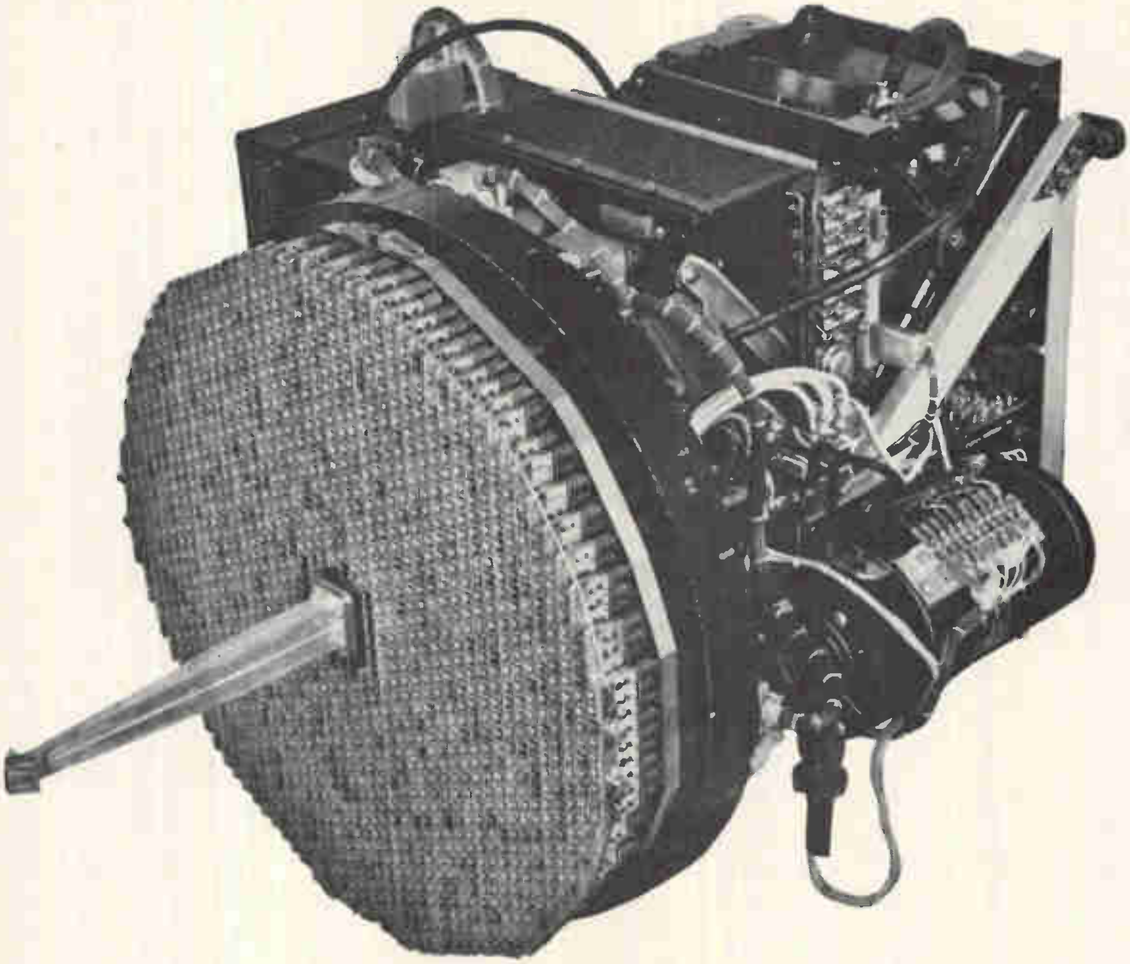
And as tiny, all-solid state microwave integrated circuits are perfected, conformal arrays may replace the planar arrangement. Such arrays would be fitted to the contours of an aircraft, becoming part of its aerodynamic structure.

The latest military aircraft being designed—the Navy's VFX and Air Force's FX fighters—will probably move into the inventory faster than new radars can be developed, but phased-array systems are being considered for later models of the planes.

Phased-array antennas continue to be studied for use in early-warning surveillance systems such as AWACS (Airborne Warning and Control System), and they're also said to figure in plans for the Air Force's Advanced Manned Strategic Aircraft (AMSA). Such radars could well help this plane penetrate hostile territory at low levels and defend itself with its on-board missiles.

Arrays could also be used for missile guidance. With its elements built conformally into the front of the weapon, such a system wouldn't have the heat problems that plague ordinary radomes at hypersonic speeds. And in space vehicles and satellites, the use of phased-array radars would avoid the motion reaction caused by moving dishes.

But the technology goes beyond radar applica-



Flying model. Demonstration Ku-band phased-array antenna built for the Navy by Maxson Electronics has 1,500 diode phase-shifting elements and is being test-flown aboard an A-6 Intruder.

tions. "With the progress being made in developing solid state array modules, we're able to tackle the total r-f systems problem aboard an aircraft, instead of treating it as a series of separate radar, navigation, or communications tasks," declares Dwaine E. Hunt, an engineer at Texas Instruments' equipment group.

In a paper to be presented at next week's Electronics and Aerospace Systems Convention (Eascon) in Washington, Hunt predicts the development within the next decade of all-solid state arrays that will not only perform several functions but will operate over several frequency bands. TI has experimented with a common-aperture receive array in which "we interspersed simple L- and S-band dipoles at half-wavelength intervals," Hunt says. "There was some shadowing effect when we went pretty far off boresight, but we proved we could get good electrical isolation between the bands while doing simultaneous—not time-shared—operations."

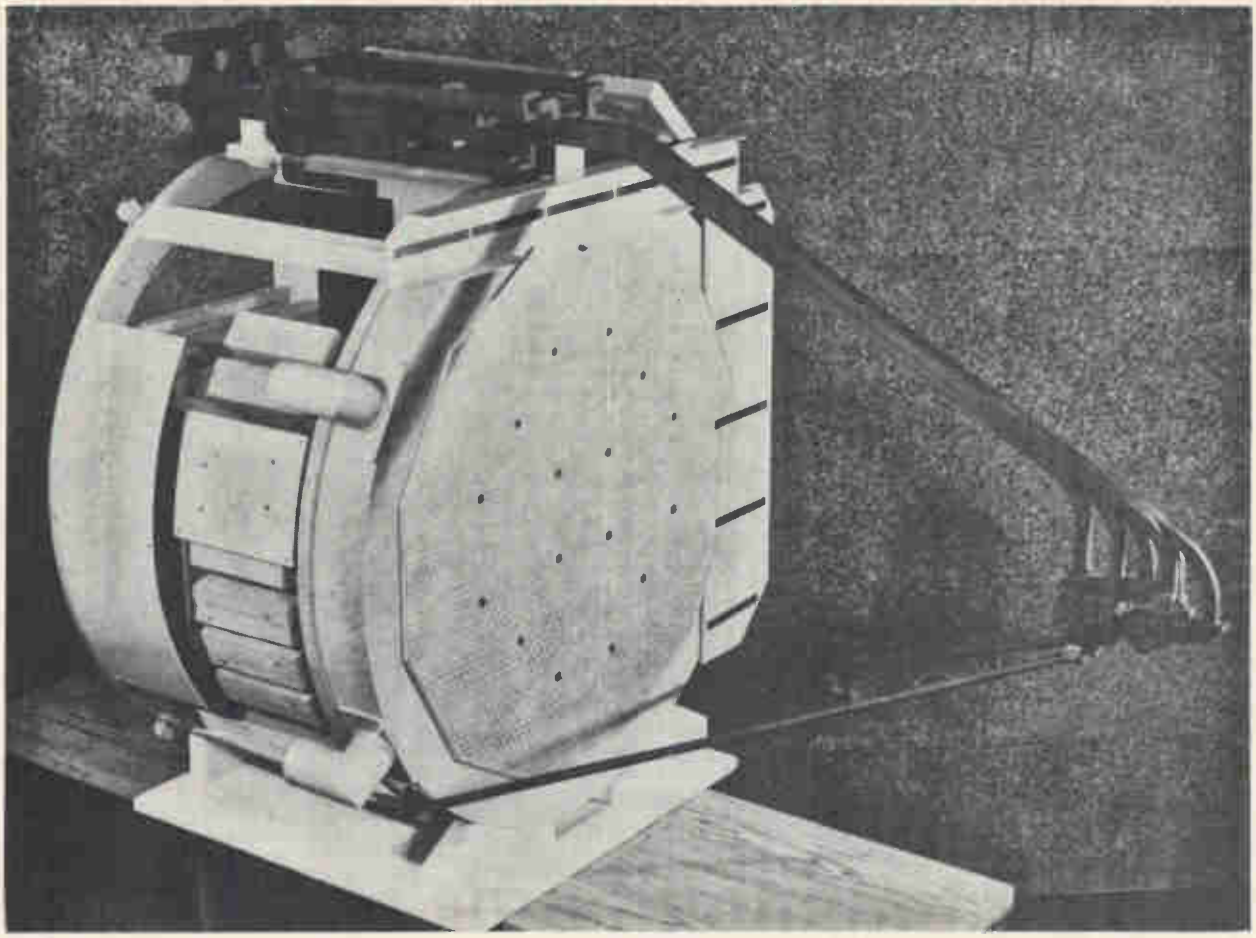
Employment of such a common aperture would reduce the prime power requirements, cost, and weight of the total system, Hunt continues, and the individual subsystems might operate more effectively. The large number of separate antennas needed on an aircraft would also be reduced.

Current projects

Several military-funded projects are aimed at simply replacing the moving dish of a conventional radar with a stationary, electronically steerable array. Receiving and power generating would be handled by conventional radar subsystems.

Ku-band arrays are receiving considerable attention in this regard. Among the arrays of this type are:

- A 1,500-element reflecting antenna (shown above) built by the Maxson Electronics Corp. An experimental version is being flight-tested in a Navy A-6 Intruder. Phase-shifting is done by p-i-n diodes.
- Antennas being developed for a program called RARF (for Radome, Antenna, and Radio-Frequency circuitry) under the sponsorship of the Air Force



Reflective array. Wooden model of the Ku-band antenna Raytheon is proposing for the Air Force's RARF program. Actual array will contain more than 4,000 ferrite phase shifters; tests of completed system should begin later this year.

Systems Command's avionics laboratory at Wright-Patterson Air Force Base.

Two different approaches are being followed here. The Raytheon Co.'s Missile Systems division is working on a technique in which energy is beamed from feed horns to an array of more than 4,000 antenna elements, shown above, each of which phase shifts the energy by a prescribed amount and reflects it back into space. The other contractor, the Electronics and Space division of Emerson Electric, is building the transmission-lens setup shown on the next page. In this arrangement, energy is beamed from behind and through the individual phase-shifting and antenna elements and then radiated into space. Both companies should have models ready for testing by the end of the year.

- A 144-element reflecting array being jointly developed for the Air Force Systems Command by Microwave Associates and the Bendix Corp. This system employs p-i-n diode phase-shifters instead of the ferrite shifters used in the RARF program.

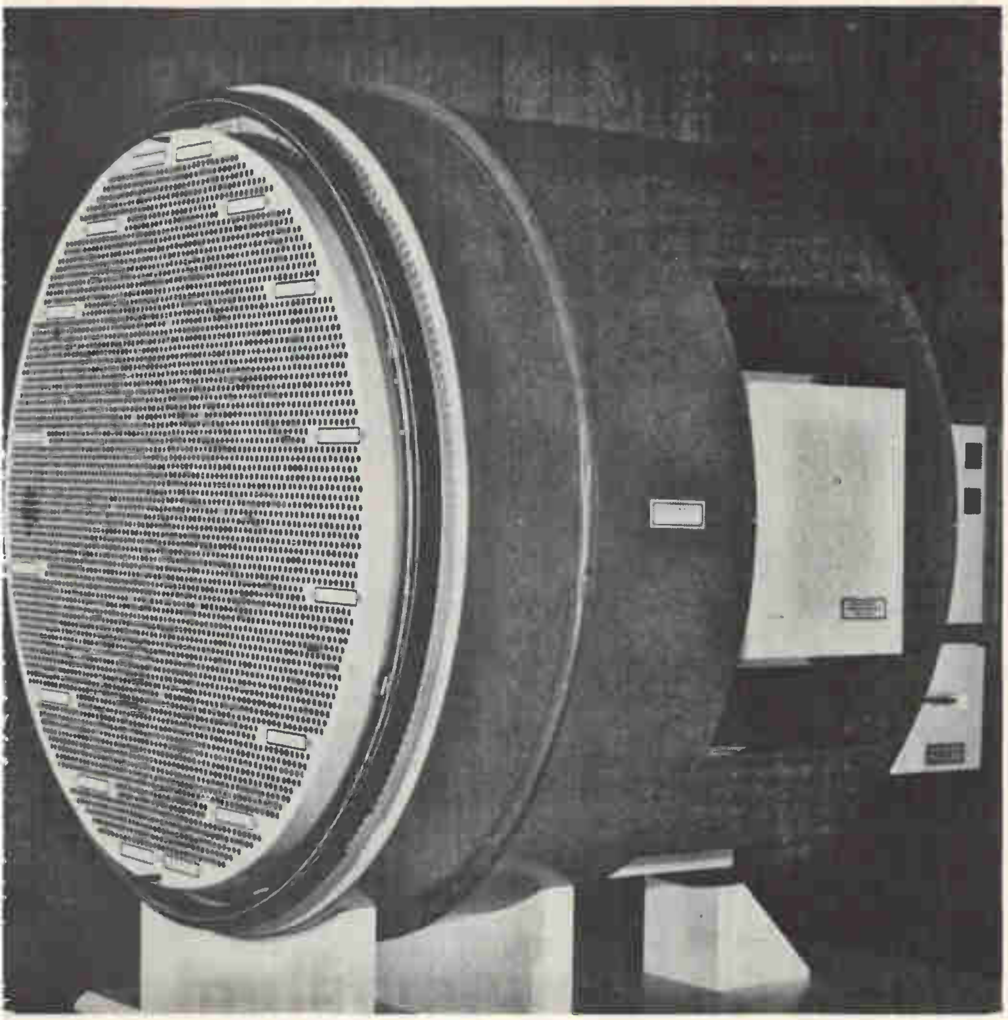
Other companies developing similar types of arrays with their own or military funds include the Hughes Aircraft Co., Autonetics, the General Electric Co., and the Lockheed Electronics Co.

But the greatest departure from current radar designs will come with the development of solid state transmitter-receiver modules incorporating phase-shifting and antenna elements. Pioneer work on this type of configuration began four years ago at Texas Instruments, which at that time undertook the development, under Air Force sponsorship, of a microwave integrated-circuit module. Some 604 of these Molecular Electronic Radar Application (MERA) modules will be combined later this year into a complete radar system.

Other projects directed at solid state arrays include:

- The Navy's MAIR program, a design study of an X-band system undertaken by two teams of contractors. The Westinghouse Electric Corp. is developing a MERA-type system, with TI supplying the microwave IC modules. Raytheon, with Microwave Associates working on the diode phase shifters, is developing a reflective X-band equivalent of its RARF array. However, the latter two companies are considering the use of a new type of solid state power source to drive the array.
- The Boeing Co's in-house development of S-band IC modules that would be applicable to airborne surveillance radars. Boeing has in mind

Fast service. Installed in the nose of an aircraft, Emerson's RARF antenna, with its transmitter-receiver package, could be mounted on slide rails to ease flight-line maintenance.



Clear view. Space-fed transmission lens is used in Emerson Electric's version of RARF antenna. Feedhorns can't be seen in this mockup because they're behind the phase shifters, eliminating the blockage problems that plague reflective arrays.

applications in advanced early-warning systems.

▪ The Ryan Aeronautical Co.'s work, with NASA support, on C- and S-band microwave IC modules capable of controlling phase without conventional phase-shifting devices. This approach could lead to radically new designs for solid state arrays.

▪ The Lockheed Electronics Co.'s effort to develop solid state modules operating at L and S bands.

▪ RCA's Blue Chip program, which aims at a whole family of microwave IC's applicable to various radar designs [Electronics, March 20, 1967, p. 112].

Long-range views

Many firms are counting on the solid state approach, with the use of transisrors and frequency multiplication if necessary, to make phased arrays pay off.

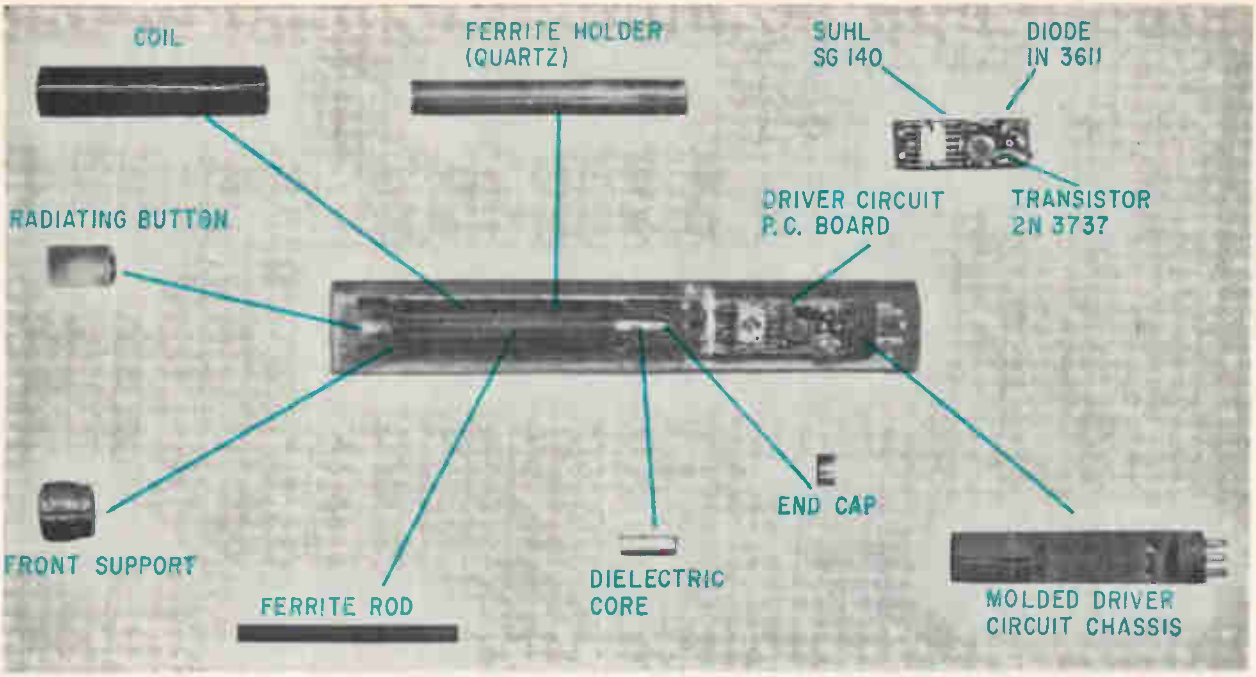
"A lens configuration that replaces the dish antenna will only be an interim solution," declares R.E. Pickens, manager of advanced systems at Bendix' Communications division. "The ultimate solution will be an active element per module."

"Transistors will be the route to highly efficient and low-cost arrays for airborne and electronic-countermeasures equipment," says Ronald Rosenzweig, president of the newly formed Microwave Semiconductor Corp. "We'll soon have power levels of 3 to 5 watts at 4 Ghz, and simple combining techniques could be used to increase the output power from each antenna module."

However, Malcolm Vosburgh of the Institute of Defense Analysis in Washington notes that though transistors have been around for quite some time, not much data has been accumulated on their behavior and life span in the microwave radar region. "We do know that it's tough to operate transistors at high peak powers for the short periods required in a radar," he says. "We don't really know what the cost per watt for transistor power would be."

And Carl Blake of MIT's Lincoln Laboratory points out that over-all systems costs must be considered when deciding how to steer a phased-array radar beam. Lossy steering at high power levels, as in a MAIR reflective array, boosts the cost of the power supply, phase-shifter drivers, and cooling equipment. Steering at low power levels, as in a MERA system, requires many little amplifiers, and thus complex—and inefficient—modules. Over-all operation might be more reliable, however.

"But," says Vosburgh, "the name of the game is



Piece by piece. Four-inch-long ferrite phase shifter for Raytheon's RARF antenna contains its own driver circuit and plugs into the face of the array.

not solid state versus tubes; it's microwave integrated circuitry. If phased arrays are carried to their logical conclusion, they will be made up of repetitive devices designed for automated production. Waveguides, choke joints, test benches and machining will be replaced by a printed-circuit-board type of line. Solid state fits this prescription like a glove; tubes do not."

Opinion is divided on the possibility of using recently developed semiconductor devices to generate power in the modules. Some say the Gunn-effect or limited-space-charge-accumulation-mode devices being made from gallium arsenide won't be ready for the job—so far as efficiency is concerned—for another five years or more. But others point out that all-solid state radar arrays won't be operational for quite some time either, and that the GaAs devices may be ready when the arrays are finally applied.

While most industry officials expect operational phased arrays no sooner than four years from now, the waiting time for all-solid state transmitter-receiver modules is estimated at eight years or more. As noted earlier, a major problem in either case is to reduce the weight and expense of the components. Another factor that could further slow development in this area is the present cutback in military spending for projects unrelated to the Vietnam war.

Adjusting parameters

Beyond solving the problems of cost and of designing electronically steerable elements, the concept of adaptability to changing mission conditions must be investigated.

If a radar is looking at a single target in the clear, there's little noise to contaminate the signal returns and it's relatively simple to specify the pulse width, pulse repetition frequency (prf), and desired accuracy.

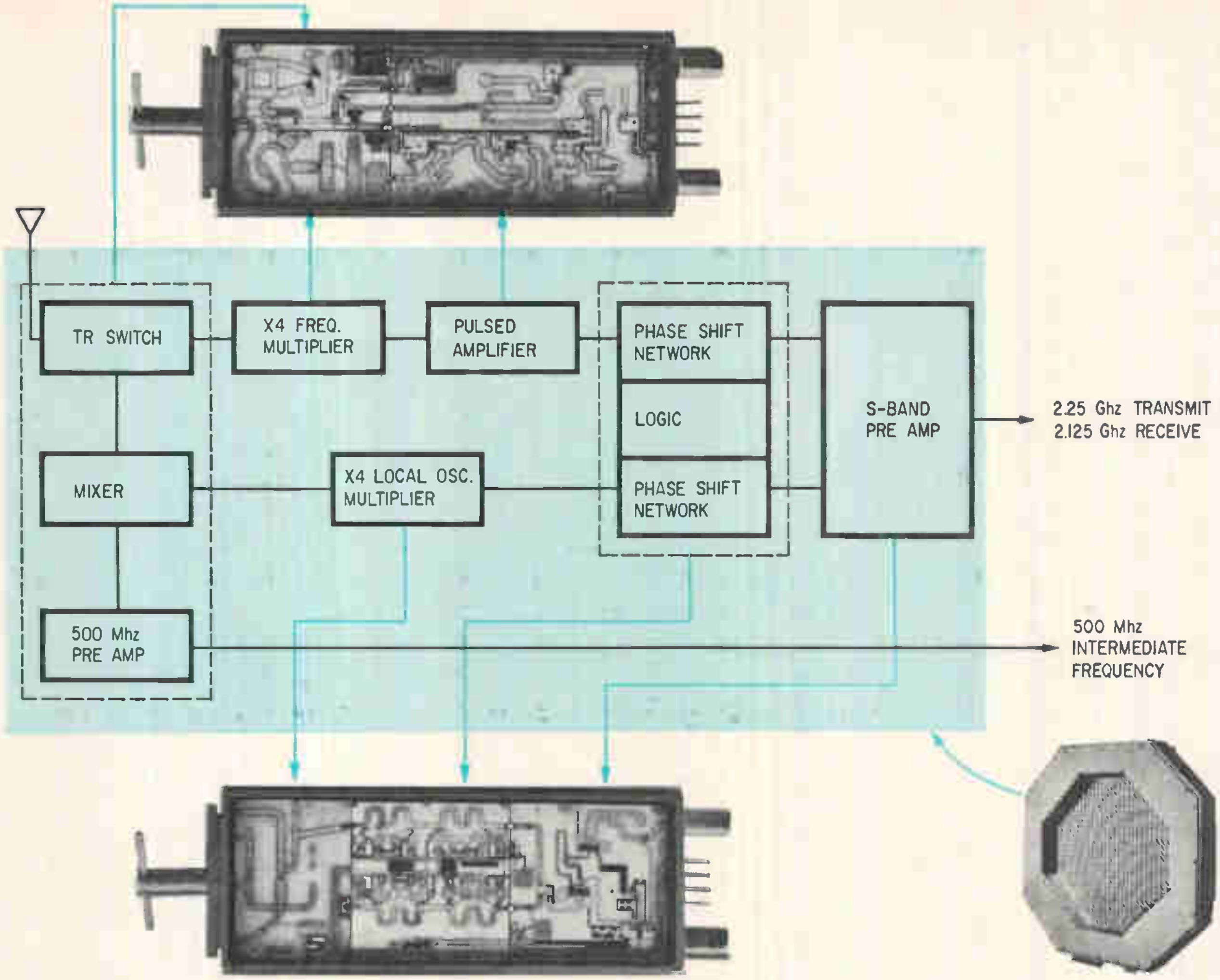
But if there's clutter or several targets in the beam, the signal processing and targeting may have to be modified, with conventional pulse processing being replaced by moving-target-indicator processing. Pulse-compression techniques might be needed to increase resolution. But these techniques should be used only when they're needed; continuous operation in a multitarget mode would contribute unnecessarily to system losses.

The answer is to adapt such parameters as pulse width, prf, bandwidth, and transmitted power to specific situations. This can be done in conventional radars but much more control is available with phased arrays. And besides main-beam sharpening or broadening, the side lobe levels can be adjusted.

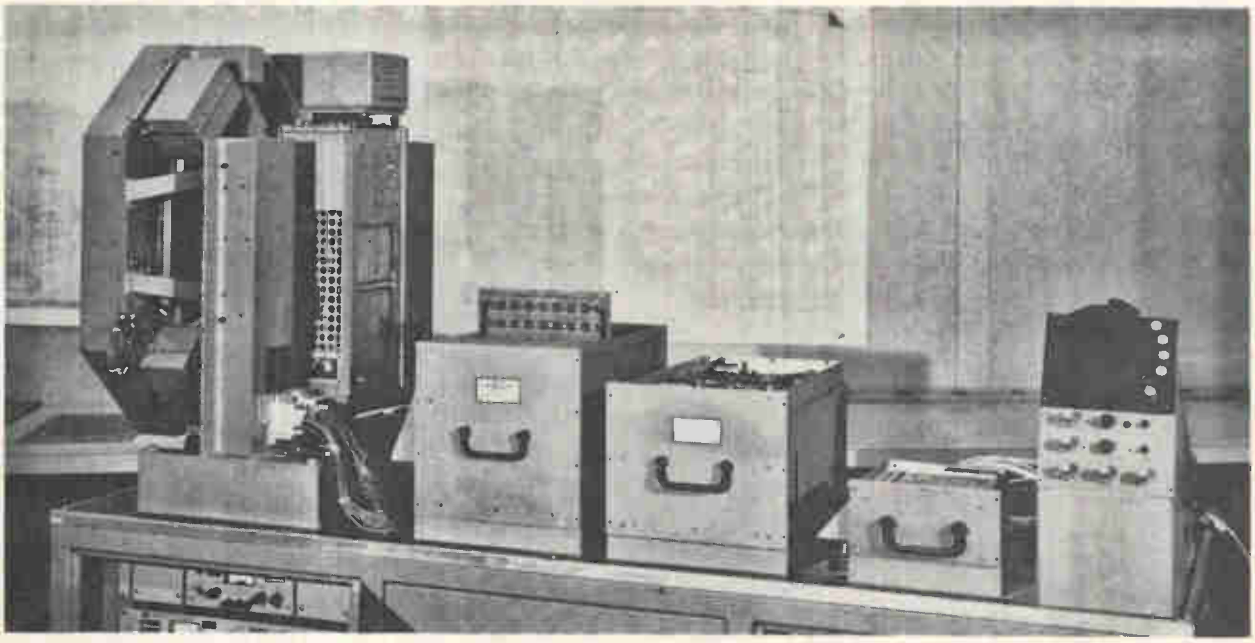
The requirements for a system whose operating characteristics can be varied over a broad range can be seen in an examination of an all-digital multimode radar being developed in-house by Raytheon. A. Michael Briana, technical director for avionics systems at the firm's Missile Systems division, calls it an extremely flexible transmitter-receiver section, and says it's the first of its class to be put under real-time digital control.

