Electronics®

Low-noise amplifier for microwave systems: page 74

Harmonic testing spots component flaws: page 93

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July 11, 1966
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Below: Selector switches colors of laser beam: page 84

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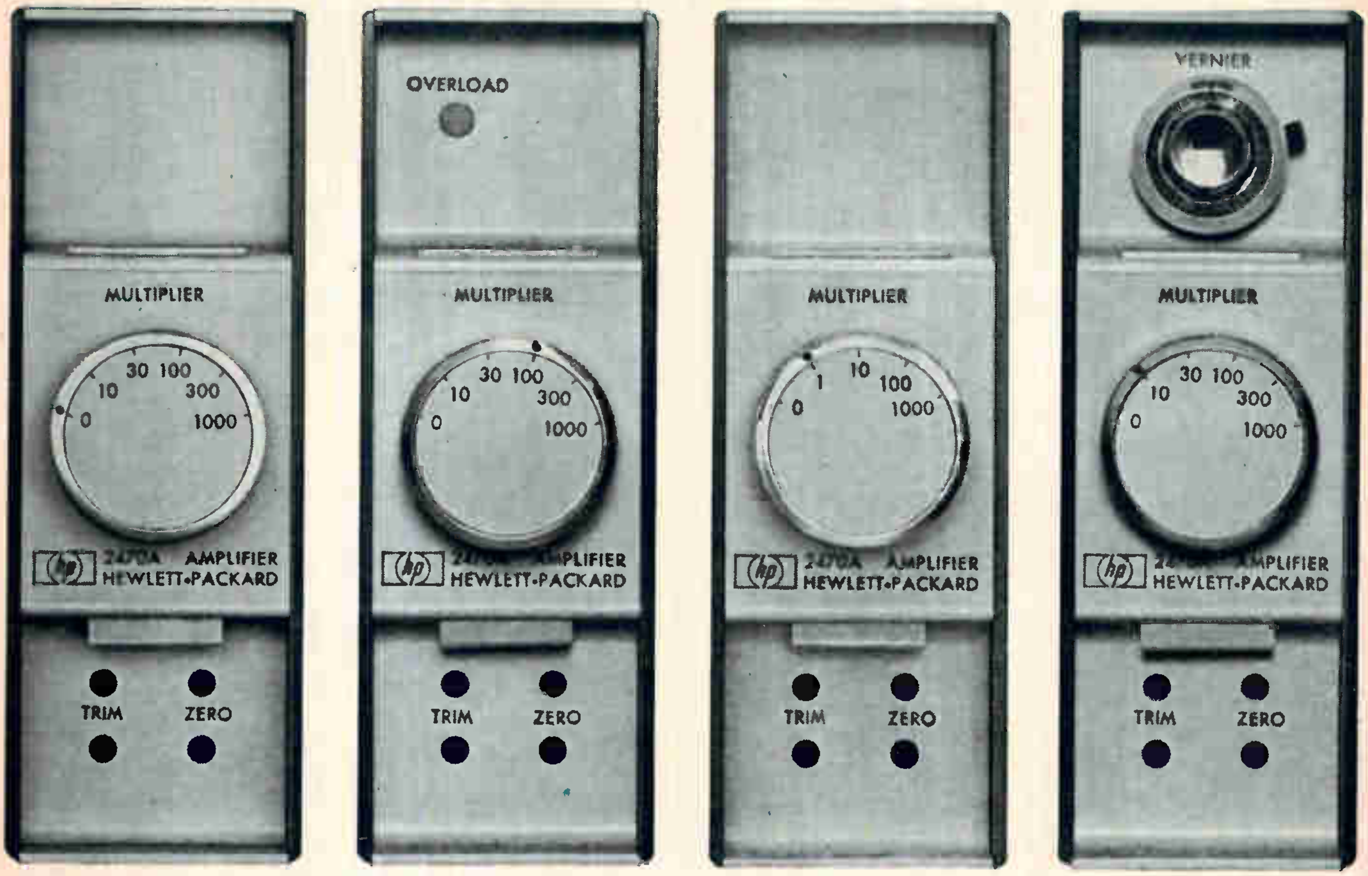

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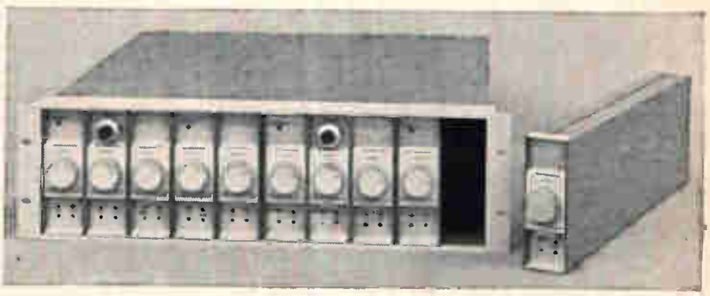

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1188

Electronics

July 11, 1966
Volume 39, Number 14

Electronics Review

Probing the News

Electronics Abroad

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I. Design

II. Applications

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Readers Comment

Wire and rod

To the Editor:

In your article "Memories on a wire" [May 30, p. 36] the statement is made that "if Univac does introduce a plated-wire memory computer . . . it will be the first U. S. company to do so."

To set the record straight, it should be pointed out that the National Cash Register Co. introduced the plated-wire NCR 315 RMC (rod memory computer) on July 13, 1964.

Deliveries of these systems began last fall, which made the 315 RMC not only the first computer with a plated-wire memory to be announced, but also the first of this type to be installed anywhere in the world.

Owen B. Gardner
Vice President
National Cash Register Co.
Dayton, Ohio

▪ The question is: what's a wire and what's a rod? Electronics is aware of NCR's rod memory, having reported the introduction of the NCR 315 [July 27, 1964, p. 30].

Today, plate-wired memory development is aimed at making memories of long wires with batch-fabrication techniques. With Univac's plated-and-etched-wiring memory, only 32 wires are needed to make a memory of 4,096 32-bit words.

NCR also starts with plated wire, but cuts it up into six-inch lengths that each store only 40 digits, or 160 bits. The rod memories are then assembled with thousands of such short lengths, plus thousands of solenoid windings.

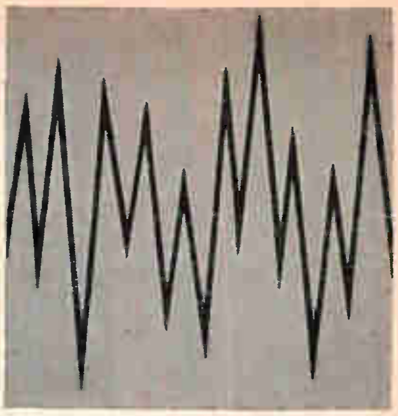
Engineering courses

To the Editor:

The article by Walter Barney on systems engineering [May 2, p. 115] prompts me to send you a leaflet that describes one of the most flexible programs ever proposed within a college of engineering. This, as you well know, is an area which has been plagued by rigidity and charged with narrowness for many years.

While we would probably agree

Sprague has what it takes to cope with any problem in electromagnetic interference or susceptibility control



And we mean any problem . . . arising at any point in the development of any equipment or system!

Sprague's interference control facilities provide one of the most complete, fully integrated capabilities you can call on . . . embracing *every* aspect of interference and susceptibility control.

Design Assistance: Black boxes . . . subsystems . . . complete systems. Using advanced interference prediction techniques, Sprague engineers replace design by "hunch" with precise analysis of electrical schematics. Suppression and shielding can be designed into pre-prototype plans so accurately that little or no modification is required upon evaluation of the model. With today's more complex equipment and increasingly stringent EMI requirements, Sprague assistance in initial design can pay for itself in a dozen different ways by helping you be right the *first* time!

Measurement, Evaluation: Sprague can help you measure interference and susceptibility characteristics of your breadboard, prototype, or production equipment to the applicable interference specification. You know where you stand before investing in further development. We can also research such areas as shielding effectiveness, screen room integrity, transient susceptibility of digital equipment, and cable cross coupling.

Component Design: Sprague Filter Engineering Specialists can design, evaluate, and sample interference control devices to your particular requirements. These range from standard feed-thru capacitors and radio interference filters to the more sophisticated packages, such as frequency-controlling electric wave filters.

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Compliance Testing: Sprague can test your equipment or system and report on its compliance to the applicable specification: MIL-I-6181, MIL-I-26600, MIL-I-16910, MIL-E-6051 or to such other specialized interference documents as GM07-59-2617A, AFBSD Exhibit 62-87 (Minuteman WS133B), LSMC Specification ERS11897 (Polaris A3) or MIL-STD-449. If compliance is not indicated, a Sprague engineer will make concise recommendations and will, if you desire, give you every assistance in achieving that compliance.

Regional Service: Wherever you may be, this integrated EMI capability is readily available to you from strategically located Filter Development Centers in North Adams, Mass.; Annapolis Junction, Md.; Vandalia, Ohio; and Los Angeles, Calif. Each is fully equipped and staffed to evaluate, modify, or qualify your equipment.

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that our definition of systems engineering might be as different from others as you indicate, we do have a defined area of academic work and, we feel, a major discipline to offer students. It grew out of work formerly conducted in electrical engineering and is now ready to stand on its own feet. It includes opportunities for work from the College of Business and the College of Social Science as well as having its major area in the College of Engineering.

Although this has been announced on this campus only for about four weeks, we have already found it to be a source of new students, attracted out of other academic areas. We believe the best way to solve the problem of an engineering shortage—if there is one—is to offer programs in engineering which are attractive to today's students. These new programs seem to do just that.

If I might violate good business practice and refer in this letter also to your editorial [May 16, p. 23] I would like to point out that we have been using the Victor Electrowriter for the past year in teaching both graduate and undergraduate courses simultaneously with classes on campus. After working out some of the initial bugs we have now become moderately enthusiastic. It certainly seems worthy of being called the "poor man's television," and many continuing education opportunities exist only at the poor man's level of financing.

J. D. Ryder
Dean
College of Engineering
Michigan State University
East Lansing
Mich.

Still in training

To the Editor:

Your editorial "School market waits" [May 16, p.23] was of special interest to me.

I believe, having been intimately associated with the adaptation of the Electrowriter into the Victor Electrowriter remote blackboard system (VERB) since its inception, that I have personally bumped into many of the shortcomings of the present equipment as related to specific problems of education and educators.

As you would expect, we are applying research and product improvement efforts to eliminate the deficiencies we are aware of because we are satisfied, like you, that simplicity, ease of operation and the ability to utilize the voice switching network are features that educational and training people want in this area.

James G. Johnson
Electrowriter Sales Manager
Victor Comptometer Corp.
Chicago

Long links

To the Editor:

I enjoyed the concept of your Vietnam equipment review [May 16, p. 95] but one detail is in error. From my experience, the longest tropo link is a General Electric Co. single sideband multiplex link south of Thule, Greenland. The next is a Radio Engineering Laboratories f-m tropo link also terminating in Thule. I am currently concerned with a longer tropo link than the Bangkok-to-Saigon link you mentioned.

Dyrck John DeWitt
Federal Electric Co.
APO New York

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People

Some metals become superconductive—that is, they offer no resistance to an electric current—below a certain transitional temperature which is inversely proportional to the square root of the mass of the ions in the metal. No metal has been found that is superconductive above 20°K, which is very close to absolute zero. The average transition temperature is 6°K. Physicist **William A. Little** theorized 1½ years ago that a module could be synthesized that would be superconductive at room temperature and far above it. In the molecule, the function of the metallic ions would be performed by electrons, which have a mass 1/100,000th that of an ion. The transition temperature, then, would be multiplied by a factor of 316 (the square root of 100,000).

Little, a 35-year-old professor at Stanford University, will be a consultant to Synvar Associates, a research company formed last month by Varian Associates, an electronics company, and the Syntex Corp., a pharmaceutical and chemical company that produces a birth-control pill. If Synvar could start churning out some kind of superconductive plastic, it would revolutionize the electronics industry. But Little is emphatic on two points—that no such thing is about to happen, and that he himself cannot speak for Synvar.

Not the details. Exactly what his function will be has not yet been defined, Little says. In his theoretical work on superconductivity, he has been laying out an "engineering blueprint" for the chemists. "What the chemists have done," says Little, "they understand. I don't—at least not all the details."

Little had considered applying for government funds to finance his own research, but such a program would involve him in administrative and accounting details which, he says, are not his forte. "The work can be done much bet-

ter at Synvar anyway," he says. "I'm very, very happy about it."

Little was born in the Union of South Africa, and lived there until he was 23. He earned a bachelor of science degree at the University of South Africa in 1950, and went on to take two doctorates in physics—at Rhodes University and at the University of Glasgow.

"One of those was sort of a mistake," he says. "I was supposed to be working on a master's at the time." While at Glasgow he won the Scottish high-jump championship twice.

Some changes. Since publication of his theory last year, he has modified his ideas on organic superconductors. For one thing, he no longer believes that the molecule need be a long chain, an idea which some researchers challenged. He says that the Russians are doing work in superconductivity and adds that "they're checking up to see whether I'm talking a lot of garbage or not." He and one of the Russian physicists correspond regularly.

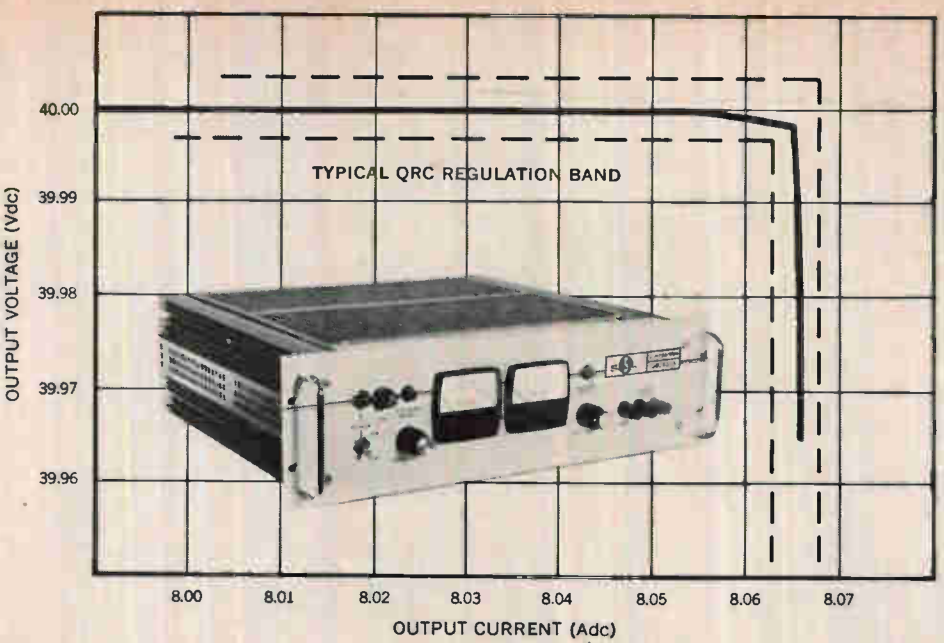
"The whole effort is like a game of chess in which you have to plan 40 moves ahead," he says. "You can engineer a molecule that looks as if it would work, but you have to be careful that it won't turn into a ring, for instance.

"What I've suggested is an idea which is probably right", he adds, "but you can't be sure. You don't really know if you can synthesize these molecules."

If it could be synthesized, he noted, the possibilities for power transmission without loss, and more efficient motors, amplifiers, particle accelerators and even computers would be fantastic.

Even transportation could benefit, since superconductors are diamagnetic—that is, they are impermeable to a magnetic field. At cryogenic temperatures, a magnet can be floated above a sheet of superconductive metal. If a plastic material could be produced that is superconductive, a magnetic car could be floated above it.

The superconductive molecule is still a dream, but Synvar Associates may make it a reality.



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MODEL NUMBER	OUTPUT VOLTAGE RANGE (Vdc)	CURRENT OUTPUT RANGE (Adc)	VOLTAGE REGULATION (LINE & LOAD COMBINED)	RIPPLE VOLTAGE (rms)	CURRENT REGULATION	RIPPLE CURRENT (rms)	RACK HEIGHT (INCHES)	PRICE
QRC20-08A	0-20	0-8	± .005% or ± 1 mv	1 mv	± .05% or ± 4 ma	1 ma	3½	$410.00
QRC20-15A	0-20	0-15	± .005% or ± 1 mv	1 mv	± .05% or ± 8 ma	2 ma	5¼	525.00
QRC20-30A	0-20	0-30	± .005% or ± 1 mv	1 mv	± .05% or ± 16 ma	4 ma	7	700.00
QRC40-4A	0-40	0-4	± .005% or ± 1 mv	1 mv	± .05% or ± 3 ma	1 ma	5 †	315.00
QRC40-8A	0-40	0-8	± .005% or ± 1 mv	1 mv	± 05% or ± 4 ma	1 ma	3½	450.00
QRC40-15A	0-40	0-15	± .005% or ± 1 mv	1 mv	± .05% or ± 8 ma	2 ma	5¼	575.00
QRC40-30A	0-40	0-30	± .005% or ± 1 mv	1 mv	± .05% or ± 16 ma	4 ma	7	775.00

†Half rack

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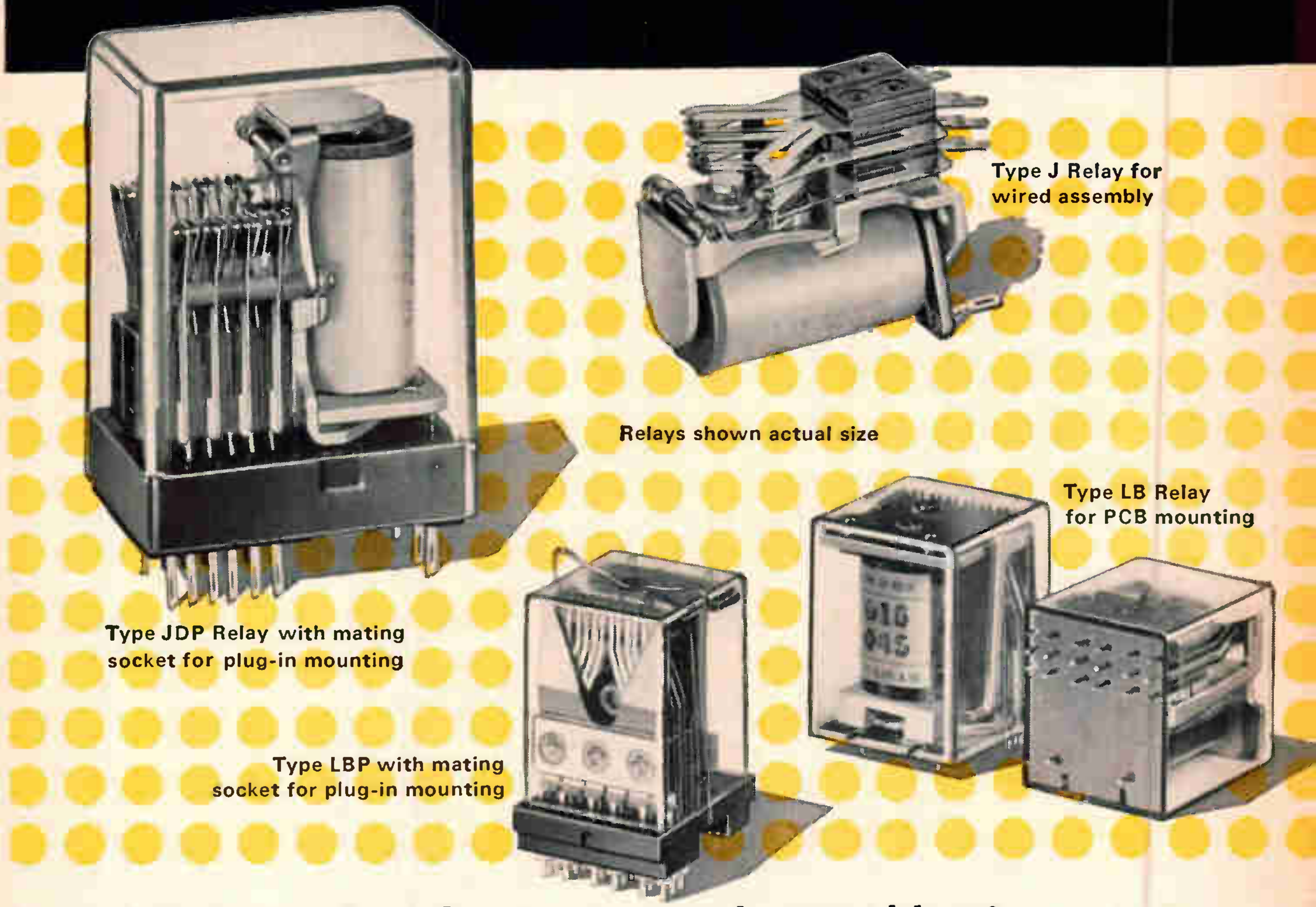

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For commercial, industrial or military applications, CLARE telephone type relays solve a wide variety of switching problems.