The system is designed to handle air-to-air and air-to-ground situations, he says, and will eventually be hooked up to the company's RARF antenna. The demonstration model will turn out 200 watts of average power.

Both prf and duty cycle will be variable over a wide range. Long-term duty cycles will run from



Solid state. Functions of a complete radar set are built into TI's X-band MERA module. Signal-distributing manifold will hold 604 of these modules in the complete system.



Full lineup. From the left, the antenna manifold and signal generator of the MERA system are joined by the beam-steering computer, receiver-processor, terrain-following computer, and radar indicator.

0.001 to 0.16, while short-term cycles may vary up to 40%, Briana says. Prf may vary anywhere from 200 hertz to 400 kilohertz. Pulse-compression techniques with ratios of up to 100:1 will be the key here.

Fast Fourier transforms will deal with the digital signals in the processor.

"Such a processor hasn't been built before but it's the only way to handle both the high and low prf's," says Briana. "The processor will have to be able to interchange range and velocity bins depending upon the tactical situation. For high prf operation, there'll be a lot of filters and a few range bins. Low prf will call for a lot of range bins backed by just a few filters."

Raytheon will use a Honeywell Alert computer as the central processor for the demonstration model.

Flying hardware

Although the antenna Maxson has built for the Naval Air Systems Command is being tested aboard an aircraft, it's really more an exploratory model than a prototype for an operational design. It was developed primarily to see how a phased-array antenna would perform in an airborne environment.

The reflective array of 1,500 phase-shifting elements is arranged within an 18-inch-diameter circle. It is putting out 50 kilowatts of peak power in the Navy tests, where it's being used in automatic tracking, search, and elevation scan modes. Maxson has, however, gotten up to 125 kilowatts of peak power in its own tests.

The beam, which can scan ±60° off boresight, is positioned by one-bit p-i-n diode phase shifters. Phase shifter, driver, and open-ended-waveguide radiating element are each less than 4 inches long and plug into a printed-circuit board. The model also includes a beam-steering computer and power supply.

Operational hardware could be ready in three years, according to Edward J. Shubel, deputy director of engineering at Maxson. It would be a more sophisticated system, he says, with some 6,000 elements in a 36-inch aperture to give a narrower beamwidth and greater pointing accuracy. Two-bit diode phase shifters would be used, along with more advanced silicon monolithic IC's than were available when design of the experimental unit began 2½ years ago.

Shubel estimates that the operational antenna will weigh about 172 pounds, and adds that this would be lighter than any comparable mechanical system or even phased-array antenna he knows about.

Cost of a complete 6,000-element array, including beam-steering electronics and power supply, is estimated at $150,000, based on a high-volume price of $20 each for the phase-shifting elements.

As many as 20% of the elements in such an array could fail and the antenna would still function adequately, according to John McLaughlin, Maxson's vice president for research and development. "It's very difficult to determine if just a few elements have failed," he says. "The deterioration is gradual. We've had hundreds of hours of test time with the array we've built and it's operated perfectly. If any of the elements have failed, we don't know about it yet."

Raytheon's reflective array and Emerson's transmission-lens approach represent two routes to a RARF antenna. Air Force tests will have to decide which is the better path.

"Our reflective array fits nicely into the nose radome of a tactical aircraft," says Raytheon's Briana. "You have blockage because the feed mechanism is out in front, but we've always had blockage with conventional radars."

But the fact that there's no aperture blockage with the transmission lens gives that arrangement a decided advantage, according to L. Bruce Long, director of research at Emerson's Electronics and Space division. Side lobe levels can be more easily controlled because of this, he says, and also because it's possible to use a larger feed-horn assembly to give more illumination taper. Emerson has a 12-horn feed; Raytheon uses four horns.

Raytheon expects its array to have side lobes of 24 decibels down and 19 to 20 db up. Emerson says its downward-looking side lobes will be 30 db.

Ferrite phase shifters

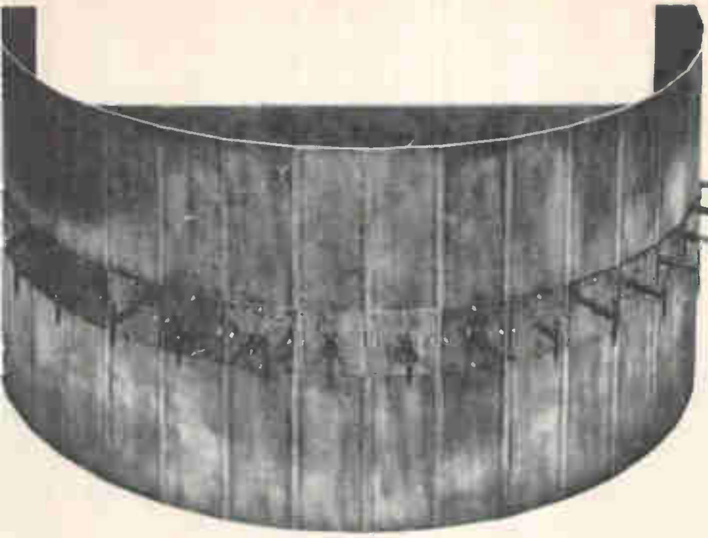
One of the most difficult problems with both systems was the design of lightweight ferrite phase shifters that are polarization insensitive and operate over the broad temperature range spelled out in the environmental specification Mil-E-5400.

Raytheon has already built almost 4,000 of these ferrite phase shifters, according to Briana. About this number, placed in a circle 32 inches in diameter, will produce a pattern around a solid cone of ±60°, he says, a pattern that can be stepped as little as a milliradian at a time. The phase shifter, shown on page 98, can handle up to 200 watts peak power and 6 or 7 watts average. It's 4 inches long, weighs 0.9 ounce, and has a six-pin connector. The driver, designed to minimize drive power and complexity, is built into the phase shifter. It consists of an IC flip-flop, an output transistor, and a diode, and it uses a pulse-width-modulating scheme that gives the output transistor a 90% operating efficiency.

The phase shifters plug into Mu-metal tubes spaced 0.43 inch apart center to center on a triangular grid, Briana explains. The metal shields one element from the next and also closes the magnetic path within the phase shifter. The tubes are spot-welded together and held within a cast aluminum frame. Air blown around the tubes cools them.

The connectors on the end of the phase shifter are picked up by a multilayer printed-circuit board. This is inherently a simpler way to do things; with a transmission setup, wires have to be led carefully between the elements because there is high power r-f energy on both sides of the array.

The ferrite rod itself is roughly ⅛ inch in diameter and 1⅝ inches long. Waveguide surfaces are silver-plated in a vacuum evaporation chamber,



Made to fit. Techniques for controlling this semicircular array of dipoles are being studied at TI as part of a program that could lead to conformal radars.

and each end is dielectrically loaded with a round quartz button to match the impedance of the guide to that of free space.

Energy from the feed enters the circular waveguide, passes through the ferrite rod, is reflected by a short-circuit back through the rod and out into space. Because it shifts the phase of the energy twice in its round trip, the Raytheon shifter can be shorter than Emerson's, which acts on the energy only once.

The Raytheon shifters are reciprocal analog devices that use the equivalent of five-bit input signals to set and maintain a d-c current level. Unlike the Emerson units, they aren't latching; they require holding power all the time. This is not a disadvantage, though, if you're going to jump the beam around hundreds of times each second, Briana states.

For its version of RARF, Emerson has developed a reciprocal ferrite phase shifter that's about 7 inches long, and has its IC driver circuitry built into one end. The amount of phase shift is determined by the width of the driving pulse. The shifter handles about 3 kilowatts of peak power and almost 10 watts average, according to Paul Safran, chief of the Electronics and Space division's microwave branch.

The phase shifter has a circular radiating element at each end, one to pick up the high power coming from the feed horns, the other to radiate it into space. Dielectric caps on the radiators match their characteristics to that of free space.

Emerson believes it has developed some proprietary techniques for producing low-cost phase shifters, including new ways to grind the ferrite and to deposit a conductive coating on the surfaces to act as the waveguide walls. Large-scale production costs could go as low as $10 to $15 per unit, Safran says.

In addition to the 12-horn feed cluster, the antenna has 16 slot radiating elements in the face of the array for identifying other aircraft (IFF), and a separate horn to supply 3 kilowatts of continuous-wave power for missile illumination.

Slimming down

Emerson is working on a minimum-depth array that could reduce the distance required between the feed horns and the phase-shifting elements. Involved here is a space feeding technique for deriving the monopulse signals, but the feed mechanism is put right up against the phase shifters. This could reduce the array's depth by 75%, according to the company.

Another part of the RARF project is a special-purpose beam-steering computer that activates the individual phase shifters. This computer, which loads the array and forms the beam in less than 200 microseconds, will take information from the general-purpose processor that selects the operating modes and translate it into signals for the phase shifters. A complete RARF system, including a transmitter-receiver and signal processor will weigh about 600 pounds.

Bendix's 144-element Ku-band reflecting array is circular and roughly 8 inches in diameter. This project is entering the second year of a two-year development contract.

"The problems here," says Pickens, "are to apply microwave integrated circuitry and diode phase shifters at this extremely high frequency, and to come up with good antenna gain and aperture efficiency, plus low side lobe levels.

"Our unit is a demonstration model to show the accuracy and power levels that can be achieved," Pickens continues. "Ultimately, the design could be part of an antenna system having anywhere from 2,500 to 3,000 elements. Power in the demonstration unit should reach 15 kilowatts peak and 750 watts average.

Another goal of the project is to perfect techniques for lightening the array and reducing its cost, Pickens observes. Each antenna element, or cartridge, will be only 3 inches deep and will contain the diode phase shifter and driver circuit. The cartridges will plug into a supporting manifold much like Raytheon's RARF grid.

A rectangular open waveguide at the head of the cartridge receives energy from the feed horn. Instead of a short-circuit at the far end, the element has a four-bit reflecting diode phase shifter. Microwave Associates, which, interestingly, is the prime contractor for the project, is delivering the shifters to Bendix.

"The circular aperture of our array will produce a 5° pencil beam," Pickens says. "Right now, the trick is to design an efficient feed that's virtually transparent to r-f energy. We're still working on several approaches to minimize the blockage problem that's present in any reflective antenna."

Under wraps

But perhaps the most unusual development in the phased-array field may be coming from Ryan Aeronautical. The company says it has developed a beam-steering technique that eliminates phase shifters.

"We're building a four-by-four array at C band, with each element consisting of a solid state transmitter and receiver," says John Aasted, program manager at the advanced systems group in Ryan's Electronic and Space Systems division.

Ryan will reveal no specific details about its phase-shifting technique at present, but it's believed that phase is adjusted smoothly and continuously as power is generated. The company may be using a gallium-arsenide power-generating device employing the Gunn effect or LSA.

Space radar

Ryan's work is being done under a NASA contract to develop a general-purpose space radar called the Combined Acquisition and Tracking radar. Functional units are put together on 1-inch-square ceramic substrates, and a receive-only array would be but 2 inches thick, according to Aasted. Adding a transmit function would double the size.

"Simplifying the design of the modules as we've done should open up many new applications for phased-array techniques," Aasted declares. "The high cost of the modules has always been a problem. The combination of our simplification with new techniques for mounting microwave integrated circuits could bring costs down significantly."

Ryan is also applying its secret phase-shifting principle to an S-band antenna being built for NASA. Separate transmitting and receiving elements have already been built, says Aasted, but they have yet to be combined in a single module.

The feasibility of building a complete radar system with microwave integrated circuits was demonstrated by Texas Instruments' development of the MERA module. To show this feasibility was the basic goal of the program when it was launched by the Air Force in 1964.

"MERA as such will never be an operational radar," says Virgil L. Simmons, microwave products manager at TI's Semiconductor Components division. "Its purpose was to develop techniques suitable for a solid state radar. The work that follows MERA will be directed at systems problems, at specific applications."

The MERA module measures 3 by 1 by 0.5 inches and consists of a transmitter-receiver, the equivalent of four-bit diode phase shifters, and a dipole radiator, as shown on page 99. It plugs into a manifold that distributes the master signal power through a stripline power divider. Peak output power of an element is 0.7 watts (down from an originally projected 1 watt) at 9 Ghz, making the array's total output roughly 423 watts. However, 100:1 pulse-compression techniques give the 604-element array an effective radiated power of 42 kilowatts.

TI says the modules could be produced in quantity for about $100 apiece. The company is now aiming to boost output to 10 watts.

Because of the high frequency at which the radar must operate, the master power is generated at S band (2 mw at 2.25 Ghz is fed to each module), and a times-four varactor multipler is used to convert the signal to X band. A separate times-four multipler handles the received signal out of a mixer.

TI is turning out some 10 modules a day and should have enough for a complete array by the end of this month, Simmons says. Final design of the module was actually frozen last February, he says, but "silly problems" like reversed or out-of-registration masks kept popping up.

The complete radar, shown at the bottom of page 99, should be put together by the end of this year, and TI plans to fly it in a company plane early next year. This test, in which the radar will be used in at least two modes—terrain following and ranging—should go a long way toward changing MERA's "laboratory curiosity" image.

A MERA radar system would operate for an average of 10,000 hours between overhauls, TI estimates, compared with as little as 300 hours with many conventional airborne systems.

The full system will include the array, a master signal generator, a beam-steering computer, a receiver-processor, a terrain-following computer, and an indicator modified from an APQ-110 radar. The feasibility of building a beam-steering computer with large-scale integrated components is being studied, but no real effort has been made to reduce the weight of the system, which should reach 400 pounds.

Fallout

But TI expects to reap greater rewards for its MERA work than simply the right to point to the world's first solid state radar. The company sees great commercial potential in the high-frequency transistors and microwave IC's it has developed for the project.

"MERA-developed transistors will be the basis for a new product line we'll have by the end of the year to cover the 500-Mhz-to-3-Ghz spectrum," confides Simmons. "For example, we expect to offer 3 watts of pulsed power at around 3 Ghz, compared with the 400 to 100 mw at 4 Ghz we're selling now."

And MERA-type components such as voltage-tunable oscillators, wideband and pulse-dispersion amplifiers, and mixers may well turn up in other firms' radar systems. TI has won contracts to supply microwave IC's for other solid state radar programs, and it's teaming with Westinghouse on the Navy's MAIR project.

The two teams of contractors studying MAIR (Molecular Airborne Intercept Radar) have each received a modest $70,000 since completing initial studies last fall.

Westinghouse and TI, applying the MERA concept, are studying active transmitter-receiver modules. Raytheon, on the other hand, is approaching the problem from the direction of its Ku-band

RARF work for the Air Force. Teamed with Microwave Associates, Raytheon has in mind a reflective array of passive modules containing only phase-shifting and associated elements.

Although the latter approach requires a higher power level for phase shifting, and thus involves higher losses, Raytheon's Briana feels it will probably be easier to make all the elements alike if they're passive. "It's hard to cover the temperature and environmental range with active elements to worry about," he says. "And as the phase tolerances go up, the main beam gain degrades and the side lobe levels increase."

Raytheon is working with Microwave Associates to develop polarization-insensitive diode phase shifters for the array. This unit could weigh as little as ⅓ ounce and have a 1.7-db insertion loss, Briana says, so that the over-all antenna could be very light. Briana expects it to weigh no more than the dish and gimbals of current airborne intercept radars—about 150 pounds.

But the most unusual design departure Raytheon and Microwave Associates are considering involves the generation of X-band power.

"The antenna element isn't the logical place to generate the power," says M. E. Hines, Microwave Associates' vice president for research. "We'd like to keep these elements—which occur thousands of times in the system—as simple as possible, containing just a phase shifter and radiator. The more complex the element, the harder it is to maintain uniformity in production. Yield goes down and costs go up.

"Also, by designing your system around power sources that are available now," Hines continues, "you may be cutting yourself off from possible future sources such as Gunn-effect, LSA, or Impatt devices."

Microwave Associates is studying a new type of transmitter that would act like a solid state version of a traveling-wave tube—a "black box transmitter" is the way Raytheon describes it. Raytheon's attitude towards this device is: if it works, fine. If it doesn't, we'll still be able to use a conventional source to power the array.

Microwave Associates isn't describing exactly what it has in mind. The transmitter could involve a lot of amplifying devices, possibly of gallium arsenide, spread out along a waveguide wall; each would add a bit of gain as a wavefront propagated down the guide. In any case, Hines looks for a kilowatt of average solid state power three to five years from now.

Standing guard

As indicated before, airborne early-warning systems are also candidates for phased-array radars. Instead of carrying its prime surveillance sensor in a rotodome, an AWACS plane might have it fitted into its fuselage. Four companies—Hughes Aircraft, Autonetics, Sedco Inc., and Sylvania—completed studies along these lines last year for the Air Force, but the service didn't choose to follow up, perhaps because of a lack of funds.

Phased arrays on an early-warning craft would provide other advantages beside eliminating the aerodynamically troublesome rotodome atop the fuselage. "We'd be able to get better side lobe control—some 10 db better—than we could with a mechanically scanned radar," says Wayne Diehl, a Sylvania marketing manager. "This is extremely important when dealing with the intense clutter problem the AWACS planes must face. Also, we could handle a multiplicity of high-speed targets with the inertialess scan, something not possible with a mechanical one."

Sylvania proposed the use of four separate arrays to give the required 360° of coverage around the aircraft. These, it said, could be built into two V-shaped antennas, one to go in the nose, the other in the tail.

Sylvania, like Emerson, has been working on narrowing the distance between the feed horns and the array elements. Sylvania wants an antenna that would be less than a foot thick at S band and half that size at X band. Power, supplied by conventional megawatt sources, would be emitted from open-ended waveguide. The company is now building a scale model containing 200 to 300 elements with its own funds.

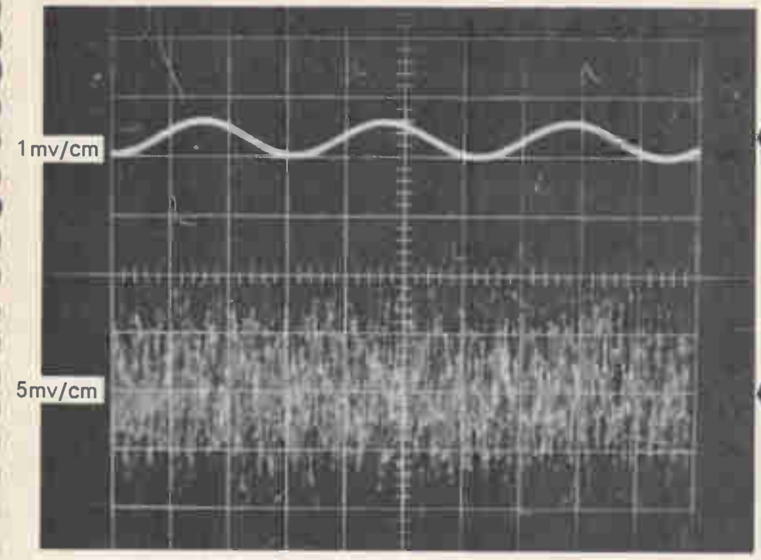
Boeing, which is in the running with McDonnell-Douglas for the over-all AWACS prime contract, is also considering phased arrays for an advanced version of the system it has proposed. With its own funds, the company for almost a year has been working on solid state MERA-type modules containing a transmitter-receiver, a diode phase shifter, and a radiator. Glenn Coughlan, manager of the airborne surveillance radar program at Boeing's Missile and Information Systems division, says the goal is peak r-f power of 20 watts and average power of 2 watts at S band.

Each module would fit into a cylinder 1¾ inches in diameter and 4 inches long—about the size of a frozen juice can, Coughlan says. With its module, a cylinder would weigh about 3.2 ounces. The complete antenna would fit into a cylindrical pod built into the airframe.

Boeing is working with thin-film hybrid circuits on alumina substrates. "We're building our own devices—varactor doublers, transistors, diodes—because we can't get them properly packaged for installation on microstrip," says Coughlan. "The commercially available devices give us too many parasitics."

However, it isn't likely that Boeing will ever manufacture its own modules.

"Building the devices ourselves is the only way to really understand the problems," says Kenneth Hammerle, Boeing's chief of radar technology. "We've found in the past that we couldn't go to vendors, tell them we wanted something, and then sit back. We'll now be in a much better position to understand what our vendors tell us, to evaluate and even guide their work, and to monitor their production once they begin fabrication."



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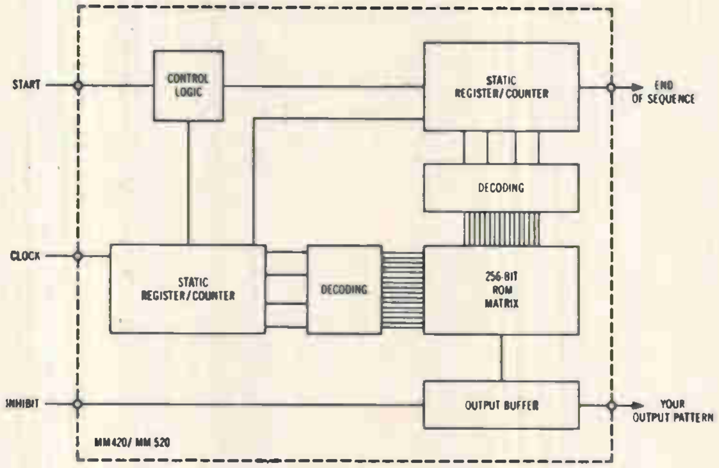

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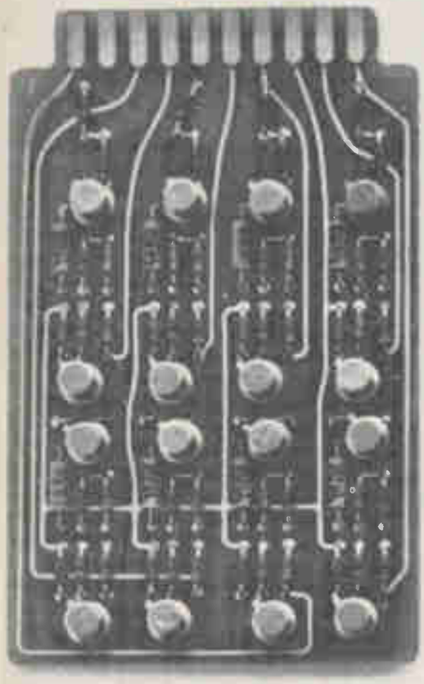

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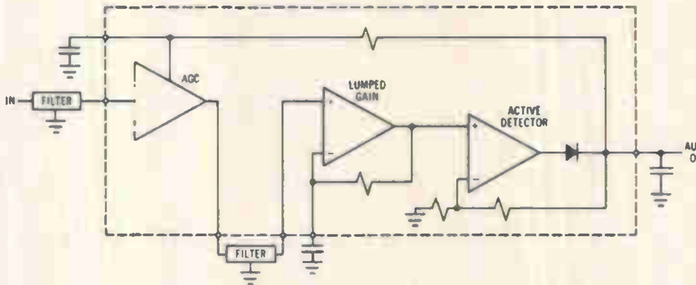

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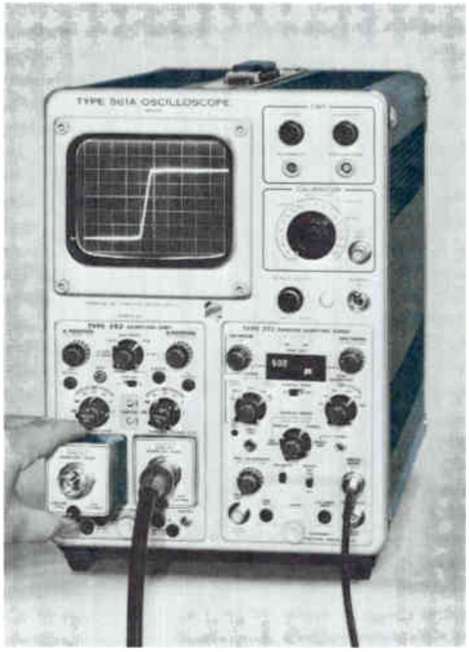
Type S-2 Sampling Head $300

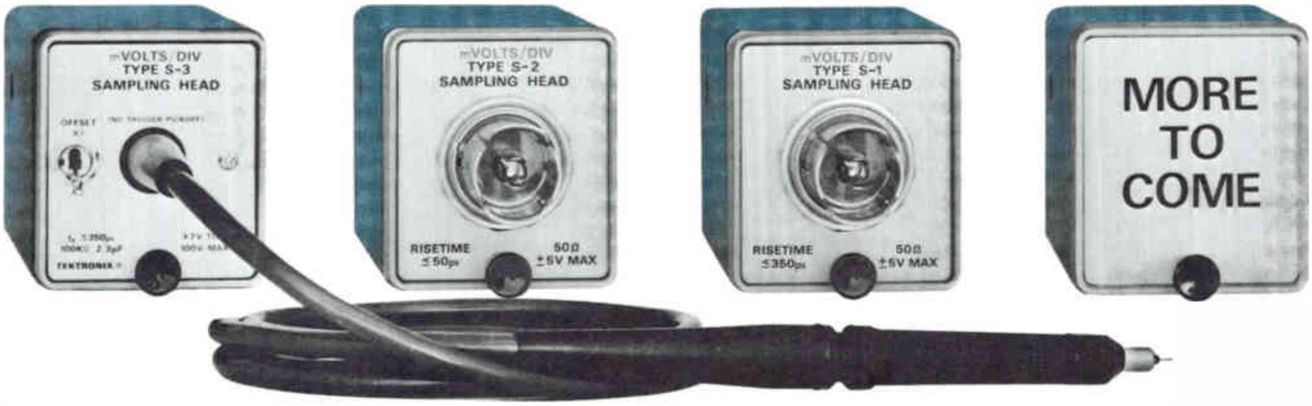


The Tektronix Type 561A Oscilloscope with the Type 3T2 Random Sampling Sweep and the Type 3S2 Dual-Trace Sampling Unit features new measurement capabilities with plug-in and extendable Sampling Heads. Six Sampling Heads are presently available offering a step ahead in measurement performance, designed to meet your changing measurement needs.

Type S-1
350-ps RISETIME

The Type S-1 Sampling Head is a 350-ps risetime, 50-Ω unit that features low displayed noise and an unexcelled transient response.

Type S-1 Sampling Head $250



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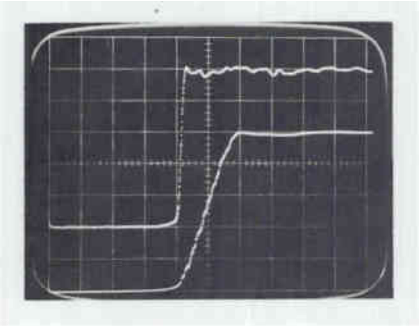
Making the Measurement . . . TEKTRONIX 25-ps Sampling Oscilloscope

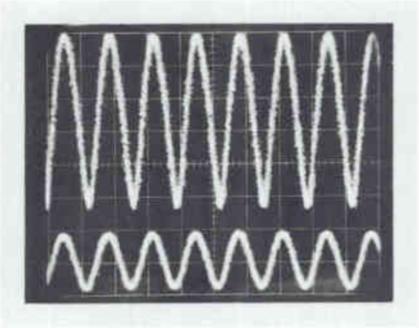
NEW! 25-ps Risetime

The Type S-4 offers for the first time 25-ps measurement capabilities in an oscilloscope. This state-of-the-art measurement performance provides increased detail and resolution of your fast pulse displays. The photograph shows the same pulse displayed with the 25-ps Type S-4 (upper trace) and a 350-ps unit (lower trace). Note the difference in detail of the pulse characteristics displayed by the Type S-4 with its 25-ps risetime performance.