TELEPHONE TYPE RELAYS

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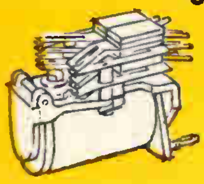
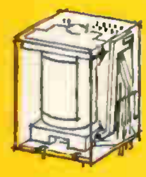


A general purpose relay whose consistent performance has been demonstrated in thousands of applications. Solder, taper-tab and printed-circuit terminals are available. Enclosed or hermetically sealed versions are also supplied.

CLARE *TYPE JDP RELAY*

An assembly providing direct plug-in mounting of Type J Relay using contact springs and coil terminals as plug pins. This eliminates costly wiring and saves 20% in height over conventional octal plug relays. Clear plastic dust cover. Two socket sizes: 28 terminals for 24 contact springs; 16 terminals for 12 contact springs. Both with four coil terminals. Three socket terminal styles: solder, taper-tab, or printed-circuit.

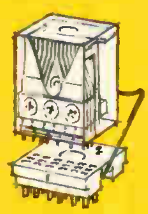
CLARE *TYPE LB RELAY*



Mounting height—
1.24 inch maximum.

A high quality, low cost relay which meets the demands of functional PCB applications where small size (1.33 cubic inches), versatile contact arrangements, wide range of contact load capacities, high contact reliability and direct PCB mounting is desired. Clear plastic dust cover. Phenolic bottom plate with tinned nickel-silver terminals.

CLARE *TYPE LBP RELAY*



Mounting height: 1½ inches
for wired assembly;
1¾ inches for PCB.

A plug-in version of the Type LB Relay with the same operating and design characteristics. Clear plastic dust cover. Choice of two socket styles: (1) solder type terminals with elongated slots for wired assembly mounting, or (2) tab terminals for PCB mounting.

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	Contact Arrangements	Contact Ratings	Coil Resistance	Nominal Operating Voltages	Operate Time	Release Time
Types J and JDP	Forms A, B, C, D, E with up to 24 contact springs max	Low level to 1000 watts, 10 amps	Up to 28,000 ohms	Up to 340 vdc Up to 220 vac 50-60 cps	Fast operate: 5 ms min Delayed operate: 60 ms max	Fast release: 5 ms min Delayed release: 125 ms max
Types LB and LBP	Forms A, B, C, D with up to 6 contact forms	Low level to 2 amps	Up to 6,550 ohms	Up to 100 vdc	6 ms min	2.5 ms min

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Microelectronics Symposium, 1966 program, St. Louis Section of IEEE; Colony Motor Hotel, St. Louis, Mo., **July 18-20.**

Fifth Reliability and Maintainability Conference, American Institute for Aeronautics and Astronautics, Society of Automotive Engineers, American Society of Mechanical Engineers; Statler-Hilton Hotel, New York, **July 18-20.**

Nuclear and Space Radiation Effects Conference, IEEE, Stanford University, Stanford, Calif., **July 18-22.**

Royal Microscopical Society International Conference and Exhibition, Micro '66; London, **July 18-22.**

Rochester Conference on Data Acquisition and Processing in Biology and Medicine, University of Rochester IEEE, Rochester Section IEEE, Group on Biomedical Engineering, Monroe County Medical Society; University of Rochester, Rochester, N.Y., **July 25-27,**

Medical Equipment Display and Conference (Medac '66), Association for the Advancement of Medical Instrumentation; Sheridan-Boston Prudential Center, Boston, **July 25-29.***

Value Analysis and Engineering Workshop Seminar, Value Analysis, Inc.; La Salle Hotel, La Salle, Chicago, **July 25-29.**

Research Conference on Instrumentation Science, Instrument Society of America; Hobart and William Smith Colleges, Geneva, N.Y., **Aug. 1-5.**

U. S. Navy Second Marine Systems and ASW Conference, American Institute of Aeronautics and Astronautics; Lafayette Hotel, Long Beach, Calif., **Aug. 8-10.**

Guidance and Control Conference, American Institute of Aeronautics and Astronautics; University of Washington, Seattle, **Aug. 15-17.**

NATO Advanced Study Institute, NATO; University of Keele, Staffordshire, England, **Aug. 15-26.**

Joint Automatic Control Conference, Automatic Control Group; University of Washington, Seattle, **Aug. 17-19.**

Symposium on Computer and Information Science (COINS), Columbus Laboratories of Battelle Memorial Institute, Office of Naval Research, Ohio State University; Columbus, Ohio, **Aug. 22-24.**

Technical Symposium, Society of Photo-Optical Instrumentation Engineers; St. Louis, Mo., **Aug. 22-26.**

Television and Radio Show; Earls Court, London. **Aug. 22-26.**

International Electronic Circuit Packaging Symposium, Electrical Design News; Sports Arena, Los Angeles, **Aug. 23-24.**

International Conference on Luminescence, Research Institute for Technical Physics, Hungary Academy of Science; Budapest, Hungary, **Aug. 23-26.**

Western Electronics Show and Convention, IEEE and Western Electronic Manufacturers Association; the Sports Arena and Hollywood Park, Los Angeles, **Aug. 23-26.**

Call for papers

Conference on Engineering in Medicine and Biology, sponsored by the IEEE, Instrument Society of America, American Society of Mechanical Engineers, San Francisco, Calif., Nov. 14-17, 1966. **Aug. 14** is deadline for submitting papers to Dr. Dennis Le Croissette, program chairman, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif. 91130

Society of Automotive Engineers Electronic Packaging Conference, Roosevelt Hotel, New York, Feb. 14-16, 1967. **Aug. 26** is the deadline for submitting papers to A.J. Favata at SAE headquarters, 485 Lexington Ave., New York, N.Y. 10017

* Meeting preview on page 16

Meeting preview

Medical electronics

Medical doctors and instrumentation designers who serve them will meet in Boston, July 25 to 29, at the Medical Equipment Display and Conference (Medac '66). The conference has two purposes: to acquaint doctors with available electronic gear and to familiarize equipment designers with the needs of the medical profession. The session is under the auspices of the Association for the Advancement of Medical Instrumentation, a group formed just six months ago to improve communications between the medical community and instrument makers [Electronics, Jan. 10, p.25].

One of the questions to be explored is: who will set standards for medical electronic equipment—the medical profession, the producers, or the Food and Drug Administration? A hint of what's to come may be contained in the keynote speech by Dr. James F. Goddard, the new FDA commissioner.

Search for standards. Dr. Matthew M. Patton of the Sacred Heart General Hospital, Eugene, Ore., and Dr. Charles D. Ray of Johns Hopkins Hospital, Baltimore, will moderate a session devoted to standards. Dr. Ray will start the session by inviting discussion on his talk, which is titled: "Standards—where do we start?" Dr. Patton will describe an outline for standards manuals and Gustave Shapiro of the National Bureau of Standards will analyze performance verification test standards.

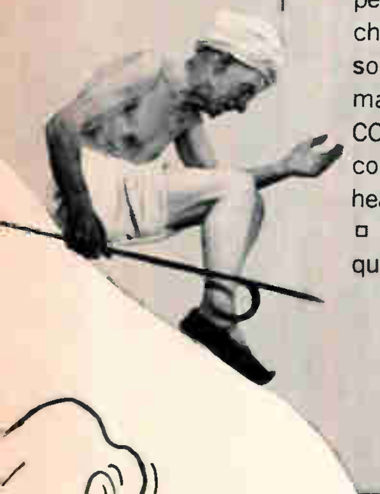
Sessions will be devoted to computers and to lasers. Dr. Gwilym Ludwick of the University of Missouri will speak on computer-aided diagnosis in radiology. Papers are scheduled on the laser microprobe and on surgical uses of lasers.

In a session on new instrumentation developments, Lawrence G. Kersta of Voiceprint Labs, Inc., will examine medical applications of the voiceprint spectrograph [Electronics, June 13, p.40].

Tibor Foldvari of the Massachusetts Institute of Technology and Dr. Ben Jackson of the Boston University School of Medicine will lead a discussion of blood flow measurement.

WHAT DO YOU DO WITH A WHITE ELEPHANT?

NOTHING TO IT, REALLY!



At COMCOR we solve *that* problem quite regularly. You know, of course, that most of those earlier model analog computers are now considered "white elephants" by their owners. Oh, they performed their tasks well enough when first purchased–but they aren't much for solving today's sophisticated simulation problems. And their maintenance cost is considerable! ◻ At COMCOR, we've come out with a *new* analog/hybrid computer–the Ci-175, maybe you have heard about it. Word *is* getting around! ◻ The Ci-175 is ideal for firms that require a medium-size economical computer for research, development, production and processing. And it lends itself perfectly to "building block" expansion; each unit will accommodate up to seventy-five 100-volt, 50 ma operational amplifiers. Electrically, it requires much less power to operate and because it's solid state throughout, all bulky air-conditioning equipment is eliminated. ◻ If your older model analog computers have outgrown their usefulness, see your COMCOR representative or contact us: Phone (714) 772-4510. TWX 714-776-2060. We won't shoot your "white elephant," we'll simply *replace* it!

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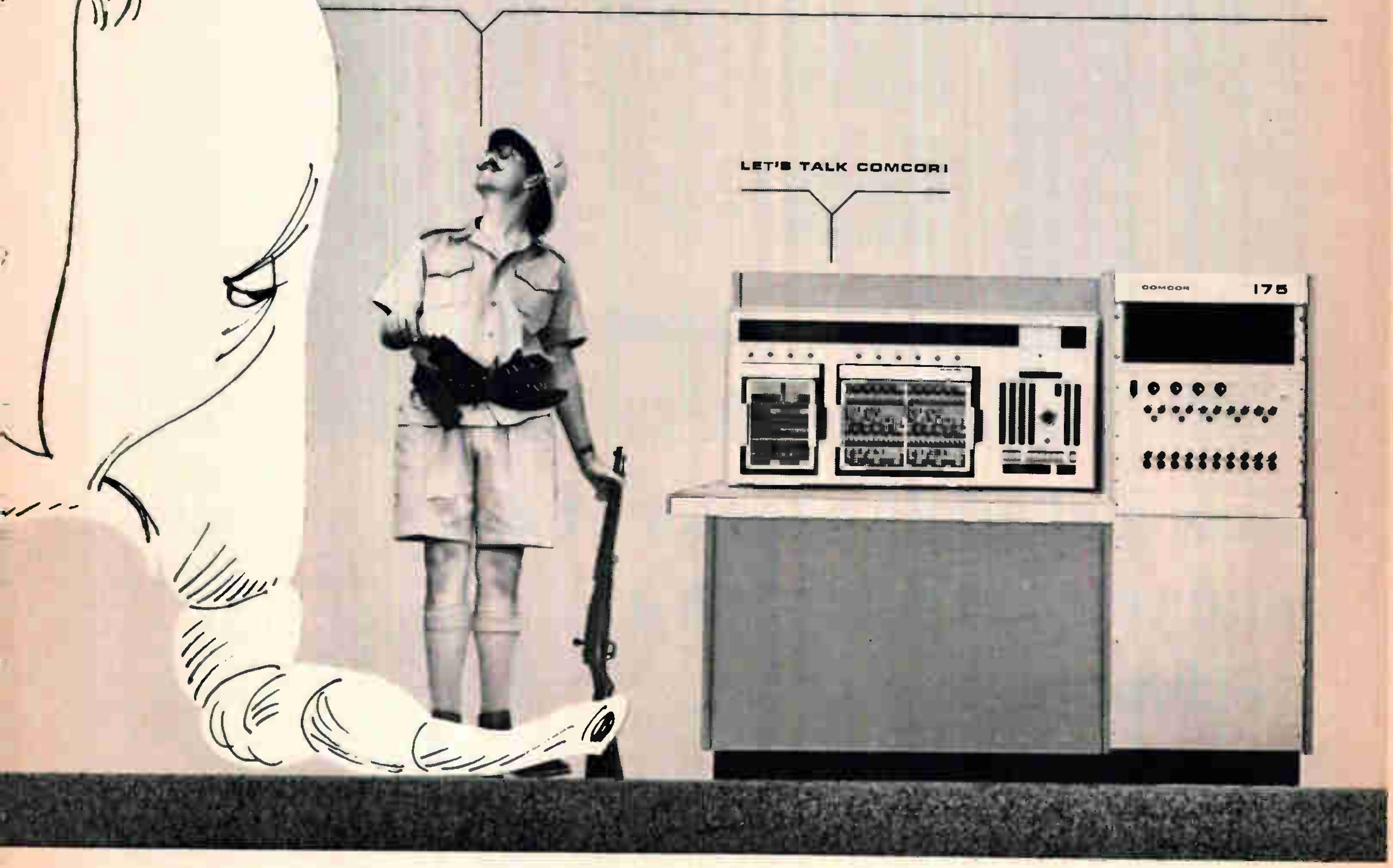
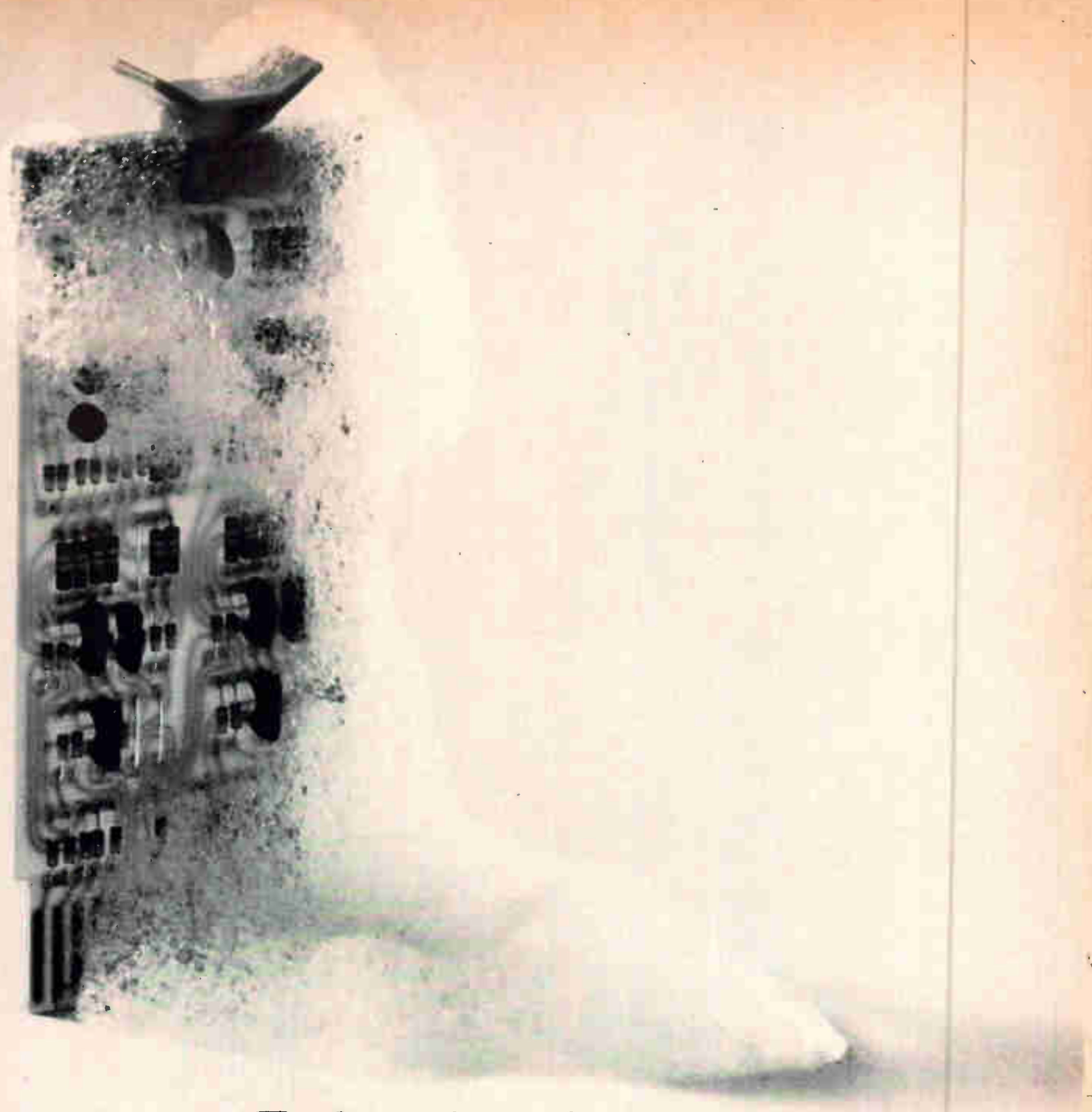


Circle 17 on reader service card



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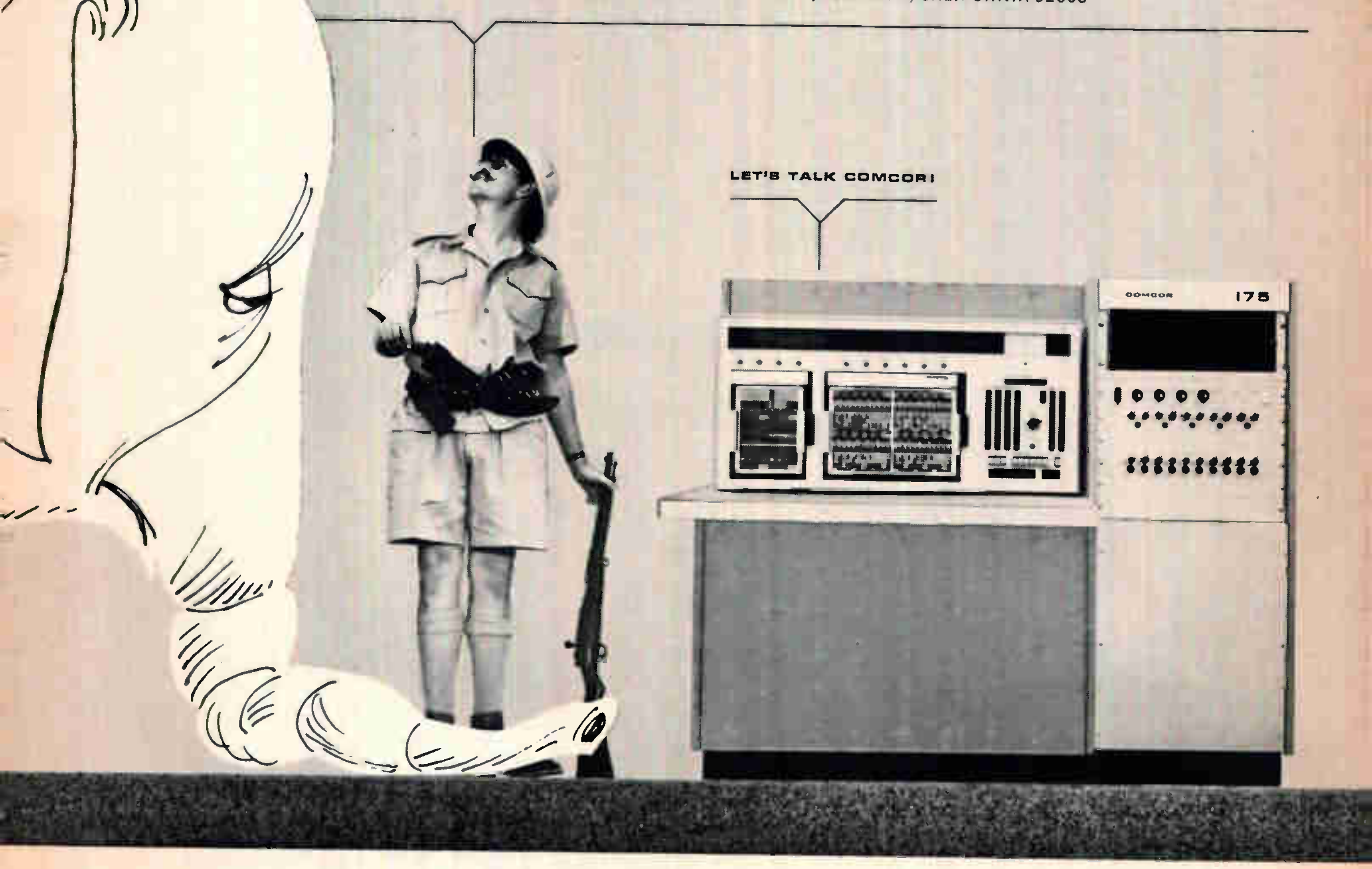