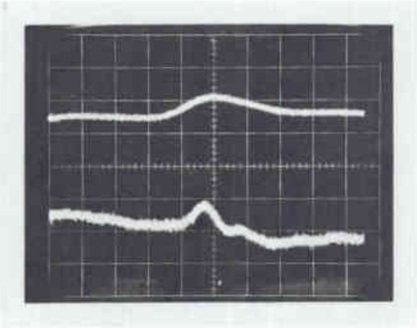
NEW! 14-GHz Displays

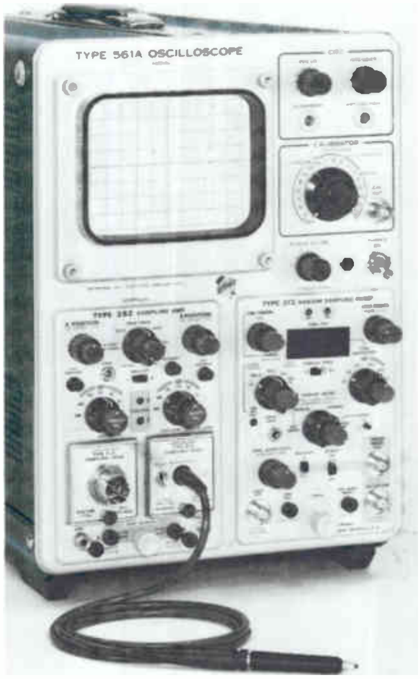
For the first time, you can see displays to 14 GHz on an oscilloscope. Using the Type S-4, DC-to-14 GHz Sampling Head with the Type S-51, 1-to-18 GHz Trigger Countdown you can see how your circuit is really performing. Two Type S-4 Sampling Heads used in the Type 3S2 (XY mode) let you measure phase shift to 14 GHz. The photograph shows the loss due to a 3-ft coaxial cable transmitting a 15-GHz signal. Sampling Heads can be used at your signal source eliminating losses due to cables.



NEW! 35-ps TDR System

The Type S-4, 25-ps Sampling Head and the Type S-50, 25-ps Pulse Generator provide a high resolution 35-ps TDR system. The double exposure photograph shows a comparison of a 100-ps TDR System (upper trace) and the new 35-ps TDR System (lower trace). Note the better resolution with the 35-ps Type S-4/S-50 TDR System.





Mix or Match!

Sampling Heads may be mixed or matched. High frequency signals and fast risetime pulses must be generated and transmitted in low impedance circuits. The Type S-1, S-2 and S-4 Sampling Heads have a terminated 50-Ω input providing excellent termination for your fast risetime pulses and a choice of risetime capabilities. Add the Type S-3 Sampling Probe Head with its 100-kΩ, 2.3 pF input impedance when it is necessary to measure high impedance signal sources.

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A Choice of Oscilloscopes

Tektronix offers a choice of sampling oscilloscopes designed to satisfy your measurement needs. Select the Type 561A Oscilloscope with an 8 x 10-cm CRT and illuminated internal graticule for conventional displays. The Type 564 Storage Oscilloscope offers the added advantage of split-screen storage. Storage is especially useful when sampling low repetition rate signals, making TDR measurements and for signal comparison. The Type 568/230 Digital Readout Oscilloscope provides digital readout of measurements without operator interpretation or error. Measurements include voltage, risetime, delay time, pulse width and many other specific measurements, readout directly in four-digit resolution.

Random Sampling

Type 3T2 Random Sampling Sweep provides all the measurement capabilities of a conventional (sequential) sampling sweep, plus it features the added advantage of random sampling operation. When used in the random sampling mode, the triggering event may be displayed on screen without the use of delay lines or a pretrigger. The Type 3T2 has a calibrated sweep range from 100 μs/div to 200 ps/div, extending to 20 ps/div with the X10 magnifier.

Plug-ins for a Plug-in

The Type 3S2 Dual-Trace Sampling Unit features a choice of six Sampling Heads that provide new convenience and versatility when making fast pulse measurements. The Sampling Heads can be plugged into the Type 3S2 or used remotely, eliminating losses due to cables. An interchannel delay control compensates for signal cables or other external delays between channels. Select the performance you need today and update your measurement capabilities with new Sampling Heads in the future.

Type 561A Oscilloscope	$530
Type 564 Storage Oscilloscope ..	$925
Type 568/230 Digital Oscilloscope	$3840
Type 3T2 Random Sampling Sweep	$990
Type 3S2 Sampling Unit	$800
Type 285 Power Supply .... (powers one S-50 or S-51)	$150

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Avionics

Air traffic control: the waiting game

Passengers wait in holding patterns while the FAA waits for money and manpower; meanwhile, the controllers themselves wait for a bigger voice in equipment selection

Sins of omission, rather than commission, on the part of the Federal Aviation Administration are at the root of this summer's jet jams around East Coast airports. And unfortunately, improved hardware appears to be only a partial solution to the current difficulties.

The latest crisis was precipitated when harried air traffic controllers, "in the interests of safety," began operating strictly by the book—a development that led to massive stack-ups at terminals and arrival delays of as much as six hours. Blame for this fiasco must fall largely on the FAA, which, despite its own high-flying projections of future air travel, has failed to press for adequate airport capacity to handle the anticipated traffic. Morever, since 1963 the agency has made only token additions to its force of air traffic controllers and has failed to sell Congress on the need for substantial investment in advanced equipment concepts.

But the airlines are far from blameless; the carriers' prediliction for high-density routes and rush-hour operations have exacerbated the traffic jams on key routes.

Up, up and away

By any standards, the growth of both commercial and general aviation has been, and will continue to be, dizzying. At the moment, the domestic airlines have about 2,000 craft, most of which are jets. Within less than a decade, the number is expected to grow to around 3,500, with most of the added planes being jumbo and supersonic jets. In addition, the general-aviation fleet, now around 104,000 planes is expected to increase to 180,000; a healthy percentage of this total will be business jets.

FAA controllers now handle upwards of 50 million takeoffs and landings a year, but, based on the agency's own data, this load will rise in 10 years to 140 million. Beset by an already overburdened control system, the FAA is making serious efforts to automate procedures at the nation's airports.

At the top of the agency's list of priorities is installation of National Airspace System (NAS) equipment at 20 en route traffic control centers. The system displays luminous blocks of data furnished by transponders carried aboard aircraft flying between U.S. cities. The blocks, called alphanumeric tags and displayed on controllers' radar scopes, automatically follow the correct blips until planes are through the area covered by the center. The system is built around an IBM 9020 computer—a modified 360/50 with modular memory—plus Burroughs Corp. digitizers to convert radar signals into computer data, and computer display channel gear from the Raytheon Co.

The en route center in Jacksonville, Fla., is scheduled to become the first operational NAS facility next July. Installation of centers in

Sunpapers—Richard Stacks

Undermanned. Air traffic control crews like this one at Friendship Airport in Baltimore are continually overworked because of personnel shortages.

. . . controllers are more than dubious about alphanumeric techniques . . .

Cleveland, Washington, Los Angeles, and Chicago is also well along; the whole project is to be completed by mid-1973.

Pragmatism. NAS work is proceeding at a faster pace than the Advanced Radar Traffic System (ARTS), a terminal control project, although research on both programs was undertaken at about the same time. "En route problems proved easier to solve," explains J.W. Rabb, chief of the systems division in the NAS program office.

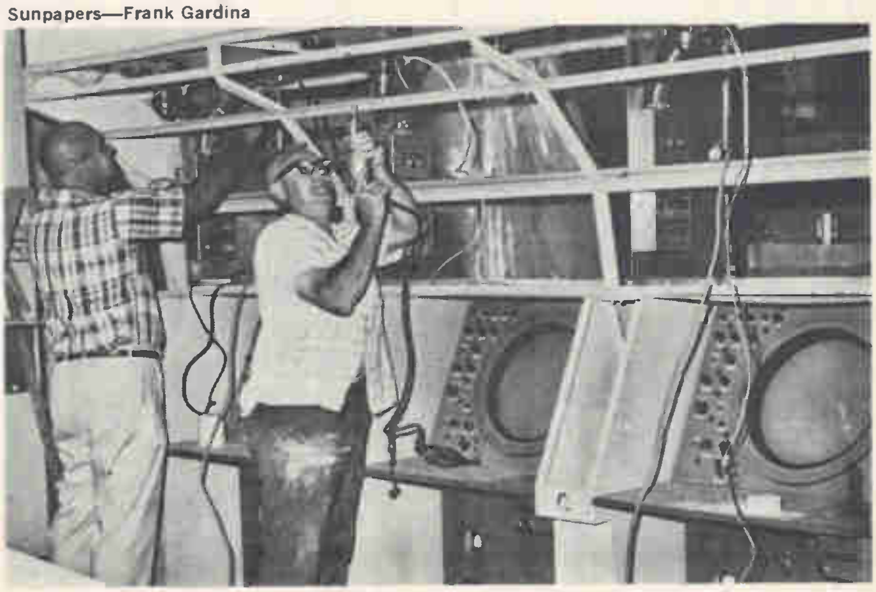
As yet, the FAA has not codified its plans for NAS much beyond setting a completion date. Rabb does note, however, that such features as collision avoidance, improved sequencing, and better scheduling are being considered. "At one time, we intended to take a giant step into Stage B, but we now think functions can be added gradually—once we get smart enough to perfect them," he says.

Plans now call for 64 airports around the U.S. to be equipped with terminal radar control (Tracon) equipment over the next three years. Tested for several years in Atlanta, Ga., as part of ARTS, Tracon will bring to terminal control the same kind of automated alphanumeric identification used in NAS. The package, designated Tracon C, is hooked up to existing terminal radars to display an aircraft's identification number, range, altitude, and speed. Typically, a system includes a video digitizer to accept data from a plane and convert it into alphanumerics written on bright radar displays. A computer processor stores flight plan information and calculates aircraft speed. Initially, the FAA will buy 17 complete Tracon C systems, including a training setup and one for the agency's National Aviation Facilities Experimental Center.

From all sides. Despite such efforts as NAS and Tracon C, the FAA is still drawing a full quota of fire from its many critics. For one thing, the Air Transport Association feels the agency isn't moving fast enough. "We're way ahead of the FAA in implementing an alphanumerics system," says a spokesman for this airlines' trade organization. "By 1970, 69% of the airlines' planes will be able to furnish identity and altitude data, and 80% will be able to send identification signals. However, the FAA will have only 30% of its centers ready by then."

On top of this criticism, air traffic controllers are more than dubious about the efficacy of alphanumeric techniques. "When beacons cross, the alphanumerics tend to jump from one block to another," complains Frank Havlin, a controller in the common instrument flight rules room at New York's Kennedy Airport. "Beacon readings are supposed to be separated by discrete codes." And Frank Kane, chief controller at Baltimore's Friendship Airport, notes that when two landing aircraft get near the field at altitudes around 2,000 feet, the alphanumeric signatures tend to get switched. But by then, each controller would know which blip was which, he says with the air of a man who dislikes such switching.

Sunpapers—Frank Gardina



New deal. Baltimore's Friendship Airport is getting a new instrument flight rules room with bigger radar scopes and a transponder system.

But even beyond specific quibbles about such matters as alphanumerics, New York controllers are bitter about not being consulted by the FAA on equipment decisions. In particular, they complain about the setup in the common IFR room, which is supposed to handle all traffic control for the area's three principal airports—Kennedy, LaGuardia, and Newark—from one central location when it becomes completely operational next year. John Meehan, vice chairman of the militant Professional Air Traffic Controllers Organization (Patco), dismisses the system as failure-prone and unworkable because of human factors. "It's not humanly possible for our people to cope with the amount of data provided," he says. "And the primary radar is at least 90% unusable. The last time the Vice President's plane flew into Kennedy, it was lost twice because of outages."

Lost horizons. His colleague Havlin agrees, noting that the information blocks, which are 7 inches long, tend to converge on display boards during rush hours. "But these problems were well known in 1966 when we went to Nafec for an eight-week course," he says. "The FAA just didn't listen to us."

Havlin is also critical of the new airport surveillance radar, claiming that storms cause white splotches, that make target tracking impossible. "With the old system, you could turn the equipment down and almost eliminate storm cells," he says. "Furthermore, displays are now projected through a radar bright scan converter. And somewhere in the process, something's been lost."

Rebutting such charges, John

Fitzgerald, a specialist in air traffic control with the FAA's Eastern office, says: "Traffic controllers are the most narrow-minded people in the world. I should know—I used to be one. The fact is, the equipment at Kennedy is new and they're just not used to it." Fitzgerald recalls that when radar was introduced at LaGuardia in 1947, the controllers wanted no part of it. "Eventually the bugs were ironed out, and we couldn't have done without it," he says. Fitzgerald concedes that controllers' beefs about having to call in for wind and runway visibility information are legitimate, but he points out that steps are being taken to include such data in the system.

Company man. Outside the FAA circle, there are, of course, other critics. Edward J. Shubel, deputy director of engineering at the Maxson Electronics Corp., takes the agency to task for selecting an approach involving transponder beacons. "If the FAA had opted for three-dimensional radar when the project was being evaluated, all the problems of the common IFR room could have been avoided," he says. Maxson has built 3-D systems.

Along the same lines, John Fling, a section chief working on ATC systems at ITT Gilfillan Inc., a subsidiary of the International Telephone & Telegraph Corp., believes continuous primary radar surveillance of all air traffic will be the solution. "Beacons are a good step, but not a final solution," he says. "The FAA did well to specify the mode C altitude-reporting feature. But this device isn't yet mandatory." Fling says, the agency, has been forced to rely on two-dimensional equipment because of the original high cost of 3-D radar. Unfortunately, he points out, office buildings and high-rise motels have been springing up around major airports, limiting coverage and inhibiting the effectiveness of such systems.

On the other side of the fence are men like Marvin Sleven, marketing manager for the Technical Products division of the Whitaker Corp. From his point of view, the use of limited-range transponders with a beacon system is an excellent approach. "Beacon systems are less apt to be a problem during bad weather," he says. "And 3-D radar is useful only in controlling aircraft not equipped with transponders. Besides, 3-D systems are expensive." Whitaker is working with the FAA on a beacon-like system known as DAIR, for direct altitude and identity readout [Electronics, July 24, 1967, p. 145]. As yet, however, the agency has not booked an order with the company.

Concrete proposals

Behind the air traffic control mess are deficiencies in facilities and manpower. Allan Horning, chief of airways facilities in the FAA's Los Angeles regional office, decries the lack of runways and taxiways. And automobile parking lots are encroaching on real estate needed for getting around the airport on the ground, he says. Another annoyance, according to Horning, is flight scheduling. "If the FAA were allowed to draw up the timetables, you could handle traffic control on the back of a dirty old envelope without all this sophisticated equipment," he says. "Without major changes in scheduling policies, no advances in systems will solve the problems faced by the nation's major airports."

The Airline Pilots Association, a trade union representing about 25,000 men, stated in recent testimony before the House subcommittee on government activities: "Immediate relief can be obtained by scheduling carriers' aircraft so as not to exceed the IFR capability of a particular airport and its environs, as well as by attracting general aviation to satellite facilities." A union spokesman notes that airports simply don't have enough runways and gates to handle traffic at peak hours. Baltimore's Kane agrees: "Most of the congestion is on the runways; it builds and backs up. There's no real problem in the airways."

Chain reaction. Fling of ITT Gilfillan also makes a pitch for satellite facilities to handle the air traffic overflow. "By trying to cram all aircraft into a limited area, we get nothing but jam-ups," he says. At Chicago's O'Hare and Midway airports, for example, it's not unusual to see 20 or 30 planes lined up waiting to take off during peak hours. However, the cause of this

. . . the FAA miscalculated its manpower requirements . . .

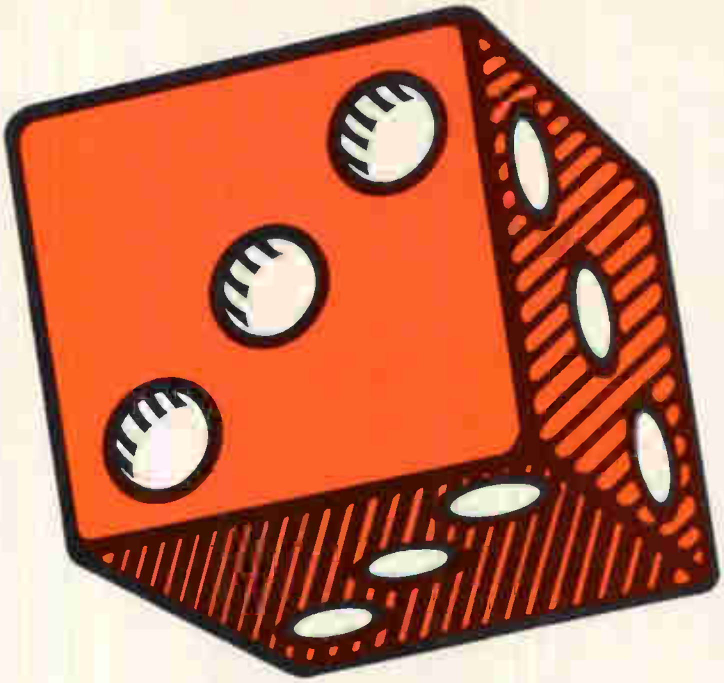
is not necessarily local. As a rule, the nose-to-tail trains of airliners on Windy City ramps result from stack-ups over metropolitan areas along the Eastern seaboard.

Fling also notes another problem area—the limited approach and departure patterns set up around big airports by the FAA for noise abatement. "Highly confined spaces inevitably lead to queues," he says. "And such narrow streets produce bottlenecks." Nor, in Fling's opinion, will the jumbo jets and SST's of tomorrow prove a panacea. "They'll simply put more people into the air more often; there won't be a reduction in traffic."

Help wanted. Another aspect of the control problem is rooted in the fact that the FAA, by its own admission, "seriously underestimated" its manpower needs. The agency's recently initiated program to hire more air controllers is at best a long-range solution. It takes from two to four years to train a competent controller, and though recruitment has been intensified, attrition continues to be a problem.

The situation at Chicago's O'Hare—the world's busiest commercial airport—is fairly typical of what's going on around the country. There, five-day work weeks have turned into six- and even seven-day propositions. And of every 10 prospects hired, six leave within a year. Some simply can't stand the pace while others wash out because of deficiencies. As a result of this turnover, there's a constant influx of trainees. At present, fully half the complement of control-tower personnel at O'Hare falls into this category.

Working conditions are much the same in Baltimore where, Kane says, his men get only one 15-minute break during an eight-hour shift. As a result, he can't train his new controllers to man every slot in the IFR room. But he bristles at the suggestion that such procedures might be risky. "There's nothing unsafe about what we're doing. When we get additional equipment, our operation won't be safer—just more efficient."



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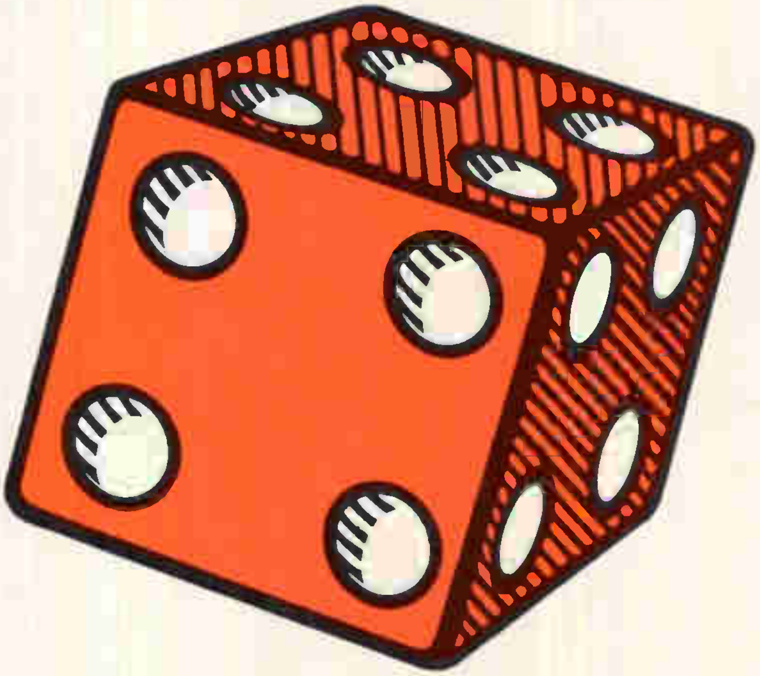

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India bids for self-sufficiency

But country's plan to boost production of electronic equipment and components continues to be hobbled by limited resources and unique sociological problems

By Bidyut Sarkar
New Delhi correspondent

By 1975, India should be turning out more than $400 million worth of electronic equipment a year, according to its government's official estimates. Since most of the capacity to produce this output has yet to be built, the country faces an enormous task. Current annual volume is less than $70 million, and, notes A.S. Rao, director of the electronics division of India's Atomic Energy Commission, about $65 million of this output depends on the collaboration of foreign interests.

India's plan for a self-sufficient electronics industry was codified two years ago when a government committee headed by the late Homi Bhabha (then chairman of India's AEC) issued a report on the subject. The committee put the country's required electronic-equipment production at around $3 billion over the 10 years through 1975, and identified consumer goods, data processing systems, instrumentation, radio communications gear, and components as the principal areas of involvement. Professing to see a silver lining in the Indian industry's backwardness and small size, the committee noted: "India is in the fortunate position of by-passing the stage-by-stage development in other countries and of planning the industry on the basis of the latest ideas and techniques."

On paper this sounds fine, but putting it into practice in an under-developed country of the size and sociological complexity of India is something else again. Thus the nation's technological goals, while modest by Western standards, may be hard to reach.

For example, the computer—now an accepted servant in industrialized societies—is proving a bone of contention in India. A month or so ago, employers and trade union representatives met in New Delhi at a special session of the standing labor committee to discuss the problem of automation. The unions criticized the increasing use of computers and other electronic equipment in offices and factories, expressing the fear that workers would lose their jobs. S.A. Dange, a Communist leader, says the country, in its present state of social development, does not require automation. Employers counter that automation would, in fact, accelerate economic development and create additional jobs for white-collar workers.

But the debate continues to be inconclusive; characteristically, a subcommittee is being set up to study the problem further and recommend guidelines for a national policy on automation. Meanwhile, the chairman of the government-owned Life Insurance Corp. announced that the company would soon put a machine in its Calcutta offices. Unionists have promised to resist such a move with "all their might," which appears to be considerable since a recent computer installation for Eastern Railways in that city had to be carried out under a heavy police guard.

Count. There are only 70 systems in the entire country, but their impact has been far out of proportion to their number. Among the first to order these machines were such public-service institutions as state banks, national railways, and other official organizations that have traditionally provided sinecures for a large segment of India's white-collar middle class. Opposition to computers is largely concentrated in this restive, vocal group.

The group's position is not without a certain reasonableness. Of the nation's 14 million jobless, a substantial number are educated. And many who support automation feel that perhaps the starting point has been ill-chosen. For example, a Bombay financial daily recently noted: "Babu (the educated clerk) is the cheapest and most surplus commodity in the country." The paper went on to argue that it would be impolitic to provoke him by eliminating desk jobs so long as the existing educational system was largely geared to producing more of his kind.

Unwelcome return. If the stakes were not so high, the computer situation would be somewhat laughable. Last month, for example, employees of the Indian Statistical Institute in Calcutta sought an audience with Prime Minister Indira Gandhi to protest against the introduction of computers at their organization. Ironically enough, the institute, which exists to utilize statistics as a key to unlock modern technology, collaborated with Jadavpur University in designing and building an Indian computer. In addition, the institute is the country's foremost data-collection and analysis agency.

Industrial applications of computers and electronic controls have so far been relatively limited in India. But many planners recommend a policy of selected introduction in export-oriented fields with well-defined growth potential; the steel, petroleum, petrochemicals, and fertilizer industries are cited. After computers have proved their worth and contributed to the general well-being in these areas, these planners reason, the machines will be more enthusiastically received

. . . a debate is also raging over the role of television in India . . .

in other sectors of the economy.

Notwithstanding the problems involved, the Bhabha committee predicted that India would need more than 5,500 digital computers by the mid-1970's; an estimated 90% of this total falls in the small-machine category. But many observers jeer at such projections, dismissing them as little more than wishful thinking. Economists and planners in India point to such problems as runaway population, insufficient agricultural output, a critical foreign exchange position, large-scale unemployment, labor agitation, and a chaotic political situation. There is, they say, a paucity of resources and conflicting demands for what's available.

Bright side

Skepticism is, however, by no means universal. For example, International Computers (India), a subsidiary of Britain's International Computers Ltd., last month began to expand its manufacturing plant in India. Asked if he's surveyed the local market, H.G. Treverton, managing director, says: "A country with population of over 500 million doesn't need a market study. It's so vast that even a small share of the pie can be very profitable."

Partnership. ICI will make its 1900 series of machines in collaboration with Bharat Electronics Ltd., a government-owned venture operating out of Bangalore where the bulk of India's infant industry is concentrated. The BEL facility will turn out semiconductor devices and electronic subassemblies for the ICI plant in Poona. In turn, ICI will set up a training school and test facility in Bangalore.

The first machine is due off the lines next May. Within the next four years, the joint venture is expected to produce some 300 computers. "We're going to start at the bottom and work up to larger models," says Treverton. Among the concerns that have booked orders for the ICI-BEL machines are Binnys, a textiles house in Madras, and the General Electric Co. of Calcutta; eventually, it's hoped, computers will be exported.

Right now, ICI has only one major sales and manufacturing rival, albeit a formidable one. IBM, which brought the first second-generation computers into the country in 1960, is turning out a full line of data processing equipment, including key punches, at its Bombay plant. And last year the company was the second largest exporter of light engineering goods from India, selling them in about 40 countries.

Generation gap. IBM recently produced its first made-in-India computer, a machine from the 1401 series. The unit was built largely with imported components, but the company, along with ICI, plans to increase the indigenous content of locally made machines. IBM will soon be making System/360 computers in India; the only third-generation machine now operating there is a Control Data Corp. 3600 that was installed at the Tata Institute of Fundamental Research in Bombay with the aid of a U.S. grant.

Honeywell Inc., though it doesn't have a manufacturing or sales facility in India, is still a major supplier of computers thanks to a special agreement with the government. Ten H-400 units are being installed to satisfy the data processing requirements of official agencies, among them the AEC in Bombay, Hindustan Aeronautics Ltd. in Bangalore, the Defense Research and Development Establishments in Poona, and the Joint Cipher Bureau in New Delhi.

Fuzzy picture

A debate is also raging about the role of television. Some ministers believe the medium should be primarily instructional, educating the Indian people in a variety of problems—national integration, food production, family planning, and the like. But others fear that such programs would draw the same response as the government-sponsored documentaries shown in movie houses—audiences frequently leave the hall for a smoke when they go on. They suggest that tv have a strong entertainment base to hold an audience and attract advertisers.

At the moment, India has only one tv station; located in New Delhi, it was established primarily for school broadcasts, which still

Consuming interest

India's vaulting ambitions for various industries have an unhappy tendency to fall short of the mark despite a succession of five-year plans and government regulation of production, distribution, and prices. The country's mediocre record thus far clouds its grandiose plans for self-sufficiency in electronics.

For example, the Bhabha report, which charts the country's technological path through the mid-1970's, bases many of its projections on the assumption that Indians should spend some $900 million on radio receivers and other consumer goods during the decade through 1975. Clearly, that sort of spending would require a sharp rise in the nation's standard of living. And since the average Indian still needs every rupee he can lay his hands on to fend off starvation, outlays for radio sets would seem frivolous.