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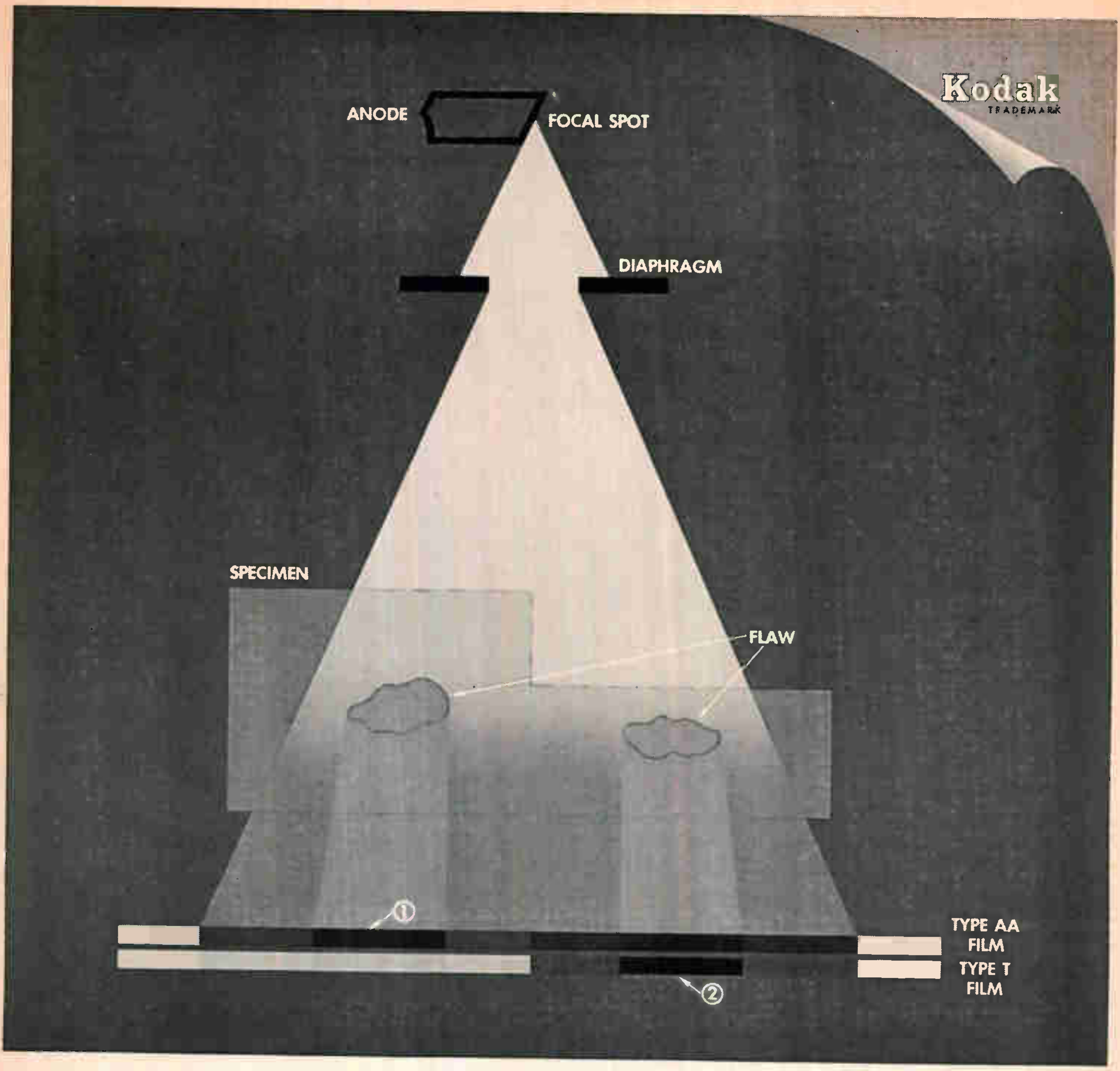


In the above illustration, (1) and (2) are the diagnostically significant images. KODAK Industrial X-ray Film, Type AA (ESTAR Base), is twice as fast as KODAK Industrial X-ray Film, Type T (ESTAR Base).

designed to do a number of critical jobs better than they could ever be done before. For instance, if specs call for an extra-fine-grain emulsion, but you need shorter exposures for higher production, you want new Type T; it has twice the speed of M, half the speed of AA.

Kodak's comprehensive line of industrial x-ray film emulsions means greater versatility and less mathematics in multiple-film exposure techniques. Now multiple-film exposures using Kodak films can be applied to a greater range of casting thicknesses, even extremely thick- and thinwall specimens.

Use the table on the right to choose the best combination of films for your needs.

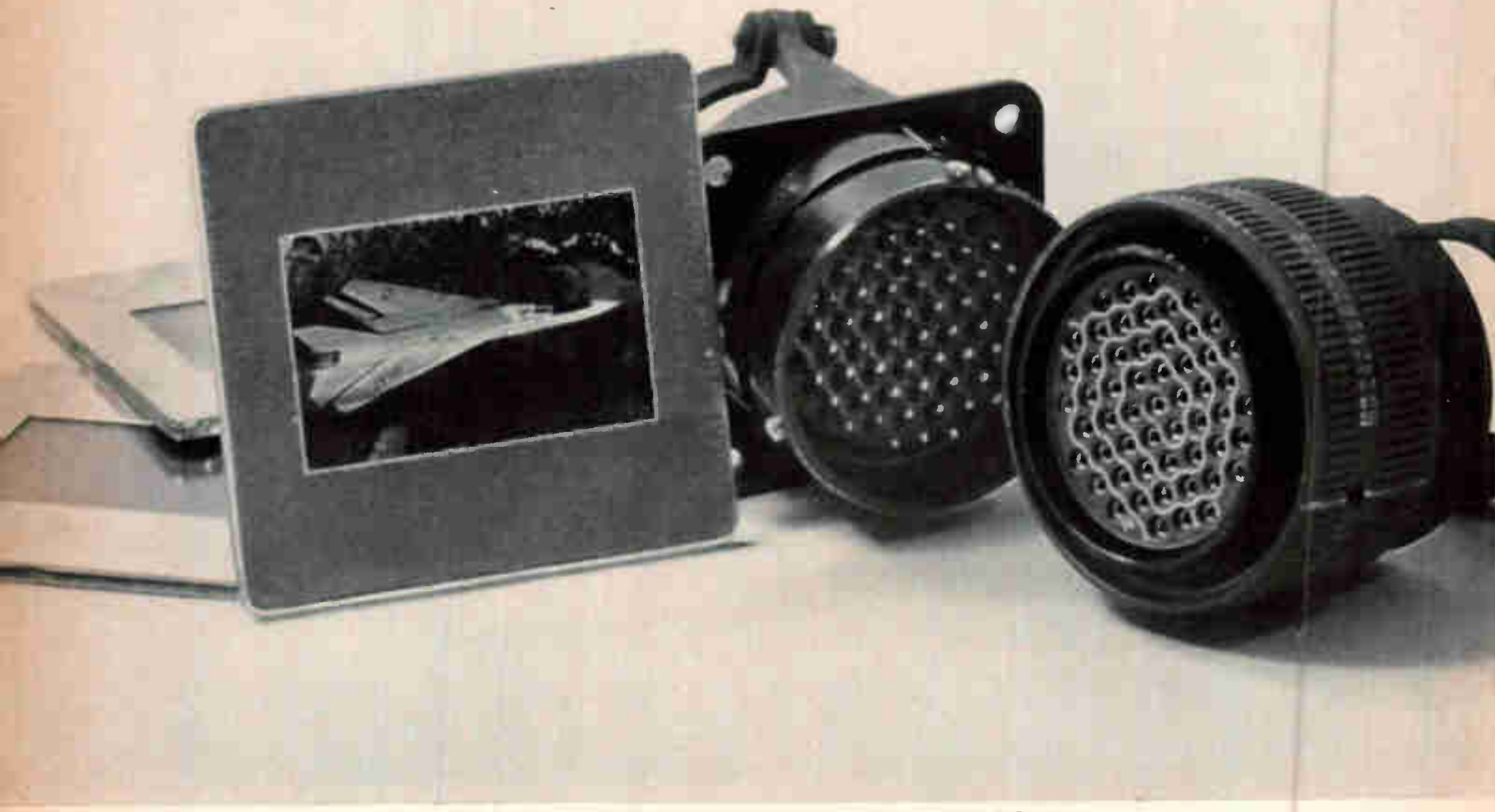
Want to know more about KODAK Industrial X-ray Film, Type T (ESTAR Base), and how the factor of 2 table can make life simpler? Contact your Kodak x-ray dealer or write us to have a representative call from Kodak's Radiography Markets Division.