Even if famine is eventually conquered—and the most optimistic official estimate defers self-sufficiency in agriculture to 1972—the electronics industry must still contend with unfavorable consumer attitudes. Traditionally, Indians have hoarded their savings—in gold or personal possessions. Manufacturers may get around the fact that most rural villages lack electricity by turning out battery-operated transistor sets. But it will take some time to overcome the prediliction of the poorer people to save whatever money they accumulate.

If radio has problems coming of age in India, television is barely born. The Indian government has made only a token provision for the medium in its fourth five-year plan. And it shows no inclination to make the massive investments in programing, studios, and transmission and relay equipment that will be needed to extend broadcasting beyond its single experimental base in New Delhi.

... prices for components have been cut by one-third since the start of 1968 ...

make up the bulk of its fare. Most —343 of 392—of the higher secondary schools in the city have receivers. But there's no real agreement as to how effective the medium is for such applications. "It's like fitting radar to a bicycle," says a teacher referring to the ill-equipped and overcrowded schools where tv tutoring looks out of place.

Ambitious advice. In a recent report on radio and tv, a government-appointed committee recommended "countrywide coverage by a television network over a period of about seven years." But the government—mainly because of a lack of funds—is thinking of establishing television services during the 1969-74 period only in metropolitan centers like Calcutta, Bombay, Madras, and Kanpur. The only definite expansion of television now on the schedule is the establishment of a station at Srinagar, the capital of Jammu and Kashmir State, by early 1970. About 2,500 sets will be installed in the Kashmir valley for community viewing, a move that's expected to facilitate national integration.

Two private companies, J.K. Electronics in Kanpur, and Telerad in Bombay, have each been licensed by the government to manufacture 10,000 sets, and a consortium of small concerns will make another 10,000. The first receivers are expected out of factory by the end of this year; the price tag on a 23-inch set will be around $250.

Ceiling

The government hasn't agreed so far to the requests of the licensed manufacturers to boost production to 100,000 sets to reduce unit costs. It has also not responded favorably to the suggestion that other companies be allowed in the field to produce sets at more competitive prices, possibly by using imported designs and components. Still, the consensus is that an annual output of 30,000 sets is woefully inadequate. K.K. Shah, minister of information and broadcasting, concedes that "Bombay alone could account for 100,000 sets in no time."

Though tv has "iffy" production prospects, radio does not. At the moment, the manufacture of radio receivers represents the biggest chunk of the Indian electronics industry. The number of sets is now estimated at around 10 million. In a country of over 500 millions, this is a small fraction, but this year another 2 million sets will be made.

The Bhabha committee estimated that India would require 14 million sets, including replacements, during the 10-year period through 1975. However, the panel also pointed out that cheaper sets would have to be produced; the cost of a locally made receiver is 50% higher than that of imports.

The high cost of components is largely responsible for pushing prices up. The committee found that the cost of locally made components needed to build a low-cost receiver would be about $8 in India, as against $4.75 in Japan.

The government-owned BEL plant in Bangalore, which supplies all of the country's requirements for receiving tubes and shares the manufacturing responsibility for transistors and related components with Semi-Conductors in Poona and Continental Devices in New Delhi, recently responded to the radio industry's clamor for lower-cost parts. Since the beginning of the year, BEL has slashed prices on transistors, diodes, and related parts by an average of one-third. Additional cuts are considered likely when and if new production facilities are brought on stream.

Foreign markets. O.V. Soskuty, a member of the United Nations mission on export production, says the principal obstacles to increased exports of Indian components and electronic equipment are high prices stemming from small-scale production and obsolete manufacturing methods. At present, the output of parts, including semiconductors, is running at an annual average of only about $8 million. But Soskuty feels this is the first segment of the Indian electronics industry in a position to make a dent in world markets—once it modernizes. "Handwork is a priceless ingredient in the efforts of artisans," he says. "But it has no place in situations requiring mass-production techniques."

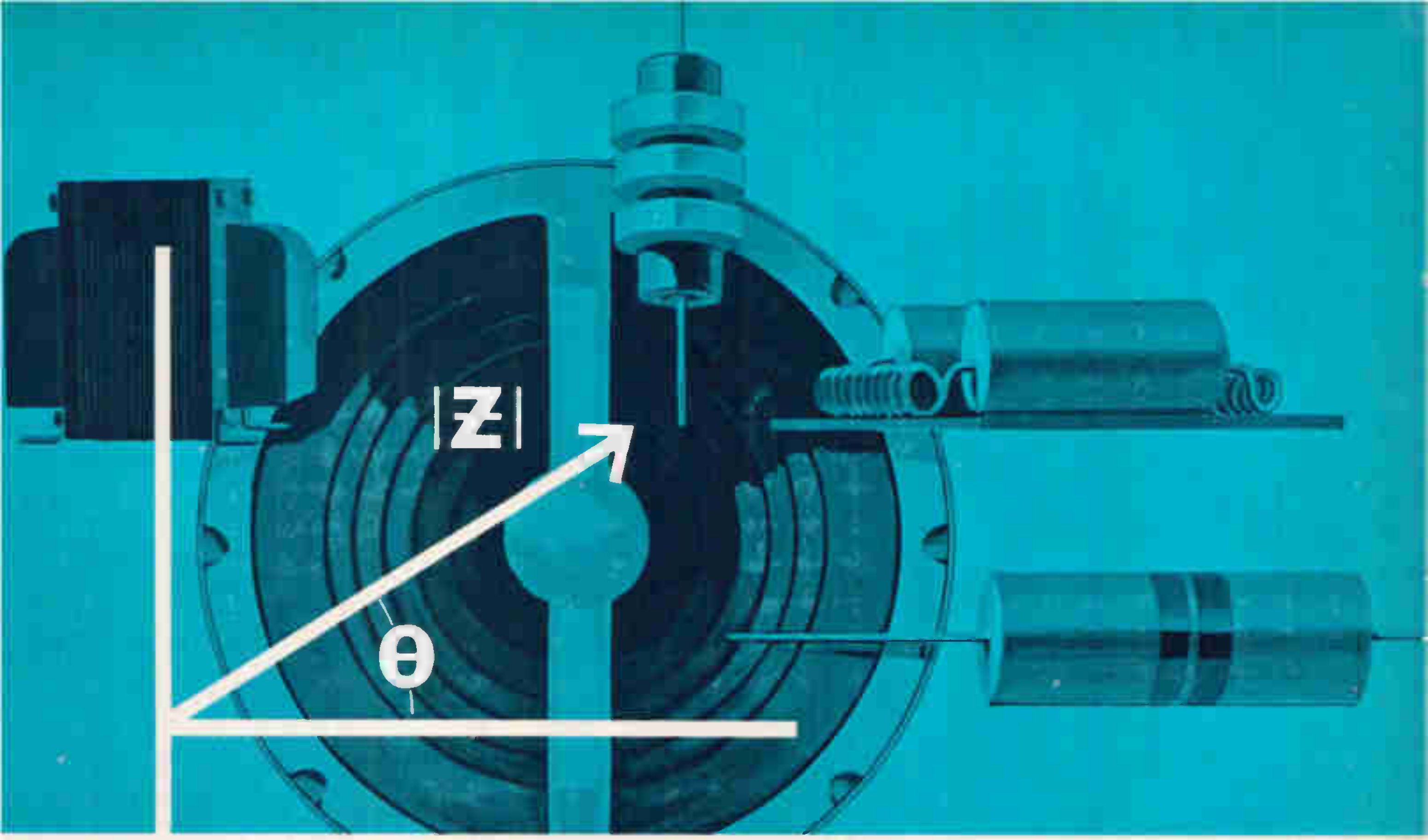
According to the Bhabha committee, after domestic radio receivers and other consumer products, communications systems, radar, and navigational equipment will constitute major fields of future development for India's electronics industry. It's estimated that India's defense services alone will account for about $700 million worth of equipment during the decade through 1975.

Defense requirements are largely met by BEL, which proposes to establish another factory to manufacture radar equipment; magnetrons will be produced by the company next year. The company is also setting up an industrial park next to its Bangalore plant. Here, small businessmen will run specialized assembly shops, producing electronic goods and components for BEL under close supervision. The company plans to double its dollar volume—now running at an annual rate of $21 million—by 1971.

In addition to defense equipment and components for the entertainment industry, BEL produces a widening range of industrial and medical electronic wares. It's also looking for export markets.

Salesman. Col. V.M. Bhide, who manages the company's business operations, visited Southeast Asia earlier this year on a sales mission. He reports that the BEL catalog came as a surprise to many who didn't realize that such a variety of equipment is produced in India. Trade delegations from Malaysia and the Philippines have since visited the BEL plant, and orders have been booked in a number of countries. Bhide's next sales mission will be to the Middle East later this year.

Another government-owned company in Bangalore, Indian Telephone Industries, produces equipment for Indian Posts and Telegraphs and other government agencies. ITI now makes more than $5 million worth of electronic equipment a year, and a new factory is expected to triple production in two years' time. Among ITI's prospective projects are entry into digital electronics and development of electronic exchanges.



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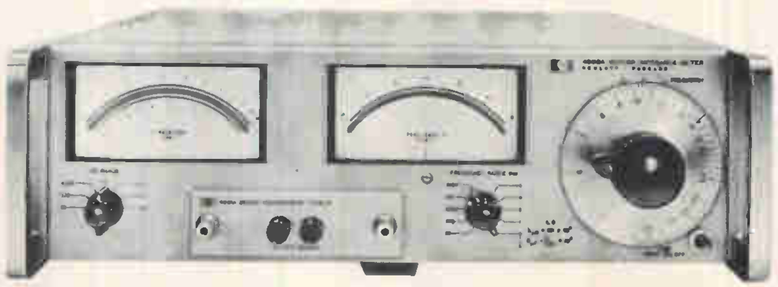

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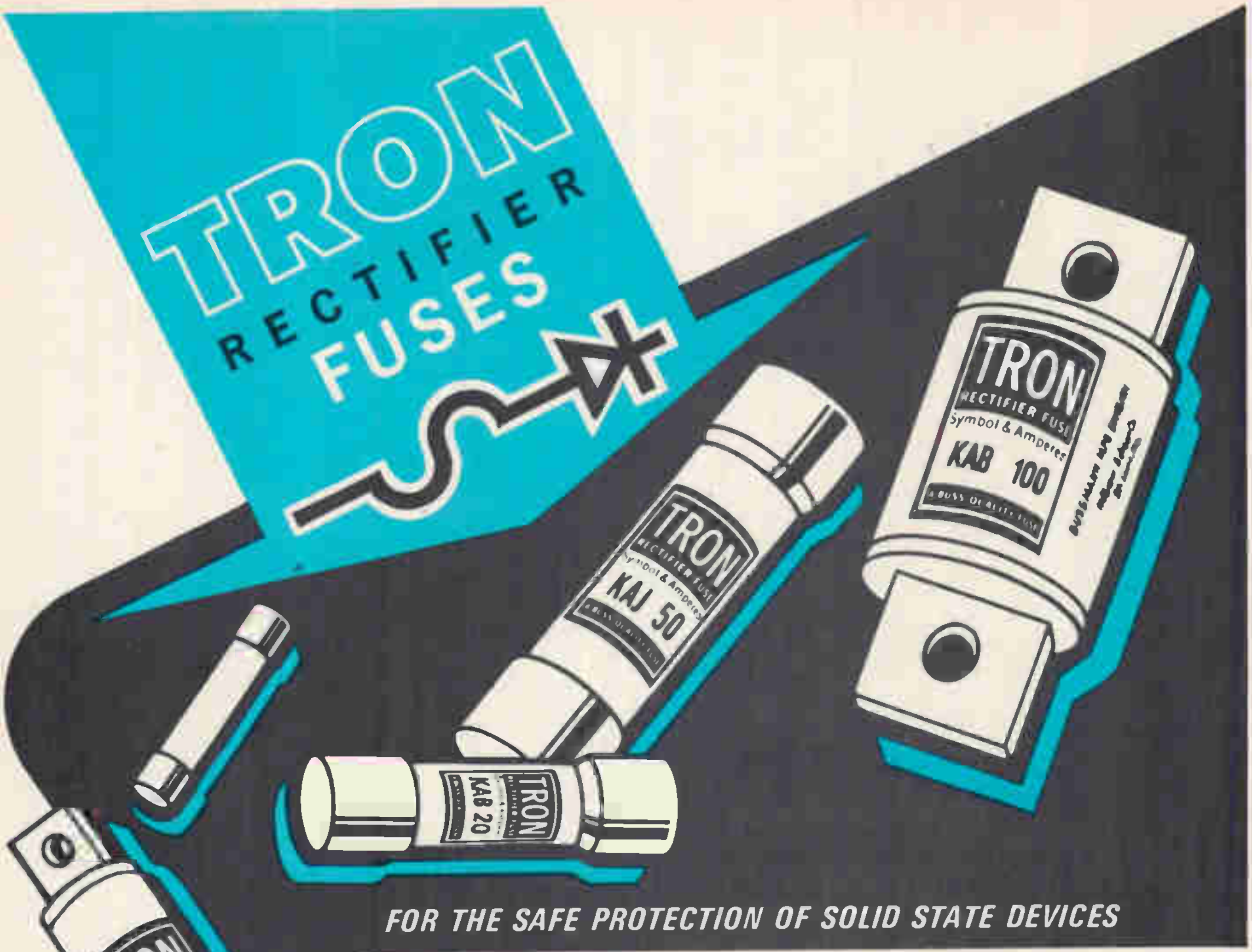

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Communications

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Scrambling and encoding devices can help police fight eavesdropping, but high costs and disagreement over methods are producing real static

Almost all policemen say they need communications privacy, but there's little agreement on how much is required or the best way to get it.

There is some consensus on the main problem. Systems with the desired features cost more than most departments can afford. This difficulty is illustrated by two new products: a device that can operate on as many as 1,024 codes but costs $2,500 in single units, and a scrambler that costs less than $300 but is conceded by its maker to be far from ideal.

On most matters, however, even officials in the same city sometimes disagree widely. In Los Angeles, for example, Anthony Gains, chief of the city's electronics division, says the traditional technique of frequency inversion is simple, effective, and reasonably priced. But Noel McQuown, the city's deputy police chief, says, "We have a man who can 'read' scrambled or inverted voice transmissions—without equipment—as well as our officers can understand regular transmissions. Voice inverters are not satisfactory. We're using this technique on one of our frequencies and we're convinced it's not the answer. It's a simple system and can easily be compromised."

And Walter Key, director of communications for the Chicago police, feels the same way: "It doesn't take much to unscramble a frequency-inverted message by someone who puts a little effort into it."

But many manufacturers believe frequency inversion fills the bill for most of today's needs. This adequacy—and the method's low cost—mean that voice-inversion devices are emphasized even though few in industry or public safety believe this technique is the ultimate solution to the eavesdropping problem.

No Federal grants

Some authorities doubt the need for voice privacy. Studies of crime list "no stated need" for scramblers, says Robert Emerich of the office of law enforcement assistance at the Justice Department. Emerich, one of the men in charge of Federal grants to police departments for testing of new devices, says that no money has been awarded for scrambler tests and that the department is looking to teleprinters and digital communications to provide security [Electronics, Aug. 19, p. 34].

But Robert Brookings, communications engineer for Burbank, Calif. says there's a definite need for simple, inexpensive scramblers. "You can go into any radio shop and for

$19.95 buy a device to monitor police transmissions," says Brookings. "The need for systems to prevent this on a daily basis is apparent, and these scramblers are most useful during civil insurrection or riots." Brookings is also chairman of the national planning commission for the Associated Public-safety Communications Officers Inc. (APCO).

First-step device. When Motorola Inc. introduced a frequency-inversion device at the APCO convention last month in Palm Springs, Calif., the company stressed that the scrambler wasn't the ultimate answer. John F. Mitchell, Motorola's vice president for communications products, told the police officials not to consider the adapter a total communications device. "That would require a vast number of codes," he said, "so that even a listener with the same device would not likely find the right code before it was changed."

Private line. Adapter for two-way radio inverts signal to foil eavesdroppers.

Audio information is received at the microphone terminals of Motorola's equipment and converted into double-sideband suppressed carrier information in a balanced modulator. Low-pass filtering then eliminates the upper sideband, resulting in a scrambled signal that's a frequency-inverted image of the original information.

In the receiver, audio from the discriminator is fed into the scrambler, where an identical frequency conversion occurs, transforming the audio signal to its original makeup. A clear or code-selector switch turns the scrambler on or off. The unit sells for less than $300.

"The usual echo or 'rain barrel' effects encountered with this type of scrambler have been eliminated through the use of fast rise-time computer switching techniques," Mitchell says.

Where are you? Chicago's Key was at the convention and pointed out a drawback of such single-code scrambling devices by asking: "What's to stop someone from stealing a squad car and stripping it of its scrambler?" Indeed, thefts of police cars just to get at their radios aren't uncommon, particularly in the big cities.

A number of police officials have long opted for car teleprinter systems that can automatically record both messages and the output of a computer. And they've sought to increase security even more by getting a system that would route the message to only the car or cars being called.

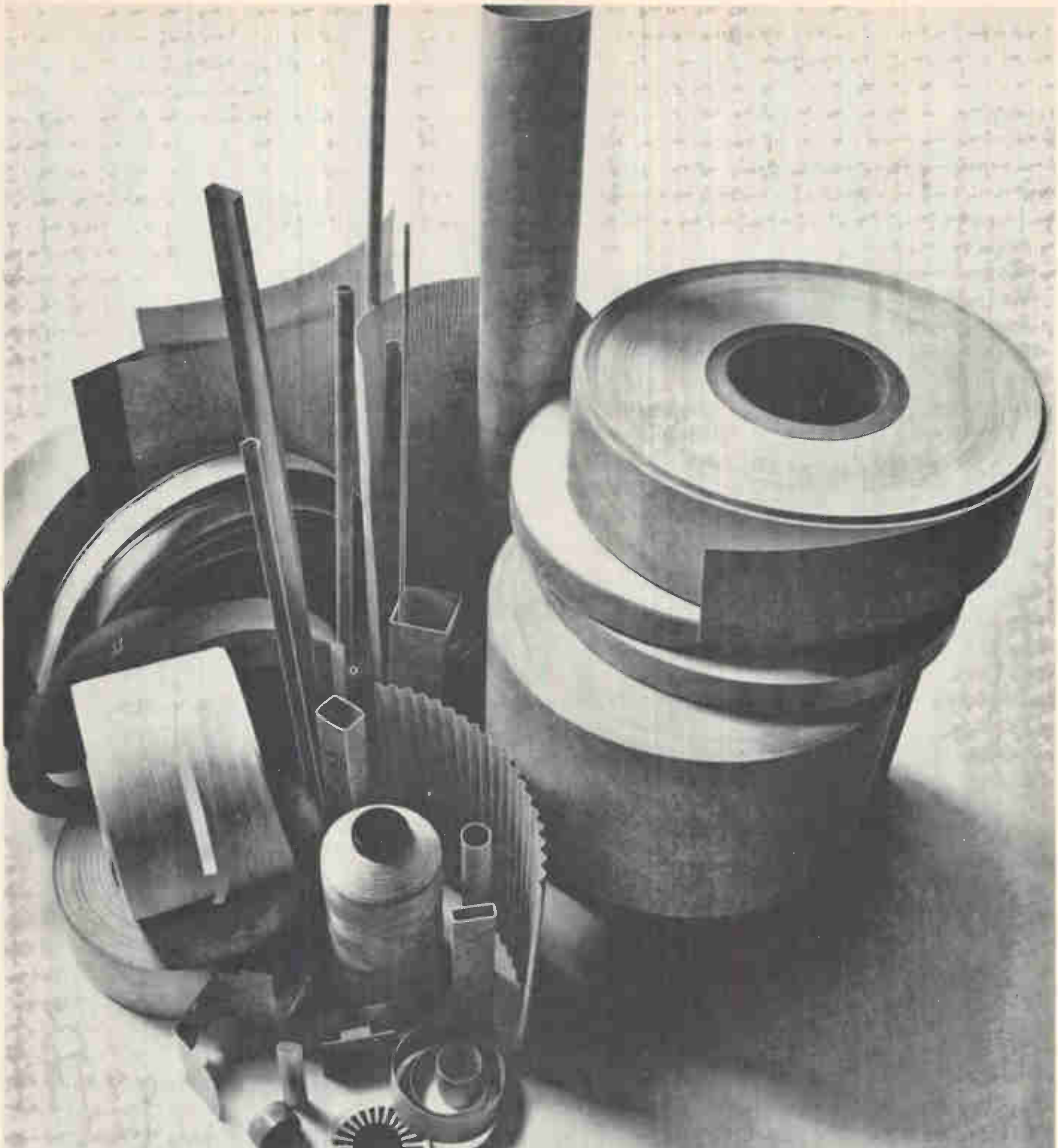
Motorola, in effect taking both sides of the voice-vs.-printer issue, also showed such a system at the convention. The VP-100, whose price hasn't been disclosed, prints 100 characters a minute. An array of 35 dots in a 5-by-7 matrix forms each character. Impulses bend six piezoelectric ceramic crystals, which deflect the printing bar. The bar forms each character's pattern of dots and spaces on paper containing a self-marking material.

Codified conversation

For those who want more privacy than frequency inversion allows, Technical Communications Corp., a small Lexington, Mass., company, has developed a voice device [Electronics, Sept. 4, 1967, p. 25] whose codes can be changed at any time by resetting one or more of 10 switches; the number of possible code combinations is so large that the chances of timely deciphering are remote.

"The device gives you safety in numbers," says Arnold M. McCalmont, president of the company. "The likelihood of a stolen unit being set to the correct code is close to zero." Units can be equipped to operate on any one of 128, 256, or even 1,024 codes.

The method of encoding, McCalmont says, "is a hybrid technique, part digital, part analog. This keeps the price down to under $800 in quantity." The $800 price is for orders between 100 and 1,000; a single unit costs $2,500.



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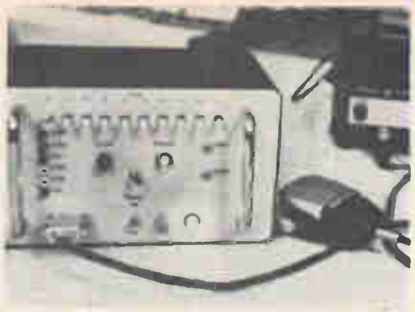


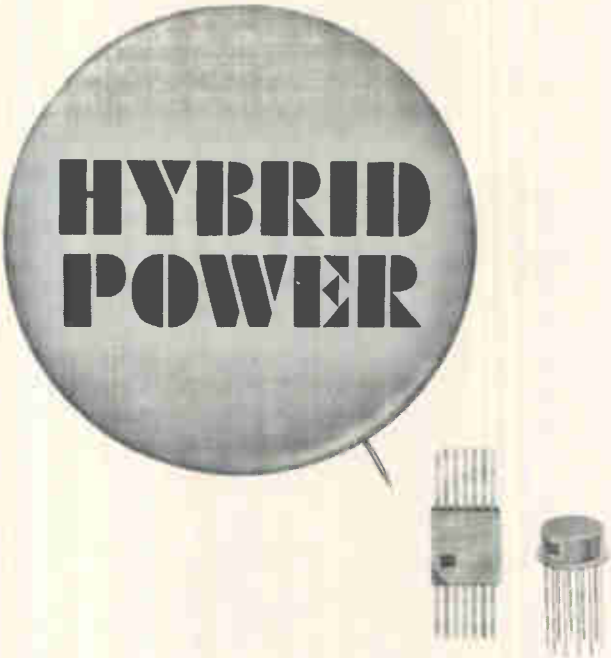
Cryptic. Changeable code makes gibberish out of audio signal.

McCalmont adds that privacy is enhanced by the way the device is attached to the radio's circuitry. "Even with the device and a police radio, a thief would still get gibberish unless the little black box were properly connected," he says. Regarding the coding technique, McCalmont will say only that after encoding, "the radio's output signal no longer looks like a voice-modulated carrier, but rather like random noise centered on the carrier frequency."

Inversion plus. Another device demonstrated at the APCO convention was the Tele-Signal Corp.'s $750 programable scrambler, called the Codavox 2193M. Up to 450 codes are available.

Built specifically for mobile radio units, the plug-in device requires no adaptation of the basic set, according to Russell A. Popp, project director at Tele-Signal, a subsidiary of the General Precision Equipment Corp. The device splits the voice signal into five 500-hertz bands, which pass through a switching matrix. This displaces and inverts them in accordance with a variable code. The code is set with thumbwheel switches or a plastic card plugged and locked into the system. "Patrolmen could be issued a card each day with the day's code on it," says Popp.

"A secure system is what the police chiefs all over the country want and need," Popp notes. "I can buy a $20 receiver plus a couple of dollars worth of components and decode signals from the $300 voice-inversion scramblers. We sell these scramblers—I tell the police chiefs we sell them and then I tell them they don't want these scramblers. Any police official who knows the communications business would throw me out if I talked about voice inversion alone."



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Circle 198 on reader service card

. . . simple plug-in device sought for privacy . . .

Cost remains the main barrier to extensive use of scramblers. "A lot of chiefs want to buy scramblers but just don't have the money," says Everett R. Sarratt, president of Mieco Inc., which makes an inversion scrambler with a twist—the transmitting and receiving frequencies can be changed independently. This not only makes it harder to intercept a conversation but also makes it almost impossible to listen to both sides without sophisticated frequency sweepers. The system sells for $3000, and even Sarratt concedes that the price is still too high for extensive police use in the nation's cities.

New York, which has used some scramblers, is installing a computer-based police dispatch system. Data from a message coming into headquarters will be typed into the computer, which will relay it to selected squad cars for printout. The system is expected to be completely operational within two years.

Even after this goes into effect, New York's finest will still need scramblers for their voice channels. Stephen Walsh, a deputy inspector, says the police want scramblers even though interception of police broadcasts isn't a big problem. He says the devices tested so far have been plagued by drift, making daily tuning necessary.

Incompatibility. These scramblers were the speech-inversion type, and all were in the $300 range. Walsh says that for a reliable system the police would probably go to $500 or $600, "but we are not willing to spend $3,000 each for sophisticated scramblers."

Jules Beckley, a shop foreman who maintains the San Francisco police network, says the city experimented a couple of years ago with a scrambler. It worked well, but it was too expensive and wasn't compatible with existing units.

"It cost $400 per unit plus $800 for the base station," Beckley says. "We have 265 patrol cars; to outfit them all would have been impossible. I don't get $15,000 a year to maintain the entire fleet."

"What's needed," he says, "is a simple plug-in adapter for under $100."