FACTOR OF 2 TABLE

Type of Film	Approximate Relative Speed*
R (Single-Coated)	1
R	2
M	4
T	8
AA	16

*at 200 kv

EASTMAN KODAK COMPANY
Radiography Markets Division
ROCHESTER, N. Y. 14650



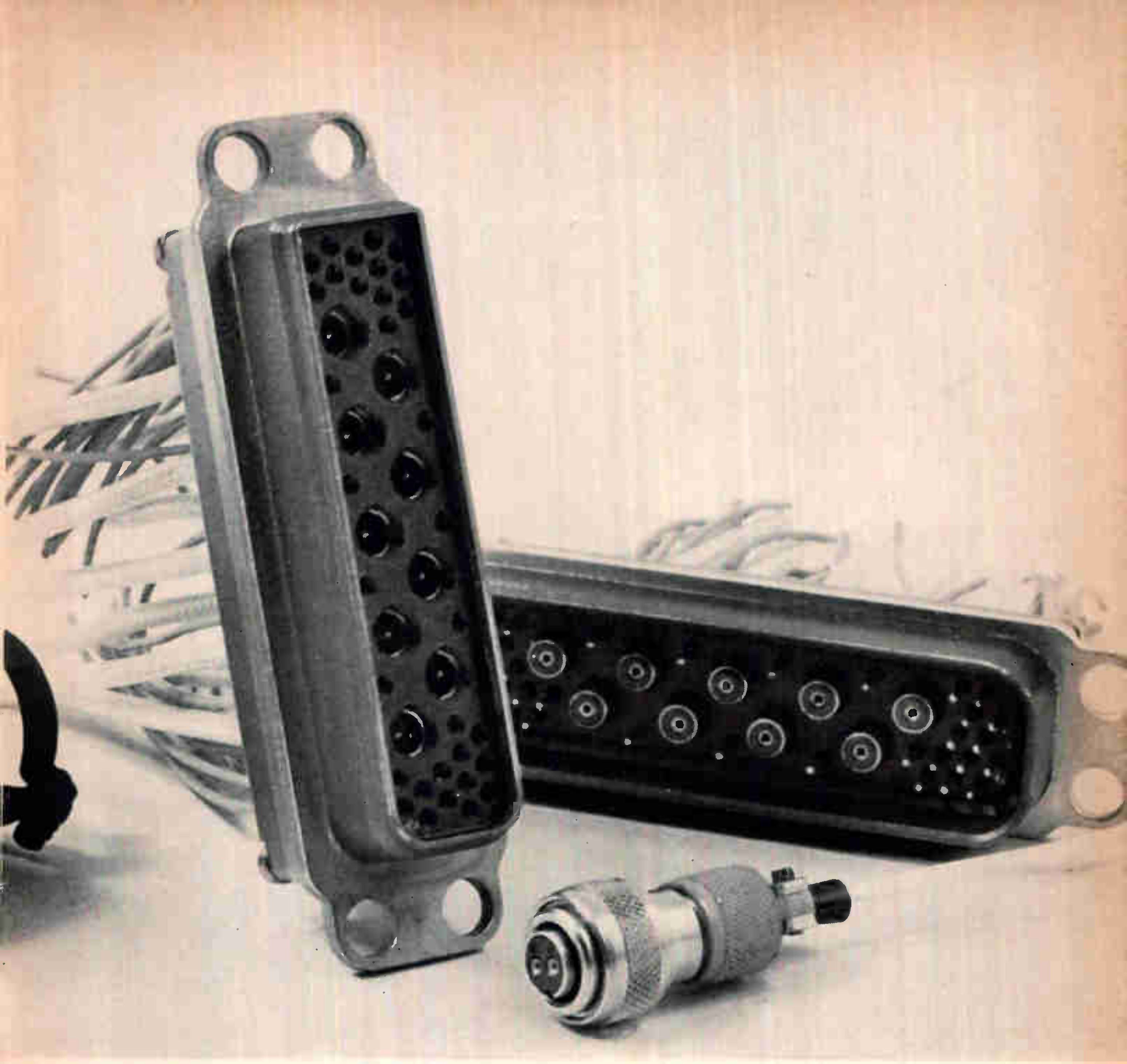
48 Series

How Amphenol helps F-111 avionics package reach a new high in reliability

200 hours mean time between failure for subsystems. Maintenance on the weapon system—35 manhours or less per flight hour.

Those are the reliability and maintenance levels set upon the avionics package of General Dynamics' versatile F-111. And the only problem in meeting them is the tremendous environmental extremes the plane will encounter. At design speed, exceed-

Circle 20 on reader service card



217 Series

115 Series

ing Mach 2.5, the F-111 skin temperature will be above 350°F. At altitudes above 60,000 feet, the F-111 will face temperatures of −65°F. In order to withstand the extremes of temperature, shock and moisture, the F-111 avionics package was designed around advanced componentry using three Amphenol connector series.

MIL-C-26500/26518. Amphenol 48 Series circular and 217 Series rack and panel connectors used on the radar and flight control systems meet these specs. Mated dielectric withstanding voltage is 1,000 vrms at 110,000 ft., 1,500 at sea level.

SUBMERSION RESULTS. Mated 48 and 217 Series connectors support 1,500 vrms submerged in salt water for 30 minutes at sea level and 35,000 ft. equivalent altitude. Connectors can operate continuously at 200°C.

NEW MINIATURE. Amphenol developed a 115 Series connector for the F-111's constant speed drive mechanism. It has two #18 contacts in a 7/10" dia., 1-1/2" body, vibration-proof coupling and environmental seal.

For more information about the Amphenol connectors on the F-111, call your nearest Sales Engineer. Or write Amphenol Connector Div., 1830 S. 54th Ave., Chicago, Illinois 60650.

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AMPHENOL CORPORATION

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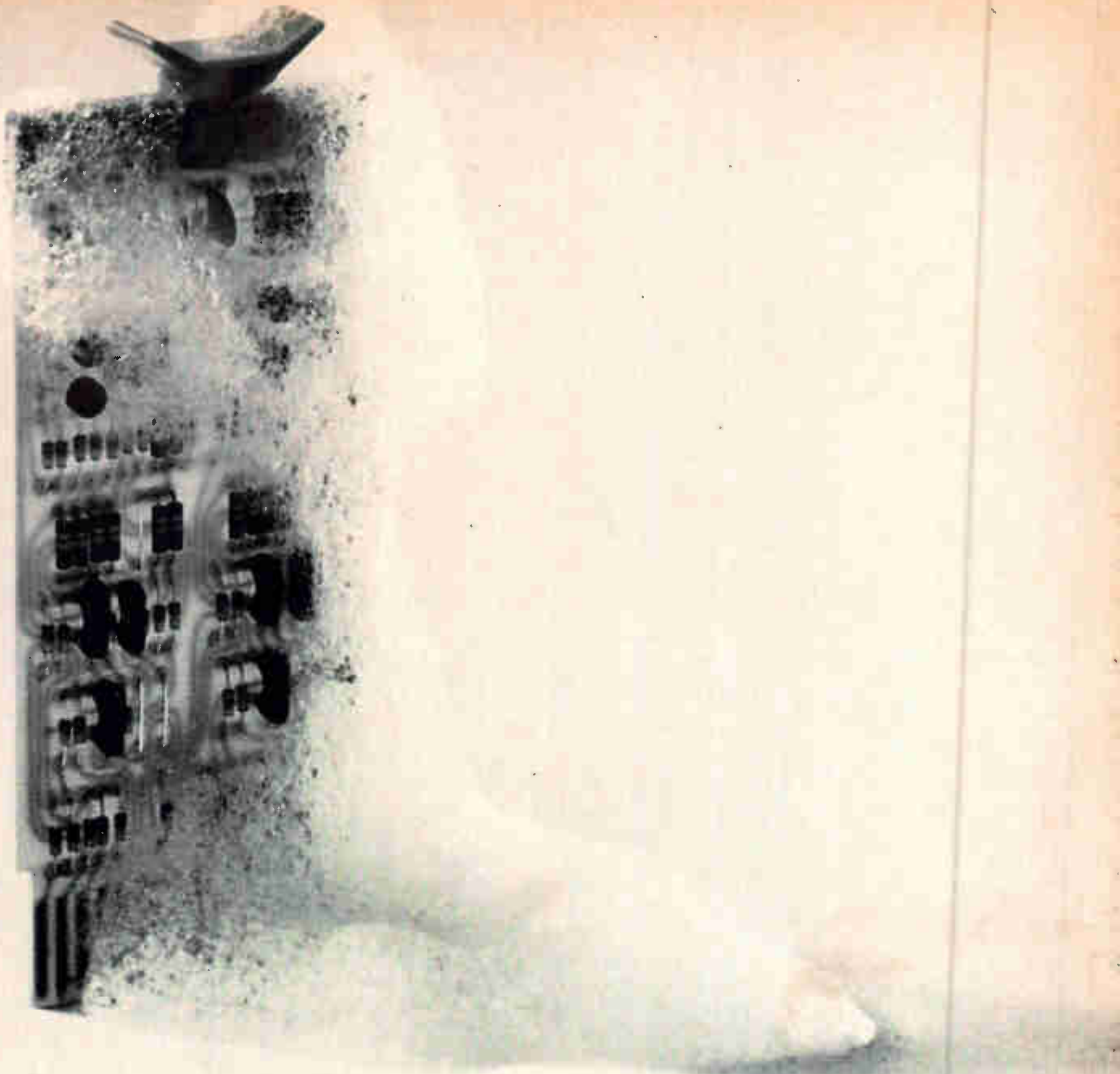

Editorial

Trade with the East
Part 1: the changing wind

In the Communist countries of Eastern Europe—Poland, Rumania, Czechoslovakia, Hungary, Bulgaria and the German Democratic Republic—a wind of economic well-being lies in trade with the West, with days. These Communist (or Socialist, as they prefer to call themselves) countries have realized that their economic well-being lies in trade with the West, with Western Europe and the United States, not with isolation and inter-Socialist trade. And in no industry is the need for trade with the West greater than in electronics.

Twenty years of economic development according to Marxist theories have wrought lopsided growth. In each of these Socialist countries there are large steel mills, machine-building plants, and chemical plants. But there is practically no light industry, and little electronics production or development. Visiting these countries to study their industry, one is struck by a mean sameness: they all build the same machine tools; they have the same currency problems (their money is no good); they have few consumer products and the quality is poor; communications are difficult and slow; and they suffer from a tremendous and widening gap in technology.

There are additional reasons, besides normal Marxist concentration on heavy industry, why development of electronics has been neglected. When they were formed 20 years ago, each of these Communist governments was a satellite of the Soviet Union, dependent militarily, economically and politically on the USSR. Russian planners told them where and how to invest their money; the object was to strengthen the economy of the Soviet Union, not of the satellites.

For much of the past 20 years, the satellites bought raw materials from the Soviet Union at high prices and sold back manufactured goods at low prices—a technique any stock market devotee will tell you is a sure way to go broke.

There was never any room in the economic plans of these countries to develop capability in military electronics, industrial electronics or communications. Production of consumer electronics was allowed only to facilitate the dissemination of propaganda or as a sop to a population that grew more and more restive every year.

Because the Soviet Union was the defender of all these nations, it did all the military electronics developments. With the exception of the famous Skoda works in Czechoslovakia, almost no plants make armaments. The armies, air forces and navies of the Eastern bloc are armed almost exclusively with Russian weapons, Russian aircraft, Russian electronics and Russian communications equipment.

On the industrial side, no country has had any real interest in applying electronics to increase productivity. With the exception of Czechoslovakia and a portion of East Germany, each of the countries was predominantly agricultural and had serious unemployment problems. The Socialist governments have been more concerned with putting people to work than in achieving the efficiency which they espouse in clichés.

Now all that is changing. In Poland, a serious-minded economist says bluntly, "We know we must change the system." Explaining what has happened, he adds, "When we started to build Socialism, we used approaches that were modeled after the Soviet Union. We went through a period of dogmatism and nobody questioned those solutions. That period is finished, though we are left with the consequences of that dogmatism."