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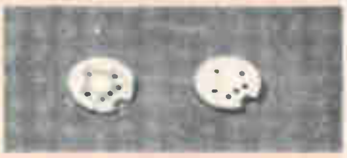
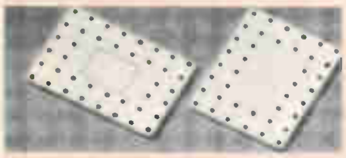


O. D. .367 ± .003
Holes .041 ± .002
Flat Within .002



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Thickness .035 ± .002
Camber .003

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Ceramic ± .002
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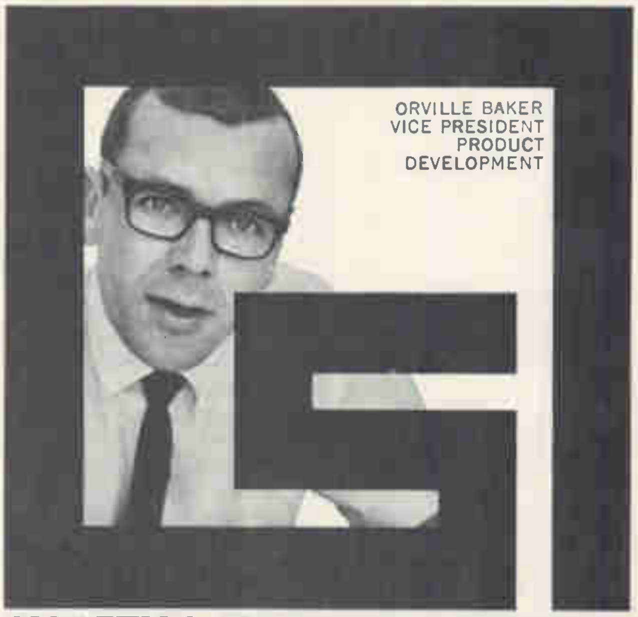

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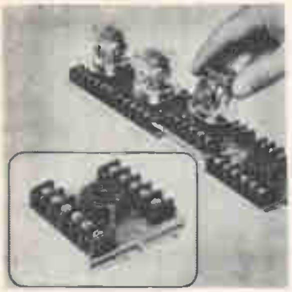
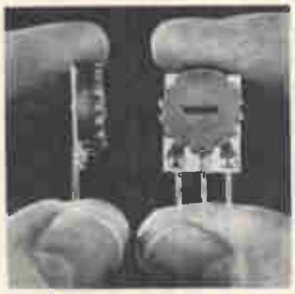
New Components Review

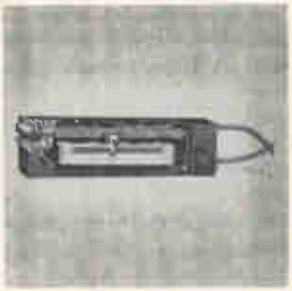


Track-mounted socket assemblies hold 11-pin 3pdt relays. Sockets have recessed center post chamber, which allows rocking out relays without danger of fracturing off center post. Prepunched vinyl track allows fast mounting of up to 16 sockets on 46 in. length, with only 2 or 3 mounting screws instead of 2 per socket. Curtis Development & Mfg. Co., 3250 N. 33 St., Milwaukee. [341]

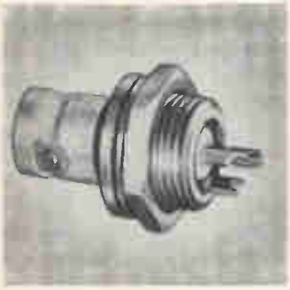
Rotary switch is available with 1-, 2- or 4-pole circuitry in less than 0.7 in. behind panel and diameter of 0.562 in. It is offered with p-c or solder-type lug terminals, military or commercial styles, shorting or nonshorting contacts, and adjustable or pre-set stops. Life expectancy for a 50 ma current level is 25,000 cycles. Grayhill Inc., 523 Hillgrove Ave., La-Grange, Ill. [342]



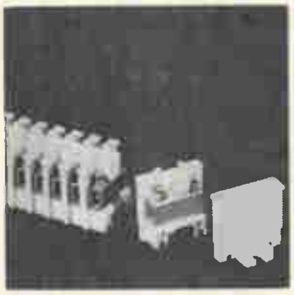
Cermet trimmer resistors called Centrim are for commercial, military and industrial applications where component space is limited. Units for commercial use are rated at 3/4 w per section at 70°C, derated to zero at 125°C; those for industrial use, 3/4 w per section at 85°C derated to zero at 175°C. Centralab Div. of Globe-Union Inc., 5757 N. Green Bay Ave., Milwaukee. [343].



Rectangular metal film trimmer 2851 is a 1¼-in. device featuring infinite resolution and low noise. It will operate at ambient temperatures up to 175°C and is humidity-proof. Temperature coefficient is 100 ppm/°C max. Resistance values available range from 10 ohms to 10,000 ohms. Amphenol Controls Div., Bunker Ramo Corp., 120 S. Main St., Janesville, Wis. [344]



BNC receptacle KC 79-67 has a Teflon insulated ground lug to isolate r-f from the equipment panel. It is designed to be mounted in a ½ in. diameter hole, on a $\frac{3}{32}$ in. thick panel. A bayonet coupling type for use with r-f cables, it is protectively coated with TR-5 tarnish-resistant finish. Price is $1.43 each in quantity. Kings Electronics Co., 40 Marbledale Road, Tuckahoe, N.Y. [345]



Polypropylene miniature 300-v sectional terminal block, with ¼-in. center-to-center spacing, handles a wire range up to No. 12 Awg and eliminates lugging. Contact sections are $\frac{13}{16}$ in. high and 7/8 in. wide. Each 12-in. length can handle 48 circuits. The contact sections can be snapped off or added as needed. Buchanan Electrical Products Corp., Union, N.J. [346]

Subminiature filters series 2500 for feed-through mounting are housed in 3/8 in. cylindrical cases. Six "Pi" and "T" types are rated 0.25 to 5 amps, with voltage ratings of 50 v d-c at 85°C to 30 v d-c at 125°C. Six "L" types have current ratings of 60 ma to 10 amps, with the same voltage ratings as in "Pi" and "T" types. RF Interonics Inc., 100 Pine Aire Drive, Bay Shore, N.Y. [347]

Time delay relay with a de-energize circuit improves both the reset time and reliability of industrial time delays. The timing section is activated only during the actual timing cycle. Reset time is as low as 0.025 sec. Rated life is in excess of 10 million cycles. Price is $10 to $30 depending on specification. Hoagland Instrument Co., 65 Chestnut St., Red Bank, N.J. [348]

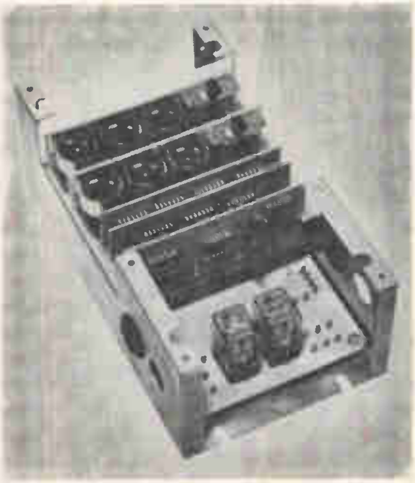
New components

Frequency switch resists noise

Device said to be cheaper, smaller, faster than its counterparts averages the input

Nobody likes being chased around by a runaway motor, let alone paying to repair one. This is one reason why most pieces of rotating machinery are watched over by frequency-sensitive switches, ready to turn off when rotational velocity reaches the danger point.

G.I.D. Ltd., London, has built a switch, the Z-Trip, that can be tripped by a change as small as 0.1% of a set frequency. The company says the Z-Trip is cheaper, smaller, and faster than similar devices with the same switching differential. Besides, says G.I.D., the



Shaping up. The Z-Trip works with any wave shape over a wide range.

. . . available with either d-c or relay output . . .

Z-Trip isn't easily fooled by noise.

According to the company, other frequency-sensitive switches use either digital-counting or analog-integration techniques. The Z-Trip compares the duration of the average input wave with a reference pulse. It's this averaging, usually done over eight cycles, that enables the device to ignore most random noise. The trip frequency is set by adjusting a potentiometer to change the pulse width.

Two routes. The Z-Trip works with inputs from d-c to 20 kilohertz, and the trip point can be set from 10 hertz to 12 khz. Trip frequency can be approached from either above or below.

The switch has two reset modes. It automatically resets itself when the frequency moves away from the trip point, or it stays tripped until reset by hand.

The output change is either a shift from 0 to 6 volts d-c or a relay closure.

When fitted with its optional integrator, the switch's output voltage is directly proportional to the frequency of the input.

In Britain, the Z-Trip's price ranges from $48 for a d-c output switch to $75 for a relay-output model that can switch a-c signals.

The switch is packed into a metal frame, 228 by 125 by 89 millimeters, and the whole package weighs 3 pounds. It's also available in a weatherproof housing that brings the weight up to 8 pounds.

In a couple of months, G.I.D. will bring out a Z-Trip that switches when the input frequency moves out of a preset band. The British price for this model will be around $170.

Specifications

Input	0.5 to 150 v, waveform unimportant
Input impedance	200 kohms
Set-point stability	0.015%/°C, typical
Switching differential	0.1% of set point (fixed), 1% to 10% (variable)
Response time (1%/sec rate of change through set point)	0.08 sec at 100 hz 0.008 sec at 1,000 hz Figures halved if rate of change greater than 50%/sec
Temperature	−10°C to +60°C

G.I.D. Ltd., 142/146 Old St., London [349]

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Circle 203 on reader service card

Another photocell senses ultraviolet

Using a phosphor to detect radiation, this British device follows U.S. unit to market

A couple of months ago, Clairex Corp. introduced the first photoresistor sensitive to ultraviolet radiation (Electronics, June 24, p. 163). Now there's another on the market, this one made by England's Hird-Brown Ltd.

But this British cell, the UVS, isn't a me-too device. Its peak sensitivity is at a lower wavelength than that of the Clairex device, and it senses ultraviolet radiation with a phosphor rather than with zinc sulfide.

Hird-Brown hasn't yet set a U.S. price, but it's offering the UVS in Britain for $30. Clairex is selling its device in sample quantities in the U.S. at between $10 and $20.

Falling off. The cell's resistance drops two orders of magnitude when u-v intensity goes from 1μw to 100μw/cm^2.

So the U.S. customer will probably have to pay more for the British cell than he would for the one from Clairex. However, for the extra money he'll get a device that's less likely to be fooled by visible violet light. The Clairex cell's greatest sensitivity is at 3,700 angstroms, the fringe of the ultraviolet region (200 Å to 3,800 Å); the UVS's response curve peaks at 2,537 Å and falls away to mini-

Both a universal counter and a DVM

Heath Universal Digital Instrument

only . . . $1250

Now you need only one instrument, the Heath EU-805A to make any digital measurement you want. The UDI will measure all these functions: Frequency, Period, Ratio, Time-Interval, Events Count, Integrating DVM and Voltage Integrator. Combining in one standard rack package a DC-12.5 MHz Multi-Purpose Counter/Timer with a 0.05% accuracy Digital Voltmeter, the new Heath/Malmstadt-Enke EU-805A offers compactness on your bench and unmatched versatility. An original modular design based on plug-in cards with TTL IC's — cards stay in place for all 7 functions. And you can add new cards for other functions and protect the instrument from obsolescence.

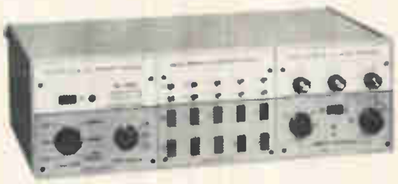
The UDI features convenient fast cycling on slow time bases, unique summing function for continuous summation without display reset, memory starts new count scaling before previous count has cleared, variable display time from 0.1 s to 30 s, 6 digit read-out plus over-range.

The two identical high-sensitivity (10 mV) input comparators provide 1 MΩ impedance, complete range of trigger controls (including Automatic Mode), oscilloscope monitoring of triggering point and four levels of input attentuation to accept up to 500 V. Input pulse resolution is better than 50 ns. Time base stability is better than 5 in 10^9 (short term) & 1 ppm (long term). Time bases range from 1 us to 10 s. Accuracy is ±1 count.

DVM section has Automatic Polarity Indication, 5 x 10^9 ohm input impedance on separate 1 V range (10 MΩ on the others) four ranges from 1 to 1000 V, 10 uV resolution, 0.1 second to 10 second integrating time and V-F output available at rear panel.

The EU-805A is obviously the instrument you need . . . and it is obviously priced right: $1250. Less DVM order EU-805D at $940. DVM conversion pack costs $340.

The UDI is part of the Heath Modular Digital System. Many of its cards may be used in the Heath/Malmstadt-Enke Analog Digital Designer EU-801:



The ADD permits investigation and design of various analog and digital circuits and instruments, by plugging-in circuit cards to its power, binary and timing modules. Connections are made with ordinary wire and component leads.

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(prices & specifications subject to change without notice) EK-253

. . . resistance drops from 27 kilohms to 1 kilohm . . .

mums at 2,300 Å and 2,650 Å.

Tough case. Hird-Brown engineers pack their cell in a stainless-steel case 15.8 millimeters in diameter and 16.6 mm high. Inside the case, which has a window of quartz-based glass, there's a phosphor that's excited by radiation and a detector that's sensitive to the light emitted by the phosphor.

In one model of the new cell, the UVS-254-53, resistance slides from 220 to 3.25 kilohms when the intensity of 2,537-Å radiation moves from 1 to 100 microwatts per square centimeter. The UVS-254-54 goes from 27 kilohms to 1 with a change of the same intensity.

Since the resistance-versus-intensity plot is logarithmic, the cell can easily be adapted to measure ultraviolet radiation as well as detect it.

Afterglow. Hird-Brown hasn't measured response times, but it puts rise time at 15 milliseconds and estimates that decay time is probably a lot longer because of phosphor afterglow.

The company had no specific application in mind when it built the cell; it says the UVS can be used any place vacuum tubes and barrier-layer detectors work. The device can be employed in hospitals to check a room's sterility by measuring the ultraviolet level, and in photography labs to detect those amounts of ultraviolet radiation that could distort colors.

A UVS handles up to 70 volts a-c or d-c, dissipates up to 0.5 watt, and works at from —40° to +70° C. The temperature coefficient goes from 1% to 1.8% per degree centigrade when intensity drops from 100 μw to 1 μw per square centimeter.

The cell was intentionally designed so that it can be easily fitted with a constant-temperature oven for increased stability.

Delivery time is one week for small quantities and six weeks for lots of more than 1,000 units. For two to five devices the price in Britain is $26.40, and in quantities to 10, the price is $24. For more than 10 cells, price is by quotation.

Hird-Brown Ltd., Bolton, England [350]

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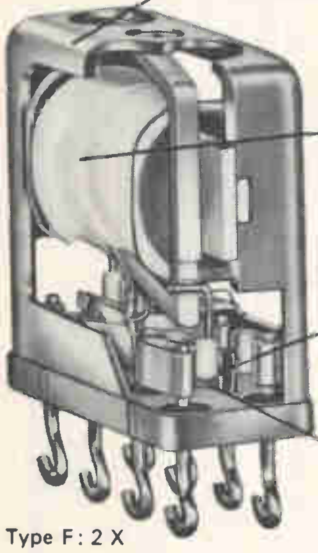
Clare meets your needs ...exactly!



Type F: 2 X

Only Clare provides the range of performance characteristics...in crystal can to subminiature sizes...to meet military, industrial, and commercial relay applications without compromise.

The simple, precision construction of the Clare F relay (left) is the proven performance base of all Clare military relays—tough, dependable, built-for-action.

For overall switching reliability, every Clare military relay meets appropriate MIL-R-5757D requirements. All serve throughout a temperature range of —65°C to +125°C. Shock capabilities range to 100G...vibration to 30G. Hermetically sealed, welded cases eliminate contamination.

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For complete information, circle Reader Service Number—or ask for data on the relay of your choice...Write Group 9N7.

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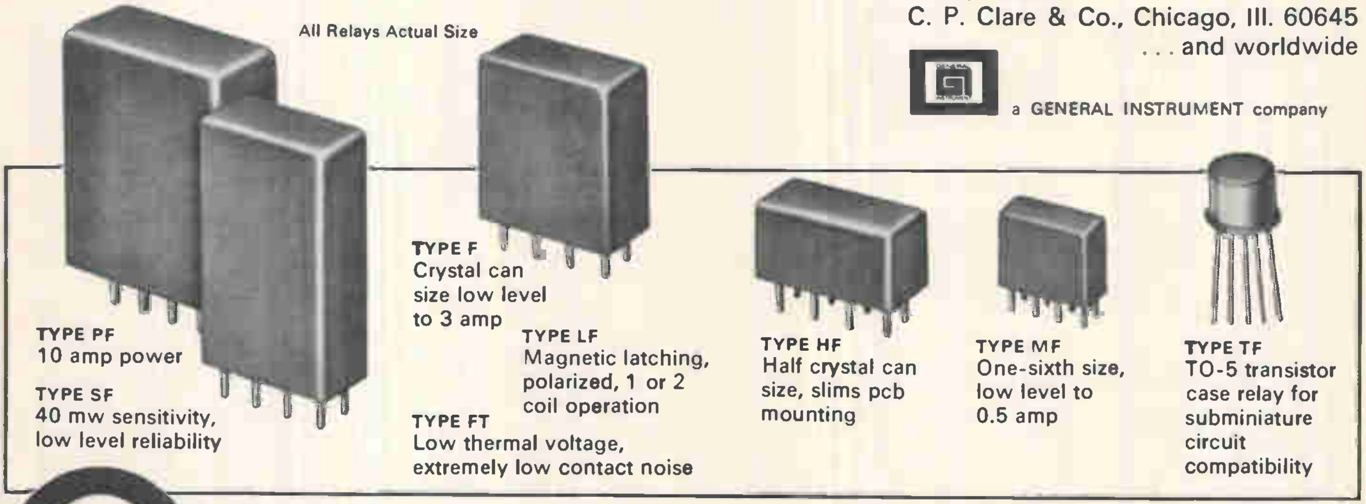
All Relays Actual Size

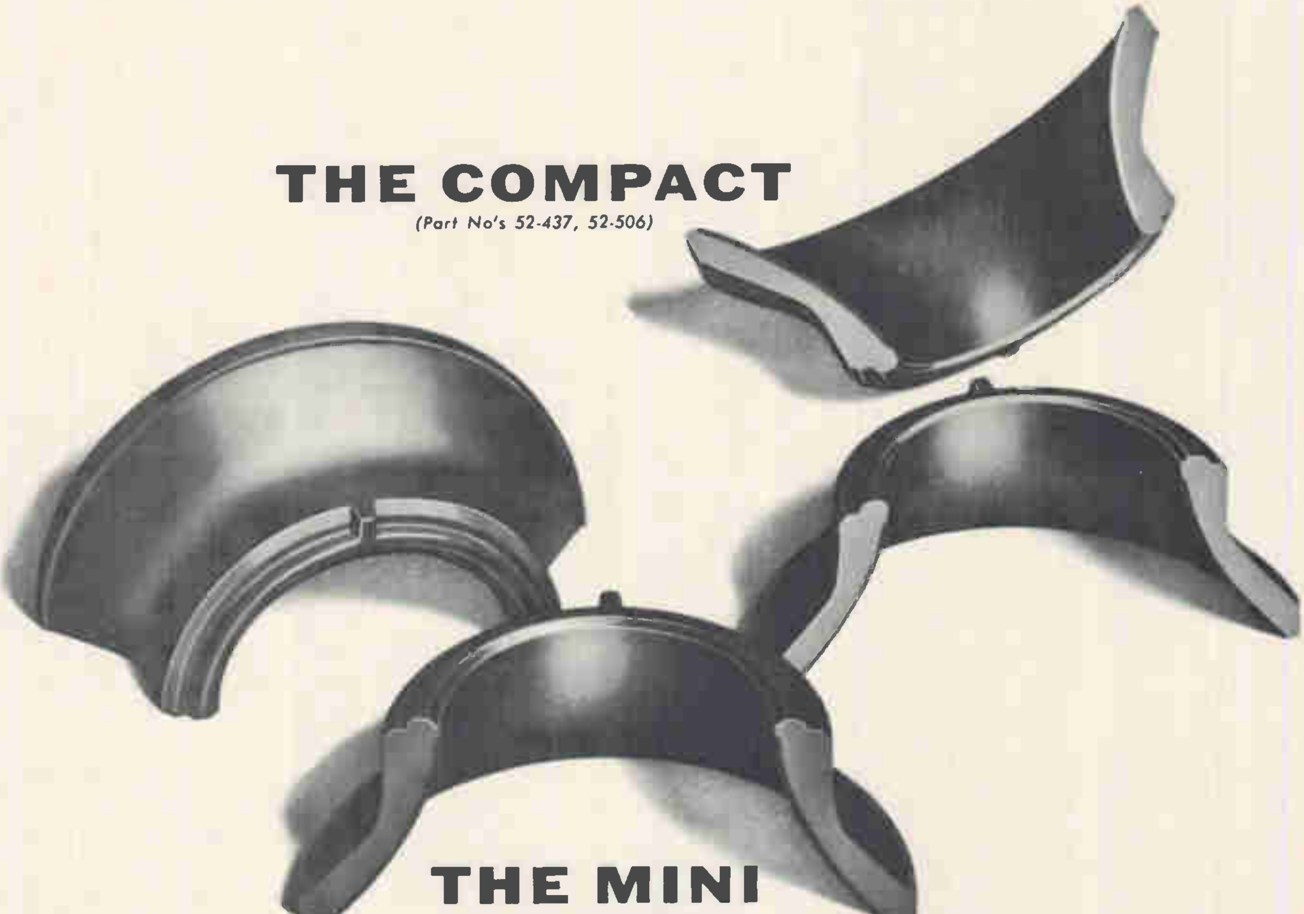


CLARE MILITARY-TYPE RELAYS

for airborne, aerospace, and ground support equipment, communications, and industrial and commercial control systems

Circle 208 on reader service card

TWO NEW CERAMAG® 90° COLOR YOKE CORES FROM STACKPOLE



With deflection yoke cores that are 25% smaller, consider the savings in copper, hardware, labor and shipping costs, too. Both the Compact and Mini yoke cores are moulded from Stackpole's standard 7B ferrite material. Even though you benefit from smaller, more compact yoke size and appreciably lower prices, there is no sacrifice of nickel content with Ceramag® 7B. Curie is 160°C. ± 10°C. For specifications, samples, prices and delivery, call: D. L. Almquist, Electronic Components Division, Stackpole Carbon Company, St. Marys, Pa. 15857. Phone: 814-781-8521. TWX: 510-693-4511.

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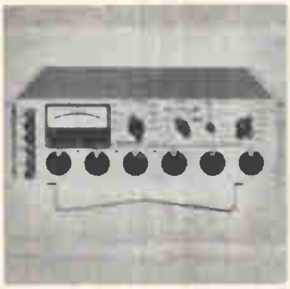
New Instruments Review

Digital multimeter 4243 measures d-c and a-c voltages and resistance to an accuracy of 0.01%. The solid state unit is for systems as well as bench-type uses. D-c and a-c voltage ranges are 0.9999 v d-c, 9.999 v d-c, 99.99 v d-c, and 9999.9 v d-c, and resistance is measured from 999.9 ohms to 9.999 megohms. Price is $850. Trymetrics Corp., 204 Babylon Turnpike, Roosevelt, N.Y. [361]

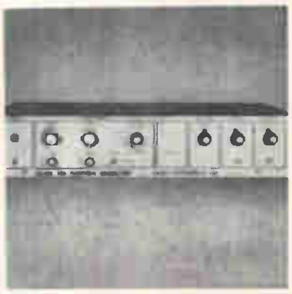
Field effect meter model FE149 features simplified operation with push-button design. With accuracy of 1.5% on d-c and 3% on a-c, plus a 7-in. meter and mirrored scale to prevent reading errors due to parallax, extremely accurate tests are assured. The unit provides 8 d-c voltage ranges to 1,500 v; 8 resistance ranges to 6,000 megohms. Price is $149. Sencore Inc., Addison, Ill. [362]



Differential voltmeter model A-72 features ±0.002% accuracy and 2 ppm/day stability. Short term stability is such that a 1/10 ppm or 0.1 μv voltage charge can be detected. The instrument has 6 readout dials and 5 ranges from 110 mv to 1,100 v full scale. Price is $1,125; availability, 10 days. Medistor Instrument Co., 4503 8th Ave. NW, Seattle Wash. 98107. [363]

Capacitance tester 1212 provides 1 Mhz digital display of dissipation factor. Capacitance is read from 0 to 1999.99 pf with basic 6-digit in-line readout accuracy of ±½% of reading, ±3 digits. Dissipation factor is read on the 3 in-line readouts from 0 to 9.99% with accuracy of ±1% of reading, ±3 digits. Micro Instrument Co., Crenshaw Blvd., Hawthorne, Calif. [364]

A-c/d-c transfer standard model ATS converts a d-c digital voltmeter, potentiometer, or any d-c measuring system to a true rms measuring system. Its rated accuracy, 0.01% of reading, covers the range of 0.25 to 1,000 v and 5 khz to 20 khz. The unit sells for $3,500 and is available from stock. Singer Co., Metrics Division, 915 Pembroke St., Bridgeport, Conn. [365]



Function generator model 503 uses 3 independent amplifiers to provide 3 simultaneous and separate outputs at frequencies from 0.0001 hz to 1 Mhz. All three output signals can be varied from zero to approximately 25 v peak-to-peak into 600 ohms. Units measure 16¾ x 3½ x 14¾ in. Price is $525; availability, stock to 3 weeks. Exact Electronics Inc., Box 160, Hillsboro, Ore. [366]

Pulse generator type 115 is a 10-Mhz, 10-v unit for use where a variety of pulse amplitudes, polarities, and shapes are required. Risetimes and falltimes are continuously variable from 10 nsec to 100 μsec and periods variable from 100 nsec to -0 msec. Pulse widths are variable from 50 nsec to 500 μsec with duty factors to 75%. Tektronix Inc., Box 500, Beaverton, Ore. [367]

Solid state noise generator model 602A-1390 provides a random output. Three output ranges of 5 hz to 20 khz, 5 hz to 500 khz, and 5 hz to 5 Mhz are selectable by a front panel range switch. Output level is continuously adjustable from 0 to 3, 0 to 2, 0 to 1 v rms on the 3 ranges respectively. Price is $330. Elgenco Inc., 1550 Euclid St., Santa Monica, Calif. [368]

New instruments

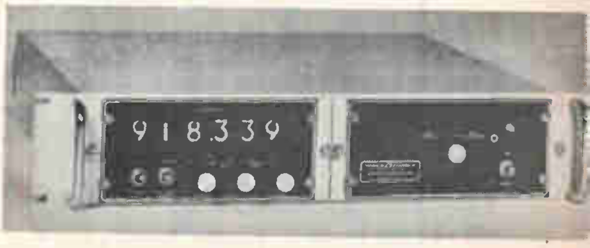
Frequency counter extended into uhf

Basic digital readout for receiver plus companion unit make up a low-cost synthesizer covering 30 to 1,000 Mhz

By pairing its $2,800 DRO-302A digital-readout counter with its new $1,750 DRX-1000 digital-readout extender, Communication Electronics Inc. has developed an instrument that displays tuned receiver frequencies from 30 to 1,000 megahertz.

"They make a poor man's synthesizer," says the firm's engineering manager, Peter S. Pao, since comparable units, designed strictly for laboratory use, cost about $15,000. Although CEI's system isn't quite as accurate as the more expensive models (the duo will stabilize a receiver to within ±1 kilohertz), it's not only cheaper but operates over a wider range than the synthesizers, which usually cover up to 150 Mhz.

Steering the tandem is the DRO-



Stretchout. Extender, at right, pushes counter's range up another 700 Mhz.

302A counter introduced earlier this year. Used alone, it can indicate the tuned frequency of a receiver with a 21.4-Mhz. intermediate frequency over a range of 30 to 300 Mhz. And it can display the tuned frequency of high-frequency receivers down to 10 khz.

The solid state DRX-1000 extends these capabilities another 700 Mhz, into ultrahigh-frequency bands. Receivers or tuners can be locked to any desired frequency in the 30-1,000-Mhz range in 1-khz increments; the frequency is indicated on a Nixie-tube display.

The extender's only operating control is a range switch that selects input frequencies in the 30-to-300 Mhz or 235-to-1,000 Mhz ranges. If the first is selected, the local oscillator signal is routed directly into the counter. In the case of the 235-to-1,000-Mhz range, the input signal is beat with the signal from a crystal-controlled transfer oscillator in a double balanced mixer to produce an output signal within the range of the associated counter.

Together, the DRX-1000 and the DRO-302A fill a standard 19-inch rack. The duo operate on 115 or 230 volts a-c and 50-to-400 hertz power. A minimum local oscillator input of 50 millivolts is needed over the full frequency range.

Each unit, Pao notes, is designed to be used with other manufacturers' devices. CEI will eventually put a common faceplate on the two devices and sell them as a single item.

Communication Electronics Inc., 6006 Executive Blvd., Rockville, Md. 20852 **[369]**

New instruments

Relay won't wait for a reading

IC switch and a meter are put in one package but act independently

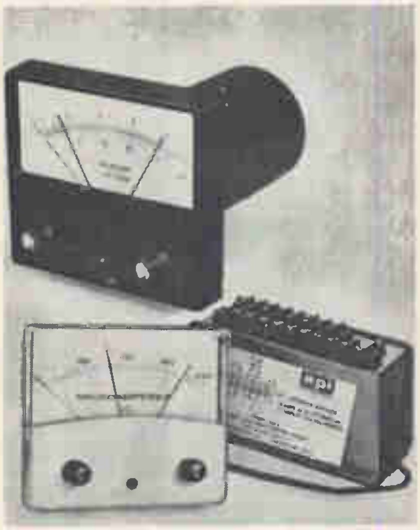
The Ultimeter is both a reporter and a traffic cop. Built by the API Instruments Co., the device is a relay-meter that measures d-c signals in ranges down to 0 to 1 microampere and 0 to 1 microvolt.

The user may find the meter fast, but the relay's a good deal faster. Built with integrated circuits, the relay has a 50-millisecond response time. As soon as the input reaches a set point, the relay trips. It doesn't wait for the pointer to move to the correct value, and will work even if the meter is broken.

API says the Ultimeter can be almost any type of measuring instrument—ammeter, voltmeter, pyrometer, and so forth. All it needs is a d-c input.

Any additional control circuitry can be supplied in an optional module, or API engineers will pack this circuitry into the Ultimeter's case, which is 3¼ by 4½ by 5½ inches.

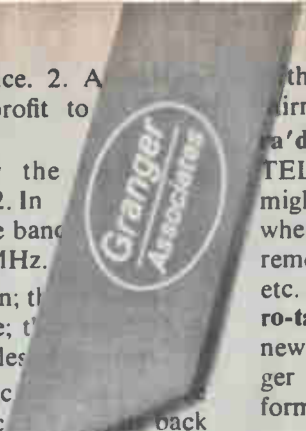
Too fast. In one way, the Ultimeter is too fast for its own good. Although generally interchangeable with existing meter-relays, the Ultimeter can't just be plugged into a line where there's a lot of noise. API points out that mechanical relays smother noise just by being slow. But the Ultimeter needs external filters to keep out high-frequency interference.



In or out. Control circuitry can be built into the Ultimeter or supplied in a separate module.

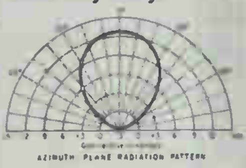
API will begin deliveries in November, and by the first of next year expects to have a model that controls temperature-regulating devices. The price ranges from $100 to $200.

API Instruments Co., 7100 Wilson Mills Rd., Chesterland, Ohio **[370]**



an-ten'na 1. A wirelike growth on the head of a lobster. 2. An elevated conductor of electrical waves; that which in log-periodic designs Granger has more of than anybody.

az'i-muth The desired direction in which G/A antennas concentrate your signal.



ba'lun 1. An impedance transformer; connects 50 ohm co-ax to open wire lines. 2. A non-porous bag filled with hot air or gas.

cur'tain 1. Opening of a great performance. 2. An ordered arrangement of wires precisely engineered and factory fabricated for easy installation and long life as part of a G/A log-periodic antenna.

dec'i-bel (pronounced dee-bee) A measure of what G/A's h-f products can contribute to your system performance; usually in groups of 40 or 50 in the important characteristics of G/A receivers.

ex-cit'er Any of the new G/A h-f products; specifically, our new solid-state h-f unit with LSB, USB, CW, AM, and with FSK-ability.

fast-switch A rapid change between two pretuned frequencies (e.g. in 50 milliseconds); a characteristic of one of G/A's new transmitters.

gain 1. That which our products contribute to your communications system's performance. 2. A tage, benefit or profit to concerned.

h-f 1. Typically the from 3 to 30 MHz. 2. In G/A equipment the banc between 2 and 32 MHz.

im'age A reflection; th receivers don't have; t' antennas use to fulles

i-on'o-sphere A fic layer used to bounc back to earth; its erratic havior can be measured in real time (see *sounder*).

log per-i-od'ic The most versatile, compact precision h-f antenna design; available from Granger in many variations (e.g. rotatable, steerable, transportable, unidirectional).

mode 1. Ice cream on pie. 2. Method of doing (e.g. SSB, ISB, FSK, CW, AM); that which you have a full choice of in our equipment.

mon'o-pole 1. A game wherein you receive $200 for passing GO. 2. A compact reliable omnidirectional antenna offered by Granger Associates.

om-ni-di-rec'tion-al Going off in all directions; a capability of certain G/A antennas.

po-lar-i-za'tion di-ver'sit-y A combination of vertical and horizontal antennas to overcome fade; a space-saver.

point-to-point From here to there ith no wires; done with ionospheric irrors.

ra'di-o-tel-e-phone (pronounced TELETRANSCEIVER) A small but mighty G/A device that goes anywhere; specif. the Australian outback, remote Pacific islands, African veldt, etc.

ro-ta'ta-ble Capable of revolving; a new log-periodic antenna from Granger Associates offering reliable performance from 5.5 to 32 MHz.

re-ceiv'er A new solid-state G/A unit that selects your message from many others and renders it clearly intelligible.

se-lec-tiv'i-ty The quality of careful discrimination, as in G/A receivers; pert. to elimination of extraneous signals.

sound'er 1. A device used in early telegraphy. 2. A precise instrument for measuring the ionosphere; an efficiency expert in h-f communications.

SSB 1. In aviation, the supersonic balloon. 2. In radio communications, what nearly everyone will be using by 1971; we can help.

trans-mit'ter A microphone-antenna interface device; available from G/A in 1, 3 and 5 kw versions.

VSWR Abbr. for voltage standing wave ratio; less than 2.0:1 in almost all of our antennas.

ze'nith 1. A vertical take-off angle. 2. The name of another famous radio company.

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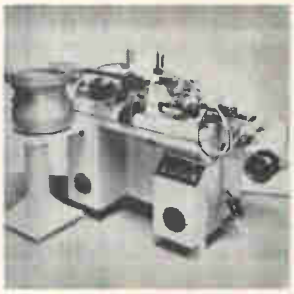
New Subassemblies Review

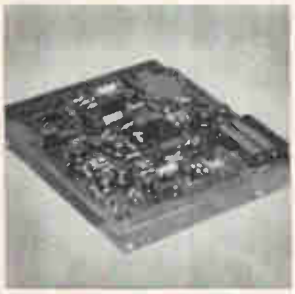
Analog-to-digital converter model DCM-1 has a 2.8 in. panel height and allows 14 converters to be installed in a 3½ x 19 in. rack adapter. Visual display of binary output is provided by 8 miniature lamps on the front panel. Output is 8 bits parallel in a natural binary code. Word conversion time is 256 μsec max., 1 μsec minimum. Defense Electronics Inc., Rockville, Md. [381]



Digital count-printer is for recording count totals and time intervals. Solenoid actuated, it continuously registers sequential input pulses up to 600 per minute, and will print the accumulated total when desired. Models are available in either 1 or 2 channels, printing in-line on a single 3-in. paper tape. Mechanics For Electronics Inc., 152 Sixth St., Cambridge, Mass. [382]

Solid state, wideband air-to-air relay link features a deviation capability of ±24 Mhz and a video baseband of 20 Mhz. The relay link consists of a model FMR 9.6 receiver (illustrated) and model FMT transmitter and meets MIL specs for airborne equipment. Typical uses are in reconnaissance and surveillance. RHG Electronics Laboratory Inc., Farmingdale, N.Y. [383]

Indium-arsenide laser model IAL-6, with an output at 3.18 microns, can be used for wavelength calibration, as a radiation source for detector response-time measurements, or for general i-r illumination, replacing more costly and complex illuminators. I-r detector rise time as short as 60 nsec can be measured. The system costs $940. Raytheon Co., Foundry Ave., Waltham, Mass. [384]



Universal operational amplifier HT58 can be used single-ended or differential, or as a buffer with variable gain. Accuracy is 0.01% to cover almost all requirements. Output of ±40 ma at ±10 v full scale will drive large capacitance loads. Slew rate is 10 v/μsec. Common mode rejection is 100 db at d-c. Scientific Data Systems, 1649 17th St., Santa Monica, Calif. [385]

FET power amplifier model KM-47B exhibits a 200-ma output at ±10 v and typical input impedance of 10^{12} ohms. Bias current is 10 pa max. The internally compensated device is suited for integrators and buffers in instrumentation, control and computation applications. Price (1 to 9) is $50 each. K&M Electronics Corp., 102 Hobart St., Hackensack, N.J. [386]

RC voltage controlled oscillator series NB provides frequencies between 1 khz and 40 khz as specified with frequency tolerances of less than ±0.2% over a temperature range of −20° to +50°C. Frequency deviation of ±10% with linearity better than ±0.1% is standard. Price ranges from $235 to $385. Accutronics Inc., 628 North St., Geneva, Ill. 60134. [387]

Disk storage drive M2500, completely interchangeable with IBM's 2311 unit, has average random access time of 48 msec and error rate of less than 1 part in ten billion. It offers a direct-seek actuator for positioning heads in a single mechanical action, eliminating errors. Price is $19,750. Marshall Laboratories, 3530 Torrance Blvd., Torrance, Calif. 90500. [388]

New subassemblies

Logic trainer has movable modules

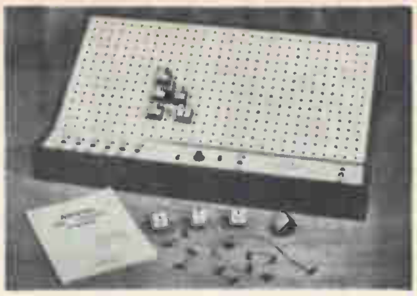
Student can set up simple or complex digital systems with plug-in circuits on device's pegboard

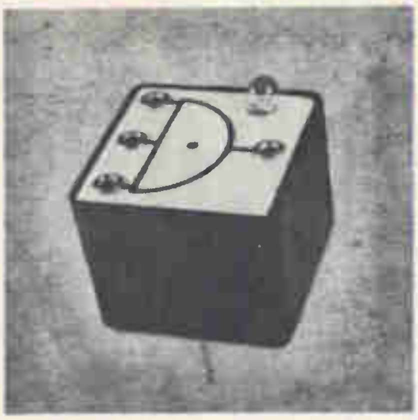
Pegboards aren't new to engineering schools or in-plant training sections, but usually they're part of a crosspatching arrangement. On the pegboard of a new training aid, the circuits themselves, not just patchcords, are moved around.

In using the device, built by Adtech Inc. for teaching the basics of logic-circuit design, the student engineer plugs in block-shaped modules, each of which performs a specific logic function.

Called the 401 Logic Laboratory, the device is for both the student with homework headaches and the designer with breadboarding problems. A user usually starts out with a logic diagram of a circuit. He selects the modules, called logicubes, that correspond to the digital circuits called for by the diagram. There are 44 types of logicubes, ranging from a simple gate up to a counter complete with decoder, driver, and Nixie display.

After selecting the cubes, the user plugs them into the 401's 32-by-18-inch pegboard, orienting them in the same way—forwards, backwards, up, or down—as the logic symbols are oriented in the diagram. He then connects the cubes with patchcords; up to 100





Warning. The light in the cube's upper right-hand corner indicates whether the cube is working.

cubes fit onto the 401's board.

Two advantages. Many competitive logic trainers have fixed-position modules. Adtech says the 401 is superior to this type for two reasons. First, it doesn't have a lot of wires obscuring the circuit. And the 401 makes it easier to learn what's going on in a digital system, because the layout on the board looks exactly like the logic diagram.

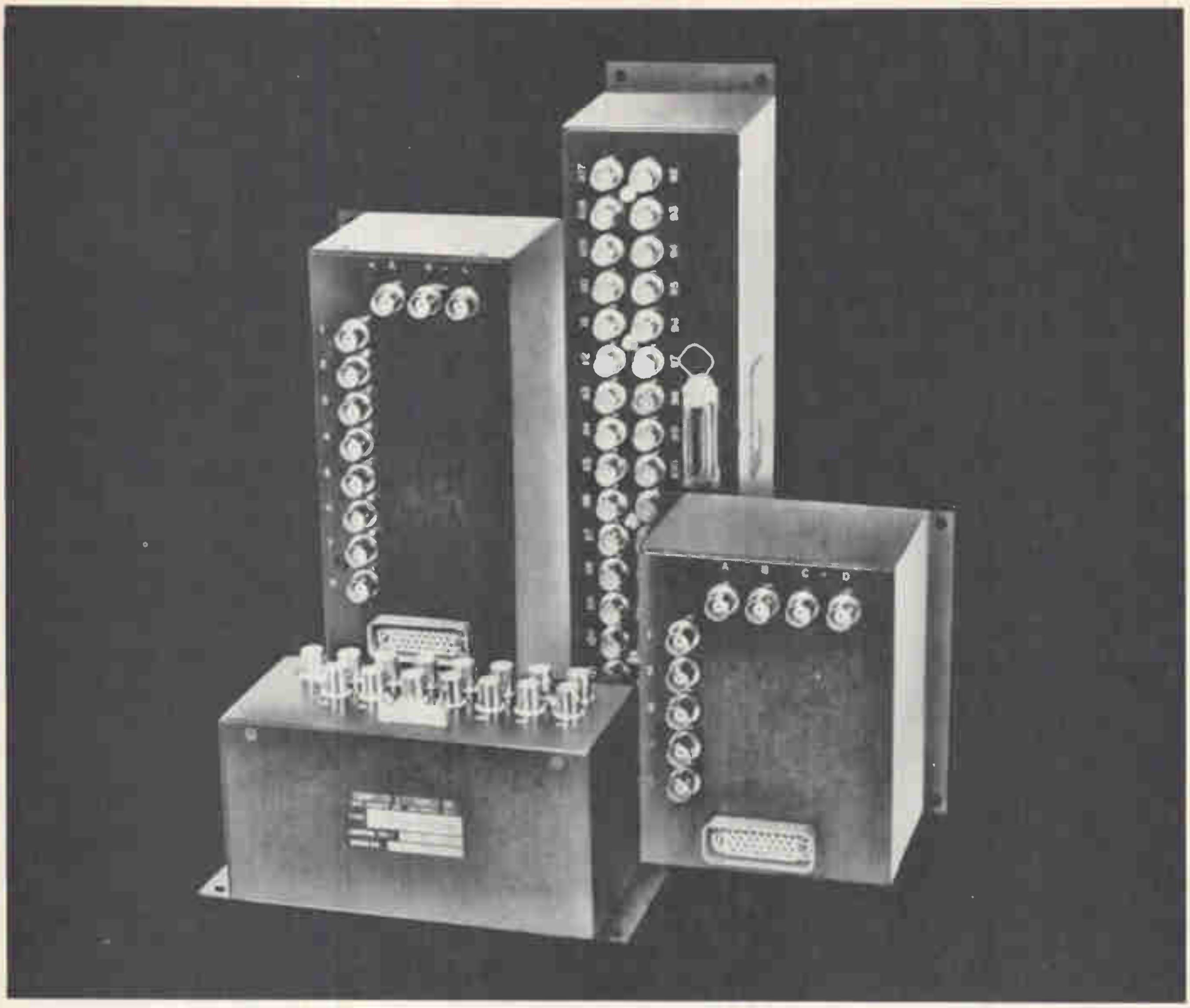
Most of the cubes are 1½ by 1½ by 1¼ inches; the ones that perform the more complex functions are 2½ by 2½ by 1¼ inches. On the top of each cube are digital input and output terminals, the appropriate logic symbol, and an indicator light that's on when the output is 1. Input-power and ground leads are on the bottom.

Prices of basic modules like gates and flip-flops are around $15; more complex functions can cost as much as $85.

A set of 26 cubes, enough to set up most basic circuits, costs $324.

Six logic sources, three clocks—1, 5, and 60 hertz—and, a 5-volt d-c, 4-amp supply are part of the 401. It's 32 by 18 by 12 inches, weighs 30 pounds, and costs $596.

Adtech Inc., P.O. Box 10415, Honolulu, Hawaii 96816 **[389]**



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Switches are available in multi-pole, multi-throw formats up to 20 poles, 20 throws in both coax and twinax.

Now, if you still want to use the modular approach...Okay! We have a building block matrix system also available that helps to eliminate a lot of the usual fuss and high cost of assembling such a system. And incidentally, we'll even take on the system's responsibility!...Ask for our new catalogue M-5.

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COMPARISON GUIDE

THE AMELCO 810CJ $5.90

The 810 consists of two complete, overvoltage and short circuit proof amplifiers on a single monolithic chip in a 14 lead dual in-line package. It is pin interchangeable with the dual 709. Typical specs for each amplifier are

Gain: 40,000	CMR: ±13 V
Offset: 1 mV	CMRR: 90 db
100 nA	Input Current: 500 nA
Tracking: 10 μV/°C	Input Impedance: 200 KΩ
1nA/°C	

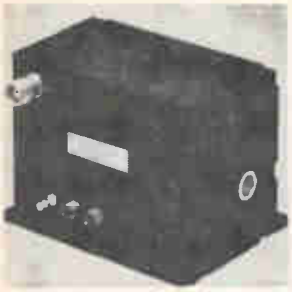
Compensation: single component with no power supply by pass necessary

Brand F	(μA709C)	2 x 5.95 . . . . . 11.90
Brand N	(LM201)	2 x 8.80 . . . . . 17.60

Competitive prices based on best information available to us—quantity 100 pieces. Ask about our 811CE offering the performance above in the 709 pin configuration.

Amelco Semiconductor, 1300 Terra Bella Ave. • Mountain View, Calif. 94040, Phone (415) 968-9241

Circle 217 on reader service card



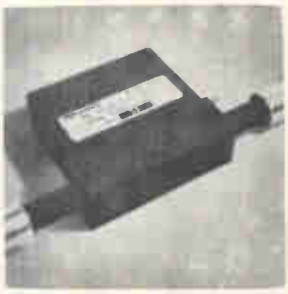
C-band, crystal controlled, phase locked oscillator is a 10-mw unit for telecommunications applications. It offers a guaranteed stability of ±0.005% from −30° to +60° C over the 5.855 to 6.455 Ghz band. Residual f-m is less than 10 hz in a 1 khz bandwidth from 10 khz to 5 Mhz. Power output is 10 dbm. California Microwave, 1188 Elko Drive, Sunnyvale, Calif. [401]

Miniature X-band coaxial isolator has 1.1 Ghz bandwidth (8.5 to 9.6 Ghz). Isolation is 60 db minimum; insertion loss, 0.5 db max.; and vswr, 1.25 max. The unit is 1½ x 1⅛ x ¾ in., weighs 3 oz, has OSM connectors, can withstand extreme shock and vibration, and is temperature-stabilized over a wide thermal range. Micromega, Del Ray Ave., Venice, Calif. [402]

R-f power generator series HV is for research applications. Power output is adjustable to 100 w at 2,450 Mhz. Built for continuous output monitoring, the unit includes forced-air cooling, time delay relay to allow magnetron warm-up, and protection against "no-load" damage. Price is $975. Scintillonics Inc., 600 Fort Collins Industrial Park, Fort Collins, Colo. 80521. [403]

Reflex klystron oscillator has 1.5-w output from 6.575 to 6.875 Ghz. Full range tuning is with screw adjustment, and a 30-Mhz band can be tuned electrically. Tube is 2.34 x 3.5 x 2.2 in. and weighs 22 oz. Cooling is by conduction or vapor. Input connector is a small-wafer octal plug; output flange mates with UG-344/U flange. Varian, 611 Hansen Way, Palo Alto, Calif. [404]

Multicoupler model M5804H operates over the 2.2 to 2.3 Ghz range. It features 12 outputs with an output-to-output isolation figure of 70 db. Intermodulation product is +3 dbm at intercept point. Gain is 1 to 5 db with an output, 1 db compression point of −10 dbm. Noise figure (ambient temperature) is 8 db maximum. Aertech, 815 Stewart Drive, Sunnyvale, Calif. [405]



L-band pin attenuator model 7950 has a dynamic range of 20 db and a max. vswr from min. to max. attenuation of less than 1.5 db. Frequency range of the 1 x 3 x 7 in. unit is 0.6 to 2.4 Ghz. Typical rise time when driven by appropriate pulse modulator is less than 200 nsec. Price is $250 in quantities of 1-9. Polarad Electronic Inst., Long Island City, N.Y. [406]

Triple stub coaxial tuner model 20360 is designed to match out reflections from connectors, adapters, coaxial terminations and measuring instruments. The match produced is frequency insensitive. Designed for the 2 to 10 Ghz range, the tuner may be used up to 26 Ghz. Dimensions are 2.3 x 2 x 0.5 in. Omni Spectra Inc., 24600 Hallwood Ct., Farmington, Mich. [407]

Voltage tuned fundamental oscillators come in 4 models. Two cover the 0.5 to 1 Ghz band; and one each cover the 1 to 2 and 2 to 4 Ghz bands. They offer power outputs from 50 to 200 mw depending on octave range over a −30° to +60° C temperature range. Harmonic content is more than 20 db below the output. Fairchild Microwave Products, Mtn. View, Calif. [408]

New microwave

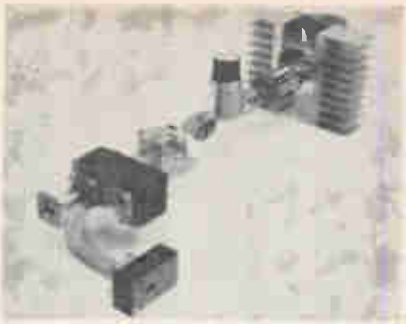
30-Ghz amplifier has 600-Mhz bandwidth

Parametric device with 15-db gain, 3-db noise figure is built with a planar Schottky-barrier diode

When radio astronomers listen to stars, they need special hearing aids. One, for example, is the parametric amplifier that handles the high-frequency wideband signals received by a radio telescope, before the signals are heterodyned. If the signals weren't amplified, they'd be swamped with noise.

How good a parametric amplifier is depends on its bandwidth, gain, and noise figure. Engineers at the Advanced Technology Corp. are now building amplifiers with operating frequencies of around 30 gigahertz, 600-megahertz bandwidth, a 3-decibel noise figure, and a 15-db gain. "Nobody building 30-Ghz sets can come close to us in bandwidth and noise figure," asserts Allan Tucker, the company's contract manager.

The National Radio Astronomy Observatory in Green Bank, W. Va., got the first of these high-performance devices, a 31.4-Ghz unit, for test. It was more a breadboard than a finished product, and it was never used in any on-line receiver. A second 31.4-Ghz amplifier, smaller than the first and completely packaged, is being readied now by Adtec for use in NRAO's antenna on Kitt Peak in Arizona.



Minus. Output frequency is difference between pump, input frequencies.

Also in the works are a 33.6-Ghz model for the Naval Research Laboratories in Corona, Calif., a 35.5-Ghz unit for the Air Force Cambridge Research Laboratories, and a 24-Ghz model for NASA.

Adtec's amplifier is degenerative—output frequency is a submultiple of pump frequency—and similar in layout to other parametric amps. A pump signal whose frequency is double that of the operating signal goes through an attenuator, an isolator, and a varactor to a circulator where it's mixed with the input signal. The result is a signal 15 db stronger than the input, whose frequency equals the difference between the pump and input frequency.

The key component in this setup is the varactor, which is made with a planar Schottky-barrier diode whose cutoff at −2 volts bias is 600 Ghz.

According to Adtec, 35 Ghz was the highest operating frequency anyone could give a parametric amplifier at the time it started to design its unit. The diodes used previously were point-contact types with low cutoff frequencies; efficiency at a given operating frequency declines with cutoff.

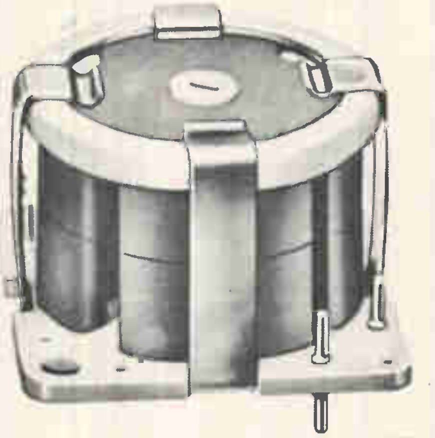
So Adtec engineers decided to use planar diodes, which they made by putting silicon dioxide on gallium arsenide and then etching and depositing anode material.

Tucker says there's no reason why Adtec can't build parametric amplifiers with operating frequencies as high as 100 Ghz, and he predicts that the bandwidth will be 1 Ghz within a year.

Cost depends on the operating frequency. The 24-Ghz model, for example, costs $27,000.

Advanced Technology Corp., 1830 York Rd., Timonium, Md. [409]

Mullard calls this a Vinkor*...



... part of a range of adjustable pot cores with Q factors from 100 to 1200, for frequencies from 400Hz to 15MHz

This is the Vinkor I.E.C. Range (LA3000)

Sizes:							
Diameter	14	18	22	26	30	36	mm
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Inductance Adjustment A unique self-tapping screw in a plastic sleeve gives, in the majority of cases, ±7% inductance adjustment without backlash.

Permeabilities From A_L25 to A_L400.

Choice of Housings Standard metal nut-and-bush mountings or clip-and-board assemblies.

Precise Inductance without core grinding, to an accuracy of ±0.02%. Long-term stability 0.1%.

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MOL 51

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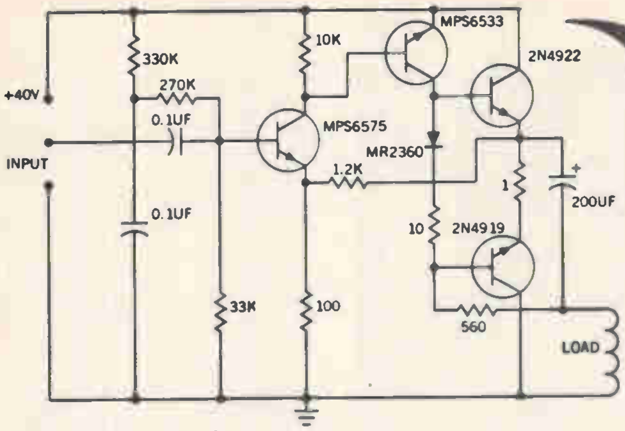
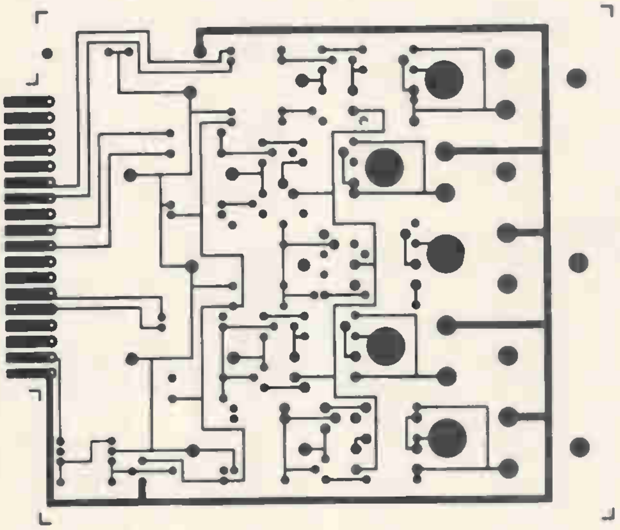
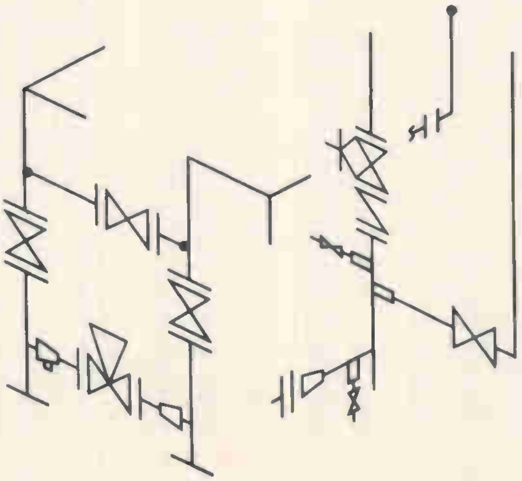


UNLESS OTHERWISE SPECIFIED RESISTANCE VALUES ARE IN OHMS. CAPACITANCE VALUES ARE IN PICOFARADS.