Probably the clearest sign of the change is the new emphasis on electronics. In 1966, almost every one of the Communist governments has a new five-year plan in which the build-up of electronics production is a major feature. Rumania, for example, expects to triple electronics activity by 1970; Poland plans to build many new electronics plants; Czechoslovakia has established a top level council to encourage and abet development in electronics technology; and the German Democratic Republic has established a separate ministry to coordinate a rapid growth of electronics production and development.

Though the plans are laid, plans are not enough. All these countries are short of the technology and investment capital needed to develop a sophisticated electronics industry. Most lag from 3 to 12 years behind the technology of Western Europe. In fact, the lag is so great that almost everyone you meet will tell you flatly the Socialist countries cannot do it themselves. They must have help from the West. And, they add hopefully, help from the United States' advanced electronics industry.

Although the Communist countries have opened wide the door for trade in electronics, the path is not as clear as they would have you believe. Doing business with these countries is difficult and frustrating. And there are some philosophical questions still to be resolved. But because the door to trade is swinging open, electronics companies must answer a complex question: how much of their hard earned technology should they trade to Eastern Europe?

This is the first of a series of editorials on East-West trade, the result of a month-long tour of Eastern Europe by Electronics Editor Lewis H. Young. The next will examine the technological gap in Eastern Europe and how Socialist countries would like to close it.

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Electronics Newsletter

July 11, 1966

Repairman in the sky?

The design concept of much spaceborne electronic equipment may soon undergo a radical change—relying more heavily on repairs of an orbiting satellite rather than on designing ultrareliable equipment. The change depends on the outcome of a study contract that will determine the practicality of sending an astronaut into space to repair a faulty satellite. The National Aeronautics and Space Administration has awarded a $150,000 contract to the Ball Bros. Research Corp. of Boulder, Colo., to assess the feasibility of the repair-in-orbit concept. Part of the study contract is being subcontracted to the Emerson Electric Co. of St. Louis.

The Marshall Space Flight Center's advanced study office, which is coordinating the project, says that **if it's decided to proceed with the program, it would test the concept on an Orbiting Solar Observatory.**

IBM develops high-resolution laser scanner

Most of the dozen or so laser scanning techniques of the past few years need a relatively large amount of power to deflect the beam and they have low resolution. Researchers at the International Business Machines Corp. have developed a laser scanner that overcomes both these obstacles—it uses a cathode-ray tube to deflect the beam. **The result: the laser can generate a matrix of about 120 by 120 beam directions. The ultimate resolution, say developers R.V. Pole and R.A. Myers, is a matrix of 2,000 by 2,000 directions.**

The scanner works on this general principle: if the length of the laser cavity is an exact multiple of the laser beam's half-wavelength, a spot of light is generated; but if the cavity is not the correct length, that portion of the beam is nulled. To change the cavity's length, the IBM scientists made the face of the crt one end of the laser cavity. They placed a sheet of potassium dihydrogen phosphate (KDP) on the outer face of the tube and put a mirror behind the crt. **When an electron beam is trained on the KDP, the crystal's index of refraction is changed—in effect altering the length of the cavity.** Hence, only when a discrete electron beam hits the face of the tube will a discrete laser spot appear.

Gravity-gradient satellite to try station-keeping

The second-generation gravity-gradient test satellite now being rushed to completion at the General Electric Co.'s Valley Forge Technology Center [see page 46 for additional details] will carry a "momentum disturbance experiment." **A bolt-on, off-the-shelf cold-gas engine (0.002-pound thrust) will be fired in a series of experiments to determine if such thrusting is compatible with a gravity-gradient stabilized satellite for station-keeping and station-changing.** The tests will simulate station-keeping only. A 40-man team at GE is hurrying to meet a possible August flight date of the next Titan-3C launch.

Crime doesn't pay electronics industry

Electronics companies that want to sell equipment to law-enforcement agencies will have an uphill battle. That was the conclusion drawn by industry representatives at the first National Conference on Science and Criminal Justice held in Washington last month. The hardware to do the job is available, the producers say, but law enforcement agencies generally lack the money to buy the equipment. Another obstacle to the use of electronics in law enforcement: **the average police official lacks**

the background that's needed to apply electronics to police work.

There are some exceptions. New York State, for example, reported that it has $4 million to spend. High on its wanted list is an inexpensive ($500) portable television camera that can be used to record interrogations from arrest to trial.

On the Federal level, the Justice Department's Office of Law Enforcement Assistance has paid out nearly $3 million this year for research projects. There may be more money in the future. The conference sponsor, the Institute of Defense Analyses, is preparing a report which will probably recommend that the Attorney General establish a formal research-and-development program in 1968.

Crack-free YIG crystals

Bell Telephone Laboratories has developed a method for consistently growing large, crack-free yttrium iron garnet (YIG) crystals. YIG, an insulating magnetic material, is used in lasers, light modulators, microwave resonating media and in ultrasonic devices.

With the new technique the flux can be drained from the crucible in which the crystals are grown without removing them from the furnace; this prevents the crystals from redissolving and allows them to cool slowly enough to avoid cracking due to thermal shock.

Bell has grown as many as five half-pound crystals at one time.

NASA tests Microeye cameras

The space agency is now testing two tiny television cameras weighing only one and a half pounds and measuring 1 by 3 by 4.5 inches. Built by Teledyne, Inc., of Los Angeles [Electronics, June 28, 1965 p. 18] the Microeye cameras will be evaluated for possible use in biological research, and for use with a more powerful transmitter to monitor launch vehicle subsystems in flight.

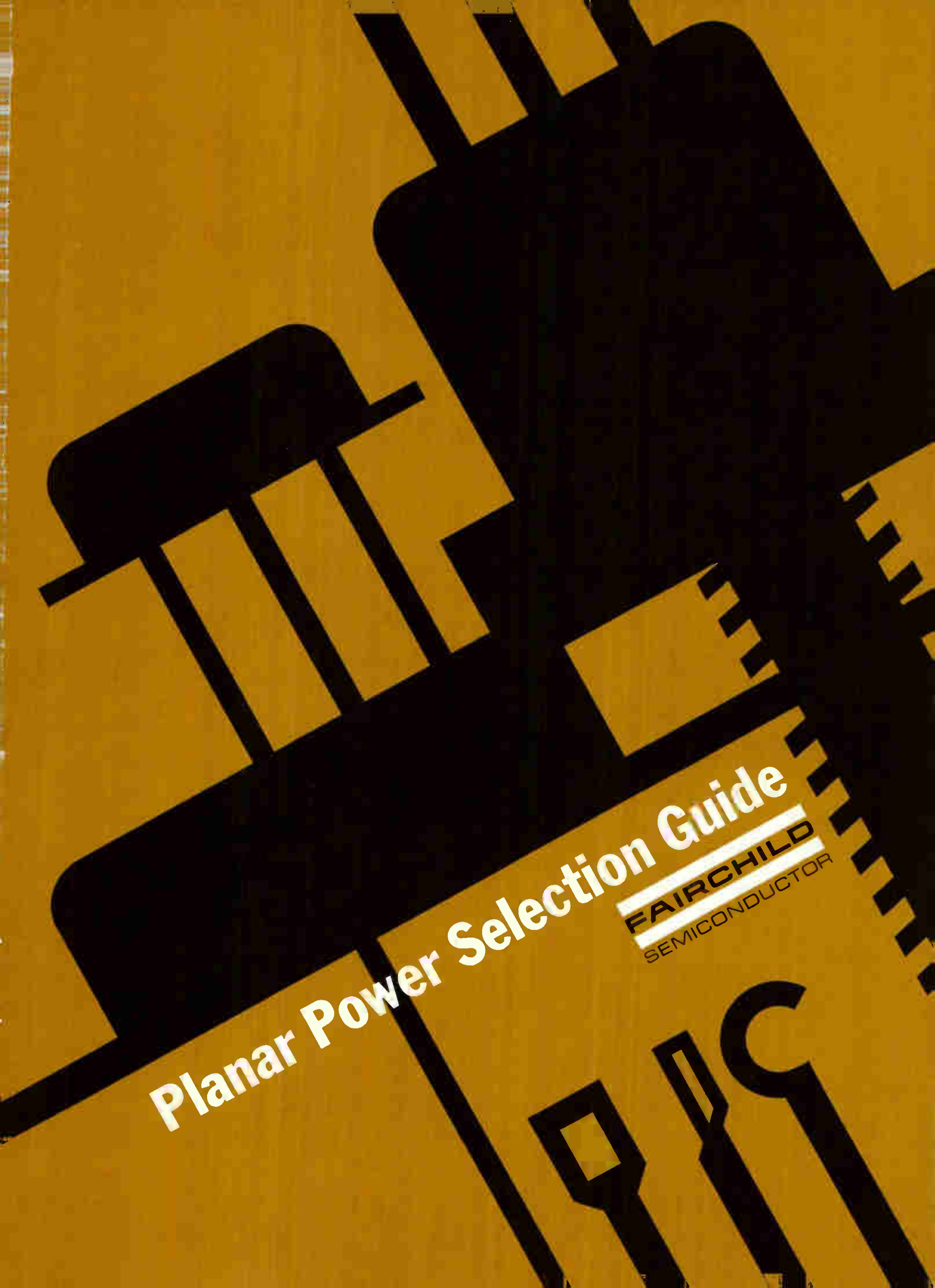
Stanford planning superconducting accelerator

Stanford University, which last month began operating its new two-mile, 20-billion-volt linear accelerator, now is planning construction of a continuous-wave, superconducting accelerator. The university received a four-year, $4.4-million contract from the Office of Naval Research to modernize its 15-year-old, billion-volt Mark 3 accelerator; but the announced plans, which have yet to be approved by the Navy, are to build a new instrument, 500 feet long. It would be buried in the ground and cryogenically cooled by a series of 20-foot Dewar flasks.

Stanford has built a four-inch-long version of the superconducting accelerator, and though the Navy is reportedly skeptical, the university believes a 500-foot accelerator can be built. Normal accelerators dissipate 90% of their power in heat; a superconducting waveguide would retain this power.

Cousins resigns technology post in Britain

Frank Cousins, the trade union leader who has run the Labor Government's Ministry of Technology since it was set up 21 months ago, resigned last week, ostensibly over the government's policy on wage increases. Cousins, though, had been under heavy pressure because of the lag in Britain's drive to make her industry more competitive through automation. Anthony Wedgwood Benn, previously postmaster-general, will take over Cousins' job.