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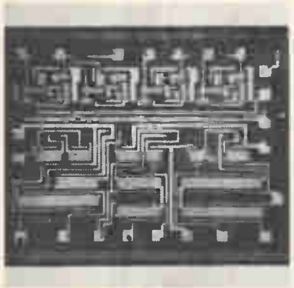
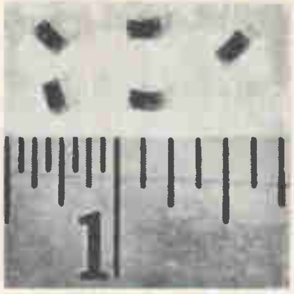
Mergenthaler the total graphic arts company

Plastic-encapsulated, single-diffused power transistors help designers lower equipment costs by replacing more expensive equivalent devices in TO-3 and TO-66 metal cans. Rated at 30 to 90 w, they meet a wide range of power and polarity requirements at 40 and 60 v. Prices (100 to 999) range from 70 cents to $6. Texas Instruments Inc., N. Central Expressway, Dallas. [436]

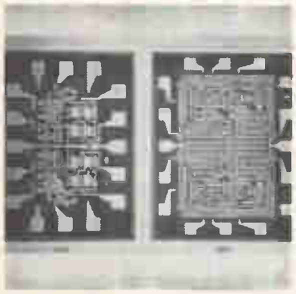
Fully compensated FET operational amplifier model 830 comes in a dual-in-line epoxy package. The device is short-circuit proof. Key specifications include: voltage gain of 300,000; 20 μv/°C drift; input bias current of 15 pa; 6 v/μsec slew rate; 10 v common mode voltage; and output of 10 v at 5 ma. Availability is immediate. Zeltex Inc., Concord, Calif. [437]



Monolithic MOSFET array HRM-2302 consists of 4 type D flip-flop and 12 switches. It is designed for d/a and a/d applications, and is capable of performing 12-bit conversions at rates of approximately 100 μsec. The 0.55 x 0.072 in. chip consists of 52 MOSFET devices. Price is $28 in lots of 1,000. Hughes Aircraft Co., 500 Superior Ave., Newport Beach, Calif. [438]



Lid packaged silicon transistors for thin/thick film and stripline circuit use are intended for uhf/vhf and microwave hybrid circuit applications. They are for low noise amplifier applications over the 60- to 2,000-Mhz range. The oscillator types range from 10 mw minimum at 2 Ghz to 30 mw at 2.5 Ghz. KMC Semiconductor Corp., Parker Road, Long Valley, N.J. [439]



Dual 5-input gate 3100 and dual J-K flip-flop 3101 are MOS building blocks for interconnecting large block functions of MOS systems and serving as timing, decoding or random control. They come in a 16-lead dual-in-line package and in an operating temperature range of −55° to +85° C. Price is in the $6 to $12 range. Fairchild Semiconductor, Mtn. View, Calif. [440]

Silicon medium power transistors are 2-amp devices available in TO-46, TO-5 and TO-66 packages. They have voltages to 300 v, leakages as low as 0.5 na, saturation voltages less than 0.1 v, uniform current gain from 10 ma up to 500 ma, and a typical gain bandwidth of 85 Mhz. Units are available from stock. Solitron Devices Inc., Riviera Beach, Fla. [441]

Ion-implanted diodes called Isodiodes are offered in package sizes ranging from 0.500 amp to 30 amps. Features include fast power, short recovery time, low turn-on voltages, high current-carrying capability and good peak reverse voltage. Units are useful in applications such as voltage supplies and regulators. Isofilm International, 20131 Bahama St., Chatsworth, Calif. [442]

Solid state a-c switch, available in a hermetic TO-5 package, is for high-frequency operation from 0 to 20,000 hz and has sensitivity of 2 ma max. gate trigger current. The switch operates in both direct and proportional modes and requires only 1.5 ma load current. It has application in low level control uses. Solid State Products, 1 Pingree St., Salem, Mass. 01970. [443]

New semiconductors

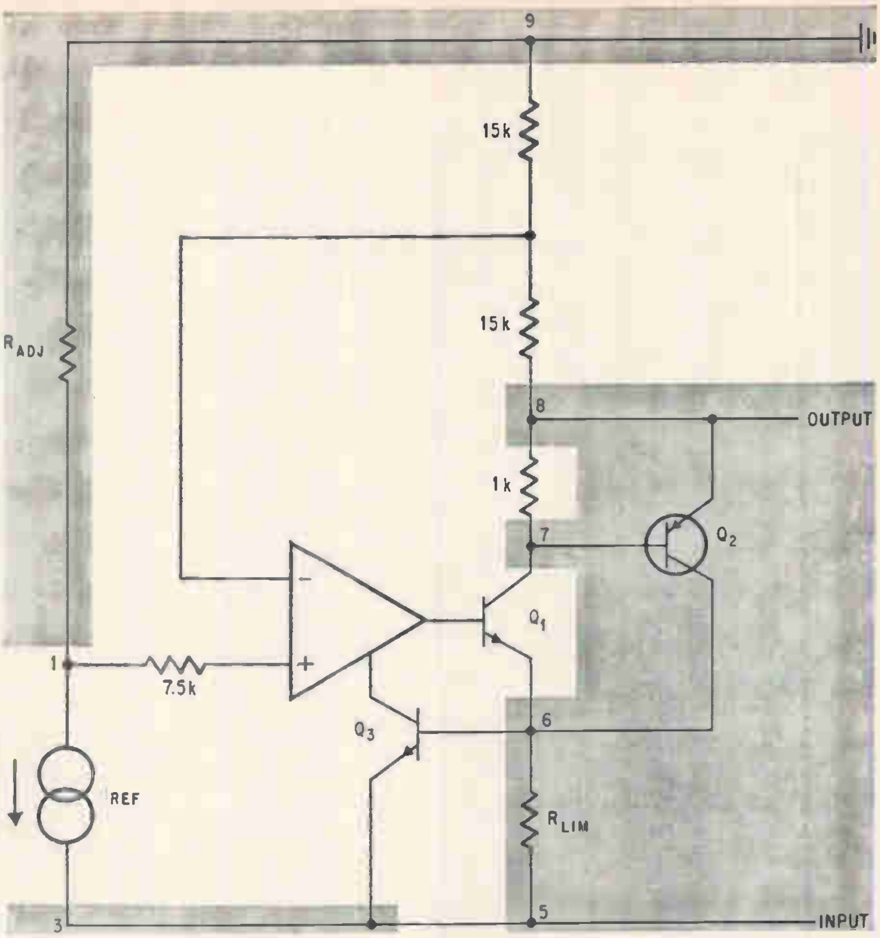
IC regulates negative voltages

Monolithic device works without bias in most circuits; with a bias, though, it can handle high voltages

A voltage regulator built with discrete components can be switched from positive to negative simply by replacing npn transistors with pnp's. With monolithic integrated circuits, however, the trick isn't so easy. There are several ways of making a positive regulator see negative potential, but most of these involve some sacrifice of performance. Merely reversing the output and ground terminals, for example, will reverse polarity, but the user will then not be able to ground his input.

The first commercial IC that regulates negative voltages has just been introduced by the National Semiconductor Corp. Called the LM104, the IC is the brainchild of Robert J. Widlar, whose first design for National was a positive regulator, the LM100. The LM104, in fact, is intended to complement the LM100 and its stablemate, the LM105.

Op amp. Central to the LM104 is an internal operational amplifier that acts as an error amplifier to deliver a constant output. The reference voltage is derived from a temperature-compensated current source, I_{ref} [p. 154], feeding the op amp through a 7.5-kilohm resistor.



Negative approach. The external components used with the negative-voltage regulator are shaded. The IC itself delivers 25 ma, and Q_2 increases output capability. Q_3 and R_{LIM} provide short-circuit protection.

A supply voltage proportional to an external programing resistor, R_{adj}, is also fed to the amplifier.

Since the amplifier has very high gain, very low output voltage will turn the output transistor on more strongly. If the output is too high, the amplifier saturates its output transistor less fully.

The amplifier drives an internal transistor, Q_1, which supplies an output voltage that's twice the voltage across R_{adj}.

Quick drop. Because the output is proportional to this programing resistor, the circuit's output can be reduced to zero merely by removing R_{adj}. Normally, regulators can't drop to a value below that of the reference voltage without using a bias power supply.

The LM104, however, works with a bias supply to regulate high-voltage circuits. In series with an external transistor, the device can regulate high voltages while seeing only 10 volts internally.

The circuit, National says, can be used as a switching or current regulator as well as a linear series regulator, its prime application. In complementing the LM100 and LM105, it should find use in systems requiring regulated voltages that have a common ground with the supply. Most linear equipment has both positive and negative power supplies, Widlar notes, and current-mode logic and complementary transistor logic use negative voltage supplies.

The LM104's, which operate from —55° to +125°C, cost $30 each in quantities of up to 24, $24 in lots of up to 99 units, and $20 in quantities of over 100. A limited-temperature-range version, the LM204, costs $21, $16.80, and $14 in similar-size lots.

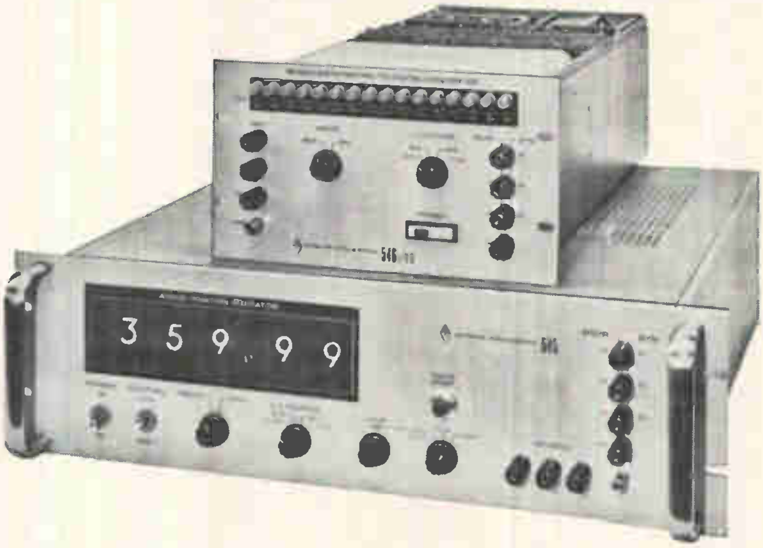
Specifications

Input voltage	50 v max
Input-output voltage differential	50 v max
Power dissipation	500 mw
Storage temperature	—65°C to 150°C
Lead temperature (soldering, 60 sec.)	300°C

National Semiconductor Corp., Santa Clara, Calif. [444]

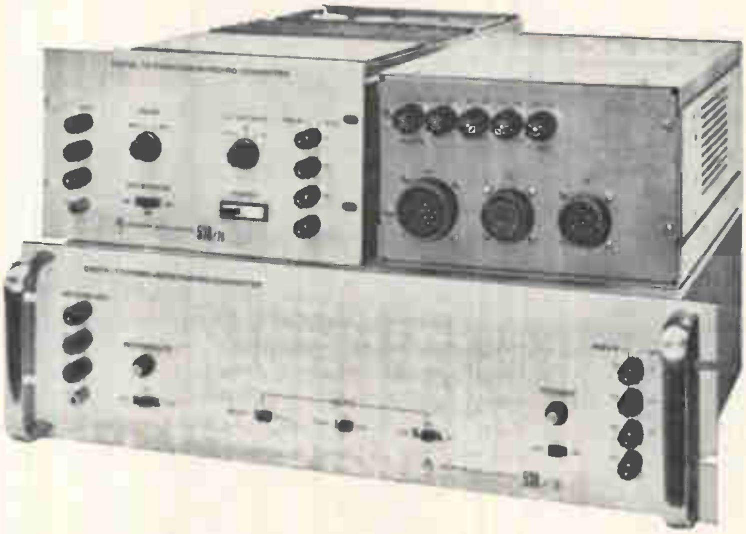
SYNCHRO-TO-DIGITAL

• 20,000°/second tracking •.01°/15 bit accuracy • binary or BCD



DIGITAL-TO-SYNCHRO

• 11 to 16 bits • accuracy to 30 arc seconds • 4μs data strobe



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New Books

Heavy on theory

Finite-State Models for Logical Machines
Frederick C. Hennie
John Wiley & Sons
466 pp., $18.50

Some books are written to introduce engineers to complex subjects in a simple way. These books often emphasize the "what" at the expense of the "why." But other books go very deeply into theory and leave the engineer who wants a little practical advice floundering.

Hennie's book, unfortunately, is an example of the latter. Though the circuit forms and computational models discussed by Hennie relate to the design of working hardware, references to these relationships are scarce and the book just about manages to ignore the real world.

The clue is in the preface, where the author warns that his purpose is to provide "specific techniques for the logic designer" and to "develop useful ways of thinking about a broad class of problems."

That's good. Nevertheless, it would have been better if a few links with actual hardware had been included. One may be somewhat put off, for instance, to be told that a truth table "is" a machine, when it more precisely represents a sequential circuit that could be built with any of several kinds of components; these would actually "be" the machine.

With these brickbats out of the way, one very large bouquet is in order. The book is very well written; the style is an easy, informal one rarely found in treatises on such abstruse subjects as this. Yet the arguments are precise and rigorous.

Because this informal presentation takes up more space than would a formal text full of equations and symbols, the author feels impelled, unnecessarily, to apologize for it in his preface.

Hennie also states: "When formalism does not contribute to understanding, its proper place would seem to come after a good intuitive understanding has been achieved." O that more technical writers would recognize the distinction between formalism and understanding!

Thought-provoking

Sophisticated Signals and the Uncertainty Principle in Radar
D.E Vakman
Translated from the Russian by K.N. Trirogoff
Springer-Verlag New York Inc.
253 pp., $14.80

The emphasis in radar is shifting from hardware to the signal itself as the limits of practical transmitter power and receiver sensitivity are approached. Increasing the sophistication of the signal and its processing is now of paramount importance in enhancing the effectiveness of radar and widening its range of application.

This well-written book, which draws upon the work of both Western and Soviet scientists, is notable for its summary of modern radar theory. As one would expect from a Russian text, the presentation is rigorous, with the central premise of each contribution subjected to thorough analysis and mathematical proof. Organization of the material is logical and the development of the essential arguments is sequential and easy to follow. Although the subject matter is both complex and abstruse, the thoughtful reader should have no difficulty in understanding it.

The book is organized into four parts: the theory and practical effects of pulse compression signals and signal processing; the uncertainty principle of Heisenberg as compared to the bandwidth-time relation in radar; the ambiguity function in the radar statistical problem; and the synthesis of signals to meet the criteria of the ambiguity function.

While the author has made an interesting contribution to the growing field of advanced radar theory, credit is also due K.N. Trirogoff for a concise and readable translation. The book is highly recommended both as a thought-provoking text for anyone interested in advanced electromagnetic radiation and as a useful reference for the radar engineer and scientist.

D.L.Kratzer
RCA Missile and Surface Radar Division
Moorestown, N.J.

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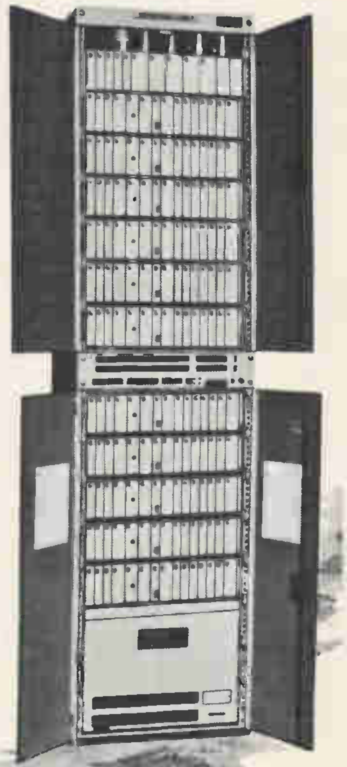

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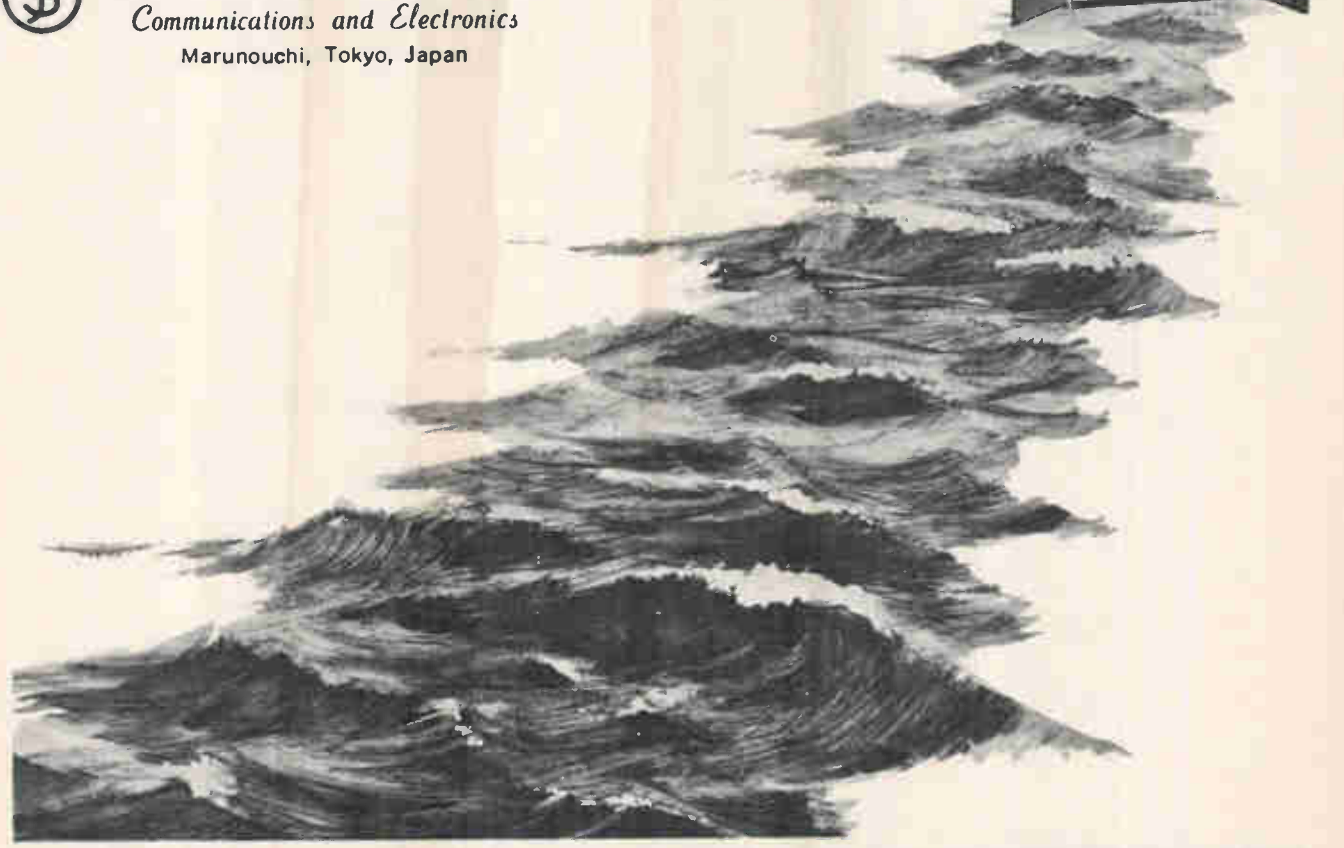

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MIC's and matches

New microwave integrated
circuit modules
Wesley G. Matthei and William Crowe
Micro State Electronics
Raytheon Co.
Murray Hill, N.J.

To serve as the key elements in an experimental solid state microwave receiver, several microwave-integrated-circuit hybrid modules were developed—a tunnel-diode amplifier, a balanced mixer using gallium arsenide Schottky-barrier diodes, and a GaAs avalanche diode to act as the local oscillator. The circuits were designed for operation in C band—about 5.5-gigahertz—and provided about 15 decibels gain over a 400-megahertz bandwidth with a 7-db noise figure.

The tunnel-diode amplifier used a circulator as a coupler to maintain stability in the face of variations in input and output impedance, and to provide good impedance matching and low voltage standing-wave ratio. The tunnel diode itself was a germanium unit mounted in a standard package to ease the problems of connection to the microstrip transmission line; one end of the package was connected to the ground plane through a hole in the alumina substrate while the other was connected to the microstrip conductor.

The passive components for a tunnel-diode biasing network were also built separately and attached to the basic substrate. The resistor was a film-type element deposited on an alumina substrate and then inserted in the microstrip circuit, and the d-c blocking capacitor was of a small, 20-picofarad chip type. The band-reject filter was a quarter-wave open-circuited line that placed an r-f short across the bias resistor at the 5.5-Ghz operating frequency.

The avalanche-diode oscillators were made tunable by adding a varactor at the end of the half-wavelength microstrip resonator. Variations of 30 volts in the bias on the varactor tuned the output frequency from about 6 Ghz down to about 5.66 Ghz.

Presented at Wescon, Los Angeles, Aug. 20-23.

Gunning for avalanches

Avalanche and Gunn diode oscillators
Meyer Gilden, Charles D. Buntschuh,
T.B. Ramachandran, and J.C. Collinet
Microwave Associates, Inc.
Burlington, Mass.

Both avalanche and Gunn diodes develop negative resistances over certain frequency ranges because of nonlinear processes under certain bias conditions.

The negative resistance of the avalanche diode is a transit-time effect resulting from the travel of bunched carriers across the depletion zone. The avalanche diode has a current-controlled negative resistance.

The negative resistance of the Gunn diode stems from the transfer of high-energy electrons from a high- to a low-mobility conduction band when the applied electric field exceeds approximately 3,000 volts per centimeter. The Gunn diode has a voltage-controlled negative resistance.

For circuit design, the active region of either type of diode can be treated as a series or parallel circuit consisting of the negative resistance and a capacitance. For the avalanche diode, the capacitance can be taken as the value at breakdown. For the Gunn diode in the parallel mode, the negative resistance is about 400 ohms.

As a local oscillator, the Gunn device is equivalent to a klystron in noise performance and electronic tuning. The noise performance of the avalanche diode oscillator in a high-Q cavity and a system using a balanced mixer will also compare favorably with that of a klystron. A 30-gigahertz avalanche diode used to pump an X-band parametric amplifier resulted in an amplifier with a 2-decibel noise figure. In a simple police speed-radar system, the avalanche diode oscillator, used as the transmitter, provided good performance. However, for more sophisticated Doppler radar transmitter applications, where the noise close to the carrier frequency is important, the avalanche diode doesn't yet appear to be adequate.

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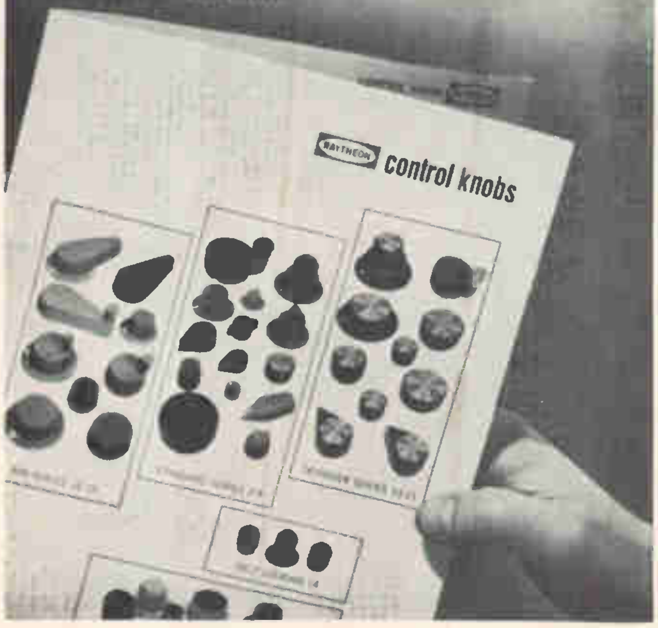

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New Literature

Tv camera system. Westinghouse Electric Corp., P.O. Box 8606, Pittsburgh, Pa. 15221. A two-piece secondary electron conduction tv camera system, for low-light-level viewing of transient and stationary images, is described in bulletin DB95-154.
Circle **446** on reader service card.

Heat sinks. George Risk Industries Inc., 672 15th Ave., Columbus, Neb. 68601, offers a catalog covering 21 different models of heat sinks. **[447]**

H-element crystals. Reeves-Hoffman, Division of DCA, 400 W. North St., Carlisle, Pa. 17013. Technical information on H-element crystals is supplied in a two-color sheet. **[448]**

Electrolytic transducers. Hamlin Inc., Lake & Grove Streets, Lake Mills, Wis. 53551, has available a four-page brochure featuring its complete EP family of gravity-sensing electrolytic transducers. **[449]**

Frequency multipliers. Kevlin Mfg. Co., 26 Conn St., Woburn, Mass. 01801. A technical bulletin describes a series of single stage and cascaded frequency multipliers using strip transmission line techniques. **[450]**

Precision counters. Melland Gear & Instrument Co., 84 Sylvester St., Westbury, N.Y. 11590, has available an illustrated catalog of precision counters designed for instrument applications. **[451]**

Semiconductor heat dissipators. International Electronic Research Corp., 135 W. Magnolia Blvd., Burbank, Calif. 91502, offers a short form catalog covering its line of heat dissipators for metal and plastic case transistors and diodes. **[452]**

High-stability oscillators. Motorola Communications and Electronics Inc., 4900 W. Flournoy, Chicago 60644. Brochure TIC-3315 contains complete information on three precision, high-stability oscillators. **[453]**

Rear projection readouts. Shelly Associates Inc., 111 Eucalyptus Drive, El Segundo, Calif. 90246. A four-page brochure describes a line of binary to decimal rear projection readouts featuring IC electronics. **[454]**

MOS products. National Semiconductor Corp., 2950 San Ysidro Way, Santa Clara, Calif. 95051, has issued a report describing quality and reliability programs including recent test results on its MOS products. **[455]**

High power terminations. Weinschel Engineering, Gaithersburg, Md., has published a data sheet on the model 569A precision high-power terminations that operate over a d-c to 3 Ghz frequency range. **[456]**

Precision resistors. Airco Speer Electronic Components, Du Bois, Pa. 15801, has issued a catalog describing the Jeffers JC series of low-cost industrial precision resistors. **[457]**

Data processing system. Varian, Instrument Group, 611 Hansen Way, Palo Alto, Calif. 94303, offers a 16-page brochure describing its SpectroSystem 100, one of several data processing options available as part of the company's SpectroPlan. **[458]**

Multilayer p-c boards. Lockheed Electronics Co., 6201 E. Randolph St., Los Angeles 90022. Basic design criteria and tolerances for multilayer p-c boards are discussed in a 16-page, two-color booklet. **[459]**

Ultrasonic transducers. Nortec, 3001 George Washington Way, Richland, Wash. 99352. A catalog consisting of 12 data sheets contains vital information on more than 25 ultrasonic transducer models. **[460]**

Digital potentiometer. Honeywell Inc., Industrial Division, Fort Washington, Pa. 19034, has issued a four-page specification on the series 40011 digital potentiometer, which precisely measures and converts low-level analog input signals to digital displays. **[461]**

Audio amplifier. Bendix Corp., Semiconductor Division, South St., Holmdel, N.J. 07733. A four-page engineering data sheet describes a 2-w audio amplifier featuring thick-film fabrication. **[462]**

Insertion loss test set. Maury Microwave Corp., 10373 Mills Ave., Montclair, Calif. 91763. A four-page brochure covers the MT-100A dual channel, d-c comparator, insertion loss test set designed for extremely accurate measurements. **[463]**

Opto-electronic components. Sigma Instruments Inc., 170 Pearl St., Braintree, Mass. 02185. An eight-page brochure describes the range of opto-electronic components and controls offered by the company. **[464]**

Wire and cable. Harbour Industries Inc., Wire Division, Shelburne, Vt. 05482, has produced a comprehensive pocket manual on high temperature wire and cable technology. **[465]**

Automation control devices. Sensor Corp., 97 Indian Field Road, Greenwich, Conn. 06830. A brochure on electronic controls for automated machinery includes devices for sensing, counting, positioning, gaging, and sorting. **[466]**

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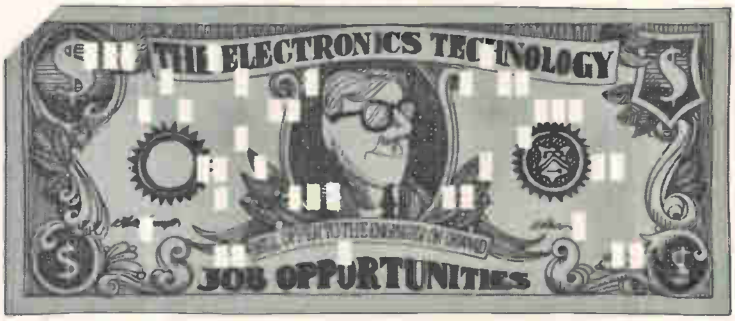

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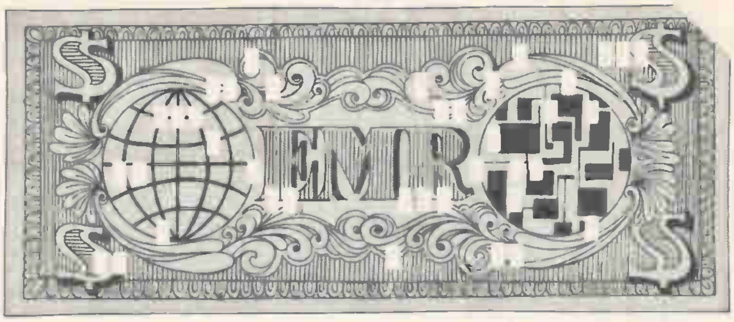

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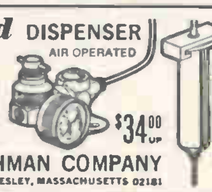

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Newsletter from Abroad

September 2, 1968

Red tanks burst comsat bubble . . .

The Russians' invasion of Czechoslovakia appears to have doomed their plan to launch Intersputnik, a Communist-bloc communications satellite consortium designed to rival Intelsat.

The plan had been branded a propaganda ploy by Western experts when it was introduced last month in Vienna at the U.N. space conference. For one thing, the U.S. pointed out, Moscow hasn't got a stationary-satellite system on the drawing boards; for another, the Russians placed great emphasis on Intersputnik's one-nation-one-vote character as opposed to Intelsat's weighted voting arrangement under which the U.S. has about 53% of the voting shares.

But even the propaganda value of Intersputnik's one-vote feature seems to have disappeared in the dust kicked up by Russian tanks in Czechoslovakia as Moscow's partners—the Czechs among them—wonder how much weight their votes would have against the might of Russian displeasure. Moreover, when the 62 nations in Intelsat sit down within a year to negotiate final arrangements for their consortium, the U.S. will take a smaller share and thereby further erode the Soviet position.

. . . but Bull-GE sure Czech deal is on

Officials at Bull-GE feel confident that Czechoslovakia's political turmoil won't wreck the deal they worked out to have the French-designed Gamma 140 computer built under license in Czechoslovakia by the government-owned organization, Tesla.

Although the five-year agreement was signed by the liberal Dubcek government, it was actually negotiated with the conservative Novotony regime. So Bull-GE thinks the computer pact will stand no matter what the country's ultimate political coloration.

A team of Bull-GE technicians had just finished installing a first Gamma 140 in Czechoslovakia when Warsaw Pact troops moved into the country. After stability returns, so will Bull-GE teams.

Computer ambitions spur Plessey's bid for English Electric

British insiders now believe that ambitions in the computer field rather than a simple desire to expand led the Plessey Co. to bid late last month to take over the much larger English Electric Co. If its move succeeds, Plessey would add English Electric's 18% holding in International Computers Ltd. to its own 18% share. This would make it the largest corporate stockholder in the British computer giant and put it in a position to take over that firm as well.

Plessey management offered $630 million for English Electric's equity and apparently stands a chance of convincing the company's shareholders that the price is right. If Plessey does, the British nonconsumer electrical-electronics industry will be dominated by Plessey-English Electric and the group put together by the British General Electric Co. (not connected with its U.S. namesake) after it took control of Associated Electrical Industries. The Plessey combine would be the larger of the two with some $1.4 billion in revenue, and would rank among the top half-dozen electrical-electronics companies in the world.

But though Plessey's and English Electric's electronics operations dovetail reasonably well over-all, the prime motive behind Plessey's move appears to be the company's belief that computers and communications add up to the most promising growth field in electronics.

Japanese squabble over vtr patents

The leading video tape recorder producers in Japan may be in for an intramural hassle over patents. At issue: the rights to two crucial techniques for low-cost vtr's—skipped-field recording, and the "Omega" tape wrap around the drum of two-head recorders.

Sony and Victor Co. of Japan are the main contenders in the skipped-field-recording patent fight. Victor obtained a design patent on the technique early this year. (With it, only one field of each frame is recorded —permitting a narrow tape—and then the field is played back twice to get adequate brightness.) Sony nonetheless still has in the works a regular patent covering a skipped-field home video recorder it put on the market nearly four years ago.

Victor says it will file objections to Sony's application before the mid-September deadline and presumably will have the backing of other manufacturers, who want to avoid having to work out license arrangements with two patent holders.

Victor's allies in the skipped-field controversy, though, figure to be on the other side in the squabble over who first invented the "Omega" wrap. Sony, Toshiba, Nippon Electric, Sanyo, and Shiba all have filed counterclaims to Victor's patent application.

22-inch color sets in offing for U.K.

Color television sets with 22-inch screens should be on the British market by next spring.

Mullard Ltd. is readying to mass-produce the 22-inch tubes and a sister company of the Philips' Gloeilampenfabrieken group, Philips Electrical Ltd., will use them in a single-standard receiver. Most color sets on the market now are bistandard—625 lines for the British Broadcasting Corp.'s second network and 405 lines for BBC-1, which broadcasts only black-and-white tv programs.

Philips figures that the 22-inch size gets around the common complaint that current 25-inch sets are too big for many British living rooms. At the same time, the compromise size avoids the "too small" label that has plagued 19-inch sets.

Mullard expects several set makers will hit the market with 22-inch receivers about the same time as its sister company. If the sets sell well —they'll be ticketed about 10% below 25-inch sets—the two other U.K. picture-tube makers presumably would follow Mullard's lead. Then, British set makers would almost surely build 22-inch sets exclusively.

German set makers color it rosy . . .

A fall spurt in color television sales now seems certain in West Germany. The country's set makers are confident that the Olympic games—which will be broadcast in color by the German network—will send buyers flocking to retailers.

Along with the games, there's a general upturn in the economy that's buoying sales. As a result, sales for the year should run about 220,000 sets. Early in the year, that figure would have seemed very optimistic.

. . . and so does AEG-Telefunken

The West German phase-alternation-line (PAL) color-tv system continues to annex territory. In Asia, Thailand and Hong Kong have adopted PAL. In two or three years, says its developer Telefunken, PAL most likely will be introduced in Finland, Sweden, Denmark, and Norway. This would make Northern Europe solid PAL territory except for France, where the competing Secam system was developed.

Electronics Abroad

Volume 41
Number 18

Japan

Sound vision

Sometimes, the best way to "see" something inside something else is to play an ultrasonic beam on it and pick up the image that's formed. Like X rays, ultrasonic waves go right through many objects that won't pass light, but the sound waves don't entail any radiation hazard.

The trick, of course, is converting the ultrasonic image into a visual one. The Tokyo Shibaura Electric Co. has found a slick way to do it —replace the photoconductive target of a 1-inch vidicon television camera tube with a quartz piezoelectric plate.

Toshiba had its ultrasonic system on hand at the Sixth International Congress on Acoustics at Tokyo last week and will probably be the first to put one on the market. Other such systems built so far have been too complex to get out of the laboratory, but Toshiba's uses a modified industrial tv camera.

Differences. In the image converter, a difference in potential is set up at points on the quartz plate where acoustic waves impinge. This difference causes a change in the number of secondary electrons generated when the tube's scanning electron beam hits "illuminated" points. Thus, there's a varying current flow through a resistor connected between ground and the conductive electrode on the face of the plate. The voltage drop across this resistor is the tube's output signal.

Internally, the ultrasonic tube is much like the usual vidicon. But because the ultrasonic image converter depends on the generation of secondary electrons, its scanning beam has to pack more energy—several hundred electron-volts instead of the several tens for a vidicon. The potential difference across the quartz plate has to be several volts for the change in the number of secondary electrons to produce a usable video signal.

Tanked. Toshiba's demonstration unit pairs the ultrasonic pickup tube, at one end of a small tank of water, with a 4-megahertz transducer at the other end. Between the two lie the object being looked at and an acoustic lens that focuses the image on the tube through a diaphragm.

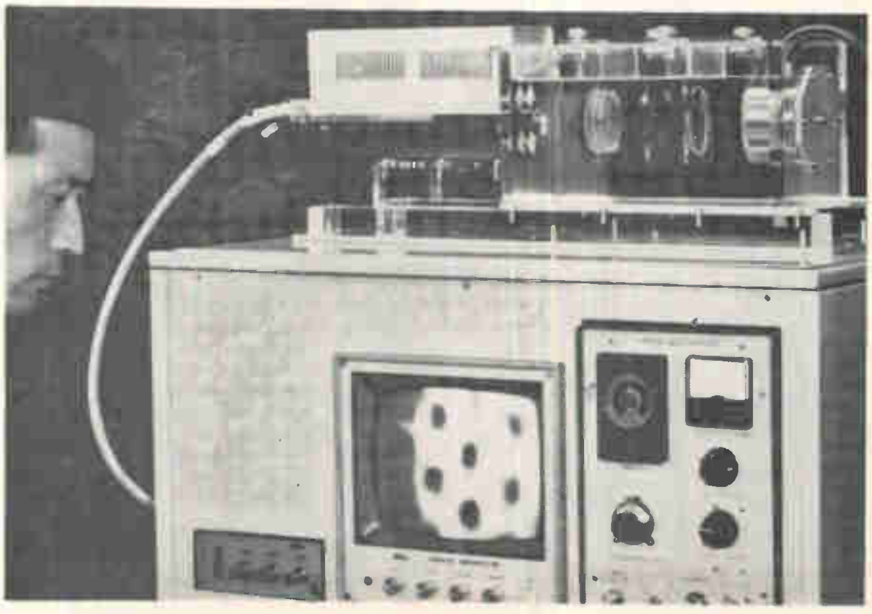
The resolution for the 1-inch tube is several tens of lines. For sharper images, larger tubes would be needed. Toshiba concedes that this would be difficult. The quartz plates are a half-wave thick—0.7 millimeter—and diameters larger than 1 inch would be hard to produce, but the company's researchers insist it could be done. Despite the low resolution, though, the standard 525-line scan is used.

Looking in. Toshiba sees nondestructive testing of light-opaque materials as the first industrial use for the ultrasonic system. Doctors one day may use it to check internal organs. And Toshiba researchers say the system is a natural for inspecting construction jobs going on in turbid waters.

If the ultrasonic tv doesn't catch on, Toshiba has another development to fall back on—cells filled with aluminum flakes suspended in liquid. Where ultrasonic waves hit the cell, the flakes line up and the cell appears bright; elsewhere, it's dark. At present, resolution is better than in the tv system, but the flake-filled cell is hard to use and the persistence is too long for viewing moving objects.

Crystal clear

It's not only the research crew at Toshiba (see story above) that's putting strange scenes on its television monitor screens. The solid



Screen test. Small perforated iron plate about 0.8-inch square in tank looms large on monitor of Toshiba's ultrasonic tv system.

state group at the Broadcasting Science Research Laboratories of Nippon Hoso Kyokai has found a way to show what's happening inside crystals while it's happening.

NHK, a nonprofit public-service corporation whose main business is running broadcast stations, says its researchers are the first to see crystal structures "live" on a picture tube. The secret behind their success: a very powerful source of X rays and an X-ray vidicon.

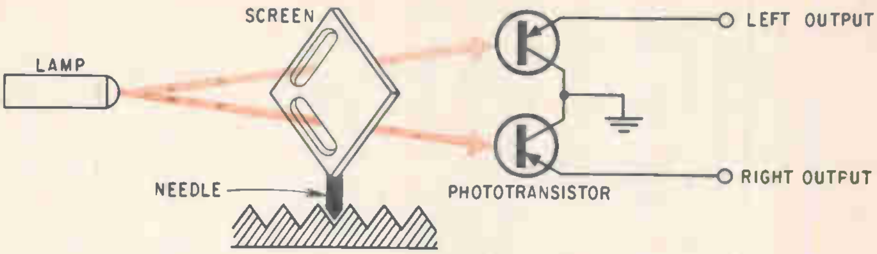
Run-of-the-mill crystallography requires about 12 hours to get a series of diffracted X-ray images showing defects in crystal structures—defects that make all the difference in the characteristics of semiconductors. The slowness stems, essentially, from the low-intensity X rays put out by the industrial generators generally used for diffraction studies.

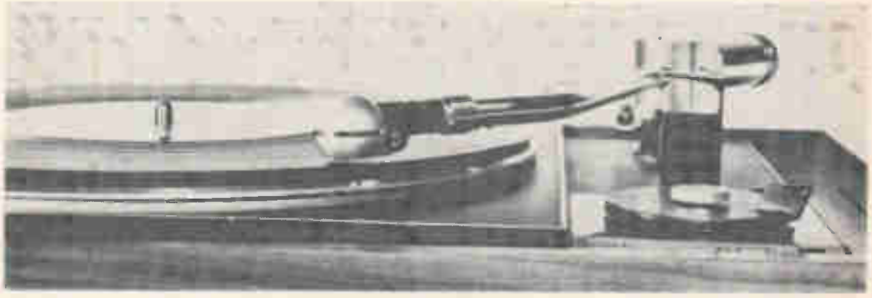
In a minute. Three years ago, NHK's solid state group started work on a generator that could develop X rays 100 times more intense than those of conventional generators. Early this summer, the group completed an experimental version that bombards a rotating target with a 60,000-volt, ½-ampere electron beam. As a result, films can be exposed in only about 1 minute.

The new X-ray source also makes possible electronic viewing at the standard frame rate of 30 per second. To transform the X-ray diffraction pattern into a video signal, NHK developed a special vidicon. Its window is beryllium—transparent to X rays—and its target is lead oxide. The oxide's characteristics are tailored to get maximum sensitivity to the soft X rays produced by diffraction.

Good tip

High-fidelity addicts in Japan will have a new issue to take sides on this fall—the merits of a light-modulating, lightweight stereo phonograph cartridge.





Light fantastic. Special germanium phototransistors and a low-mass screen are chief ingredients in Toshiba's recipe for low-distortion phonograph pickup.

The Tokyo Shibaura Electric Co. plans to start selling the cartridge in its home market in October. The $78 price includes both a preamplifier that carries the power source for the light and—according to Toshiba—the lowest harmonic distortion anyone offers. Toshiba will export the cartridge, but hasn't decided when.

Groovy. The cartridge itself has a miniature lamp, a screen jiggled by the needle, and a pair of special germanium phototransistors. As the screen moves it modulates the light falling on the transistors according to what's in the grooves.

Because the needle moves only the screen, the moving mass of the pickup cartridge is a mere 0.3 milligram. Coil pickups have masses of about 0.4 mg and other types—moving magnet, ceramic, or crystal—have to push about 1 mg. Like most top-drawer pickups, Toshiba's has a 1 gram tracking force.

The phototransistors were designed for very high linearity, and they make for a frequency response over a range from 20 hertz to 40 kilohertz. Under standard distortion-measuring conditions—1 khz and tracking velocity of 5 centimeters per second—harmonic distortion is 0.65%, exceptionally low. At the same 1-khz frequency, the channel separation is 32 decibels.

The direct audio output of the cartridge is 75 millivolts. The preamplifier, which contains equalizing circuits for the two channels, boosts the output to 200 millivolts.

Light-headed. Toshiba also has something new in cartridges for consumers who'd rather buy a phonograph than put components together. The company's high-priced consoles are going to get an integrated-circuit cartridge that's just slightly larger in diameter than a kitchen match.

The small size, Toshiba says, stems from the IC's field-effect transistors. Because of them, the output from the piezoelectric elements driven by the needle can be very low—several millivolts. The cantilever rods attached to the needle can be shorter and lighter because the piezoelectric elements need not be deformed as much as in conventional cartridges. Since the cartridge is so small that a conventional plug wouldn't make sense, Toshiba does not plan to sell it as a component.

Great Britain

Thin slices

Ask a semiconductor expert why silicon slices are almost always more than 100 microns thick and he'll probably start explaining how anything thinner than that is too brittle to be of any real use.

Not so, say three researchers at Standard Telecommunication Laboratories, one of the British units of the International Telephone and Telegraph Corp. Like everybody else, they found that silicon wafers do become brittle at first when thinned down below the presumed 100-micron limit. But, partly by accident, the trio also discovered that the brittleness practically vanishes when slices are 10 microns thick or less.

The three researchers, Derek Mash, Gordon Henshall, and Brian Eales, say that a 5-micron slice can be folded almost double before it cracks, like a piece of celluloid. At the Second Conference on Solid State Devices at the University of Manchester later this week, they intend to double over some slices and discuss what very thin silicon might lead to.

Lapped. The trio's discovery was an offshoot of its work on a high-slope varactor, one with a much-higher-than-usual change in capacitance. One of the ideas was to lap down the back side of a slice all the way through the substrate and into the diffused region, turning the p-n junction into a ring. The result was a slice less than 10 microns thick. Much to the trio's surprise, the wafer—so thin it was transparent—didn't disintegrate when it was picked up.

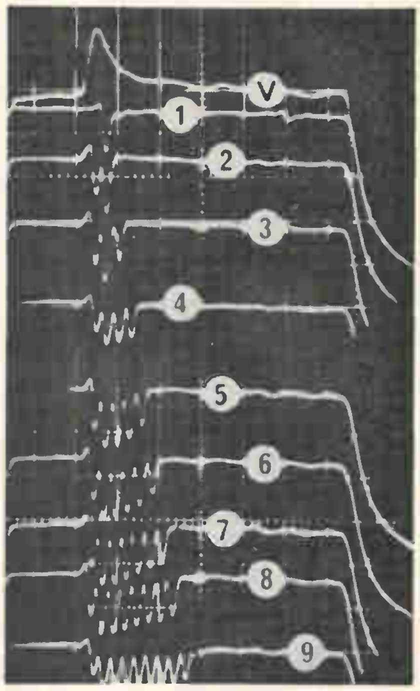
Mash says his team can make 5-micron wafers up to 1 inch in diameter and can hold thickness variations to ±0.2 micron. To fabricate the thin slices, Mash laps down ordinary 100- or 200-micron wafers, using alumina slurry. The transparency makes the thickness easy to measure optically. The lapping is sometimes followed by a chemical etch to clean off work damage, but Mash doesn't think this step would be necessary in full-fledged production. It takes about four hours to polish a slice down to 10 microns.

Junction rings in the thin slices have about the same electrical properties as junctions in ordinary slices. Breakdown voltage, particularly, is comparable for the two. The team currently is checking out in detail the properties of 5-micron slices. From results obtained so far, Mash predicts that devices with a capacitance of 0.1 picofarad could be easily made.

Up with power. The thin slices, Mash thinks, will lead to higher power outputs for high-frequency devices; the thinner the slice, the better its thermal conduction to a copper heat sink. Perhaps the first device to come will be a varactor diode for harmonic generation.

A high-slope varactor also looks like an early thin-slice device. It would have a diffused area whose outline would look like that of a daisy. At low voltages, the depletion layer is narrow and would closely outline the serrations around the junction ring. At higher voltages, the depletion layer gets larger and thus would tend to fill in the serrations. In other words, the area of the outer wall of the depletion layer is reduced—compared to the inner wall's area—as voltage increases. This results in a greater capacitance change than in an ordinary varactor.

Still another class of thin-slice devices would have metalization on both sides. An obvious example, Mash points out, would be a decimal-to-binary converter. It would comprise a matrix of diffused regions connected in horizontal rows on one side and in vertical rows on the other. The device could be made in four steps: diffusion, thinning, metalization on one face, and metalization on the other face.



Fast count. The output pulses of a Gunn diode give a digital readout of analog voltage. An analog input pulse lasting 12 nanoseconds triggers the "9" reading at bottom.

Gunned-up pulses

Add pulse-code-modulation transmission to the fast-growing list of potential applications for Gunn diodes. The devices, report two researchers at the University of Sheffield, should perform admirably as generators and regenerators of very fast pulses—with durations from 1.4 to 6 nanoseconds.

The two, Hans Hartnagel and Touraj Izadpanah, work with ordinary gallium arsenide crystals made into diodes from 140 to 600 microns long. They've recorded power gains from 8 to 11 decibels. That's high enough, Hartnagel figures, to make possible production of pulse regenerators built around Gunn diodes. There's still a heat dissipation problem, but Hartnagel thinks the solution is diodes with cross sections 100 microns by 100 microns or smaller. In their experimental work, Hartnagel and Izadpanah have skirted the heat problem by using pulses to bias their diodes.

Domains. In a Gunn diode, high-field domains move through the crystal one at a time when it's biased above a threshold value. As each domain forms, the resulting current drop can be transformed into a voltage pulse by putting a load resistance—50 ohms in this case—in the circuit.

As pulse regenerators, the diodes work best biased at just below the threshold for domain formation. The pulse output from one diode triggers a domain in the next. Once a domain forms, though, it will continue to pass through the crystal even though the pulse that launched it has ended, because the bias voltage exceeds the extinction level.

The load resistor can be in series

with the diode or in parallel with it, but Hartnagel and Izadpanah found the series arrangement best over-all. Parallel circuitry, with a current source for bias, gave greater gain than the series arrangement, but suffered from reflection effects. There isn't any reflection in the series configuration, because the input and output pulses have opposite polarities.

Converter. Hartnagel and Izadpanah also see the Gunn diode as the basis for a very fast analog-to-digital converter. Their scheme: use a trapezoidal diode to trigger a conventional one biased, like the pulse regenerator, just below the threshold for domain formation.

The trapezoidal diode generates a triangular pulse that's fed to the second Gunn diode, whose bias is set so that with a low-input analog voltage the domain threshold is reached only at the apex of the triangular pulse. This triggers a single pulse from the output diode.

As the analog voltage increases, more of the triangular pulse lies above the threshold level and there's time for more than a single domain to move across the output diodes. The number of output pulses thus depends on the input voltage level. The pulses have amplitudes between 3 and 4 volts; a digital count of "9" requires an input pulse of 12 nanoseconds.

Hartnagel and Izadpanah are scheduled to talk about their work later this week at the University of Manchester solid state meeting.

West Germany

Back in the air

West German avionics producers long have counted on a big military program—replacements for the Luftwaffe's aging F-104 Starfighters—to airlift them off their current low sales plateau. The order for the next batch of military planes is still to come, but a ripple of optimism went through the industry late last month as the government announced it would back development of a short-haul jet.

The 36-passenger plane—the first commercial jet to be built by West Germany's once high-flying aviation industry—will come off the production lines of Vereinigte Flugtechnische Werke GmbH at Bremen.

Loaded. Rolf Stuessel, who will run the program, says the prototype will fly by 1971. The sales target for the jet, called the VFW 614, is 375 planes. At an average $1.9 million apiece, that would mean something like $712 million in sales for VFW and the other companies participating in the project.

If VFW's sales plans pan out, West German avionics producers stand to pick up a good part of the estimated $32.8 million in electronics hardware the jets would need. Standard systems for the plane include four very-high-frequency radio sets, two direction finders, two compass systems, a flight-control system, an autopilot, distance-measuring equipment, a transponder, weather radar, and a flight-data recorder. An automatic landing system will be among the options.

The Netherlands

Right-light chip

Japan's Yashica Co. stole a march on its competitors early this summer when it marketed an electronic camera with an integrated circuit that shows when the shutter speed and aperture setting are right [Electronics, July 8, p. 221].

But like many a technological pioneer, Yashica may soon find itself with an obsolescent product. Philips' Gloeilampenfabrieken has developed a monolithic IC for electronic cameras, and it's a good bet that some camera maker will snap it up before too long. The Philips IC develops an output that operates a shutter-closing solenoid. Yashica's circuit, manufactured by the Nippon Electric Co., is a thick-chip hybrid that controls lamps.

Wide range. The Dutch IC, developed at Philips' Eindhoven research facility, has on the chip all the key components for an exposure meter, including a photodiode. Its output voltage is measured, with very little current consumption, by a differential amplifier.

When the shutter opens, the circuit starts integrating the difference current. The integration continues until the amount of light that has passed through the lens is right for the aperture setting and the film rating. Then, the voltage across the integrating capacitor is high enough to switch a trigger circuit that controls the shutter solenoid.

The circuit, Philips says, can handle a wide range of camera settings—apertures from f2 to f16, shutter speeds from 1/1,000 to 20 seconds, and film ratings from ASA 25 to ASA 2,800. Philips has kept details of the circuit to itself but will report on it at the Solid State Sensors and Transducers Symposium in Minneapolis next week.

Around the world

Australia. Down Under electronics producers will turn out about $224 million worth of hardware this year, the government estimates. The figure for 1968 is up $22 million from last year's output and is split about equally between consumer goods and heavy equipment.

Japan. The Ministry of Transportation expects to have a nationwide data-transmission network ready by 1971 to handle auto registrations. The system will link the ministry's 63 regional offices to a Nippon Electric NEAC 2200 Model 500 computer in Tokyo. Last year the ministry handled 20 million registration transactions. The figure is expected to reach 100 million in the next five years.

Great Britain. The Marconi Co. has landed a contract to supply some $2.4 million of television transmitters to the British Broadcasting Corp. between now and 1971. The order covers five 40-kilowatt, two 25-kw, and nine 10-kw transmitters. All are uhf units.

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GENERAL	DC triode sputtering. Metals, conductors.	RF triode sputtering. Conductors, semi-conductors, non-conductors.	RF diode sputtering.	Production-type system with DC Crossfire™ and RF capability on in-line basis with air to air substrate transport.	DC Crossfire™ with rotary work holder, multiple targets.
APPLICATIONS	Laboratory and limited production. Ideal with CV-18 vacuum system.	Laboratory and limited production when used with PlasmaVac 100.	Sophisticated research applications. Reactive sputtering, sputter etching, semi-conductors, dielectrics, etc.	Bridges the laboratory/production interface. Modular concept so process can be developed, then scaled up to meet production needs.	Batch-type production unit for pilot plant operation.
Deposit Metals	Yes	Yes	Yes	Yes	Yes
Deposit Dielectrics	No	Yes	Yes	Yes	Yes*
Deposit Semiconductors	Some	Yes	Yes	Yes	Yes*
Deposit Cermets	No	Some	Yes	Yes	Yes*
Deposit Alloys	Yes	Yes	Yes	Yes	Yes
Deposit Organics	No	No	Some	Some	No
Water Cooled Target (for use of thermally sensitive materials)	No	No	Yes	Yes	Yes
Water Cooled Substrate	No	No	Yes	Yes	No
Reactive Sputtering	No	Some	Yes	Yes	Some
Bias Sputtering	Yes	Some	No	No	No
Sputter Etching	Few	Some	Yes	Yes	No
Type of Chamber	Bell Jar	Bell Jar	Bell Jar	Production-type modular chamber	Low profile metal chamber
Multiple Target Sputtering	Yes	Yes, with PlasmaVac 100	No	Yes	Yes

*Available on special order.

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