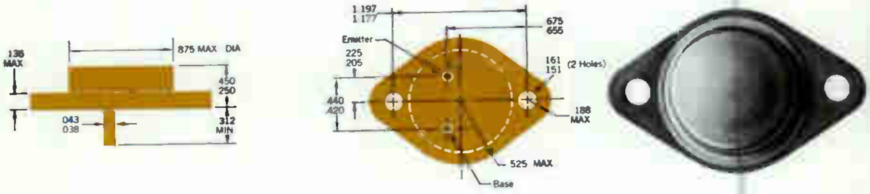

Planar Power Selection Guide
FAIRCHILD
SEMICONDUCTOR

Power Packages

TO-3

Fig. 1

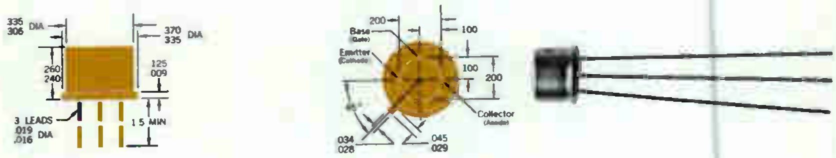
All dimensions in inches
Leads 1 and 2 electrically isolated from case
Case is third electrical connection (Collector)
Leads are nickel-alloy
Package weight is 8.71 grams



TO-5

Fig. 2

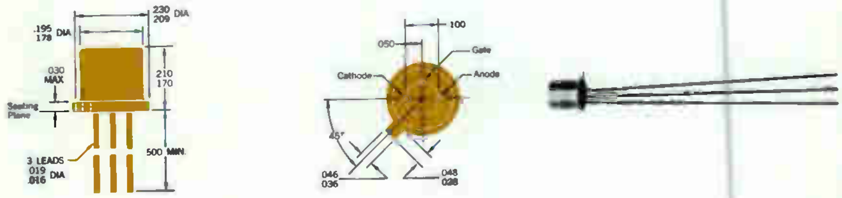
All dimensions in inches
Leads are gold-plated KOVAR*
Collector internally connected to case
Package weight is 1.10 grams



TO-18

Fig. 3

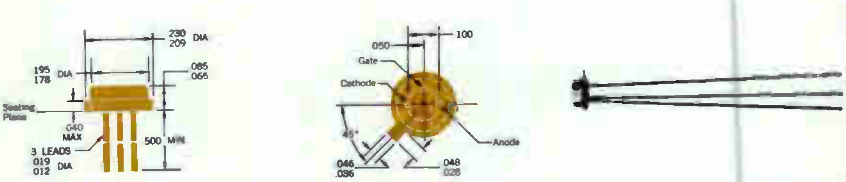
All dimensions in inches
Leads are gold-plated KOVAR*
Collector internally connected to case
Package weight is 0.43 gram



TO-46

Fig. 4

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

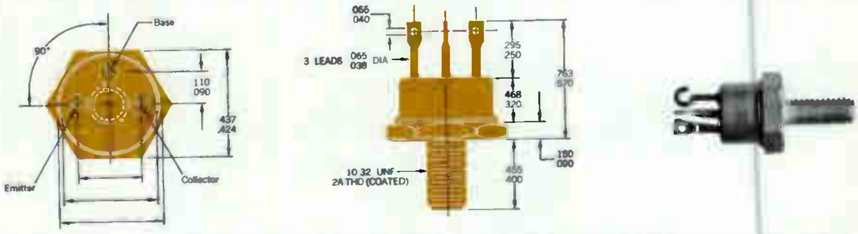


TO-59

Fig. 5

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

(also available with isolated collector)

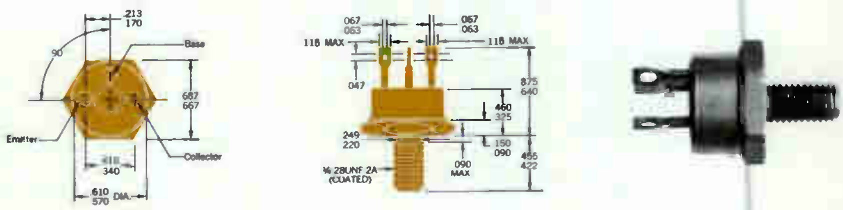


TO-61

Fig. 6

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

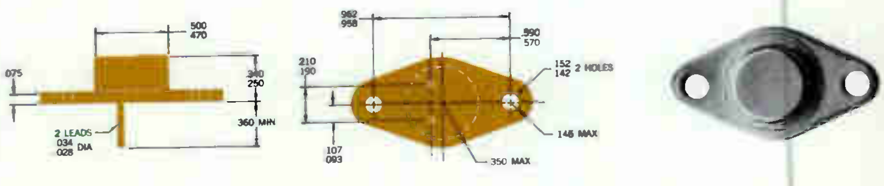
(also available with isolated collector)



TO-66

Fig. 7

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



*KOVAR is a trademark of Westinghouse Electric Corporation

Silicon Controlled Rectifiers

FAIRCHILD SEMICONDUCTOR

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

Planar Power Transistors

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

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

Planar Power Transistors

FAIRCHILD SEMICONDUCTOR

NPN	Package:	BV_{CEO}	h_{FE}	Test Conditions V_{CE}	I_C	f_T	Power Dissipation at case Temperature	Fairchild Device Number
2 Amp Continued	**TO-66** *(Fig. 7)*	80V	30-250	2V	1A	30MHz	10W @ 100°C	SE9001
		60V	30-250	2V	1A	30MHz	10W @ 100°C	SE9002
5 Amp	**TO-59** *(Fig. 5)* **indicates isolated collector*	80V	40 min.	5V	5A	70MHz	30W @ 100°C	2N4116*
		80V	20 min.	5V	5A	70MHz	30W @ 100°C	2N4115*
		60V	20 min.	5V	5A	70MHz	30W @ 100°C	FT7207B
	TO-3 *(Fig. 1)*	80V	20 min.	5V	5A	70MHz	30W @ 50°C	2N4113
		80V	40 min.	5V	5A	70MHz	30W @ 50°C	2N4114
		80V	15 min.	5V	5A	80MHz	30W @ 100°C	SE9041
		60V	20 min.	5V	5A	70MHz	30W @ 50°C	2N4111
		60V	40 min.	5V	5A	70MHz	30W @ 50°C	2N4112
		60V	See note 1			70MHz	15W @ 75°C	SE3034
		60V	20 min.	5V	5A	80MHz	30W @ 50°C	SE9040
	TO-5 *(Fig. 2)*	80V	40-120	2V	2A	80MHz min.	5W @ 25°C	FT34C
Note 1: V_{CE} (SAT) @ I_C/I_B=5A/0.5A = 0.4V max.		60V	100-300	2V	2A	80MHz min.	5W @ 25°C	FT34D
7 Amp	**TO-3** *(Fig. 1)*	150V	10 min.	1.2V	7A	30MHz	50W @ 25°C	SE9020
10 Amp	**TO-3** *(Fig. 1)*	60V	40-120	2V See note 1	2A	4MHz	15W @ 75°C	2N3919
		60V	100-300	2V See note 1	2A	4MHz	15W @ 75°C	2N3920
		60V		See note 1		4MHz	15W @ 75°C	SE3030
		60V		See note 1		4MHz	15W @ 75°C	SE3032
		60V		See note 2		4MHz	15W @ 75°C	SE3031
		60V		See note 2		4MHz	15W @ 75°C	SE3033
	TO-59 *(Fig. 5)*	80V		See note 1		4MHz	15W @ 100°C	FT34A
Note 1: V_{CE} (SAT) @ I_C/I_B=10A/1A = 1.2V Note 2: V_{CE} (SAT) @ I_C/I_B=10A/1A = 1.8V		60V		See note 1		4MHz	15W @ 100°C	FT34B
12 Amp	**TO-3** *(Fig. 1)*	200V	10 min.	1.5V	12A	30MHz	60W @ 25°C	SE9010
	TO-61 *(Fig. 6)* *with isolated collector*	200V	10 min.	1.5V	12A	30MHz	60W @ 25°C	FT301A

Planar is a patented Fairchild process

Fairchild Suggested Equivalents

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

EIA	Fairchild
2N389	2N1724
2N424	2N1724
2N547	2N2890
2N548	2N2890
2N1047	2N4115
2N1047A	2N4115
2N1047B	2N4115
2N1048	2N4115
2N1048A	2N4115
2N1048B	2N4115
2N1049	2N4115
2N1049A	2N4115
2N1049B	2N4115
2N1050	2N4115
2N1050A	2N4115
2N1050B	2N4115
2N1067	SE9002
2N1068	SE9002
2N1069	SE9002
2N1070	SE9002
2N1208	2N4115
2N1209	2N4115
2N1210	2N4115
2N1211	2N4115
2N1212	2N4115
2N1250	2N4115
2N1483	SE9002
2N1484	SE9002
2N1485	SE9002
2N1486	SE9002
2N1487	SE9041
2N1488	SE9041
2N1489	SE9041
2N1490	SE9041
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2N1512	FT8207A
2N1513	FT8207A
2N1514	FT8207A
2N1616A	2N1724
2N1617A	2N1724
2N1618A	2N1724
2N1620	FT8207A
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2N1648	2N4115
2N1649	2N4116
2N1650	2N4116
2N1690	2N4115
2N1691	2N4116
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2N1703	SE9040
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2N1723	2N1724
2N1724	2N1724
2N1725	2N1724
2N1768	FT7207B
2N1769	FT7207B
2N1886	FT7207B
2N2015	2N4113
2N2016	2N4113
2N2018	SE7006
2N2019	SE7006
2N2020	SE7006
2N2021	SE7006
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2N3238	2N4111
2N3239	2N4111
2N3240	2N4111
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2N3419	FT7207C
2N3420	FT7207C
2N3421	FT7207C
2N3429	2N4115
2N3430	2N4115
2N3439	FT300B
2N3440	FT300B
2N3441	SE7020
2N3442	SE9020
2N3445	FT8207A
2N3446	FT8207A
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2N3584	SE7006
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2N3773	SE9020
2N3850	2N4115
2N3851	2N4115
2N3852	2N4115
2N3853	2N4115

Planar Power Advantages

FAIRCHILD SEMICONDUCTOR

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

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

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

Secondary Breakdown

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

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

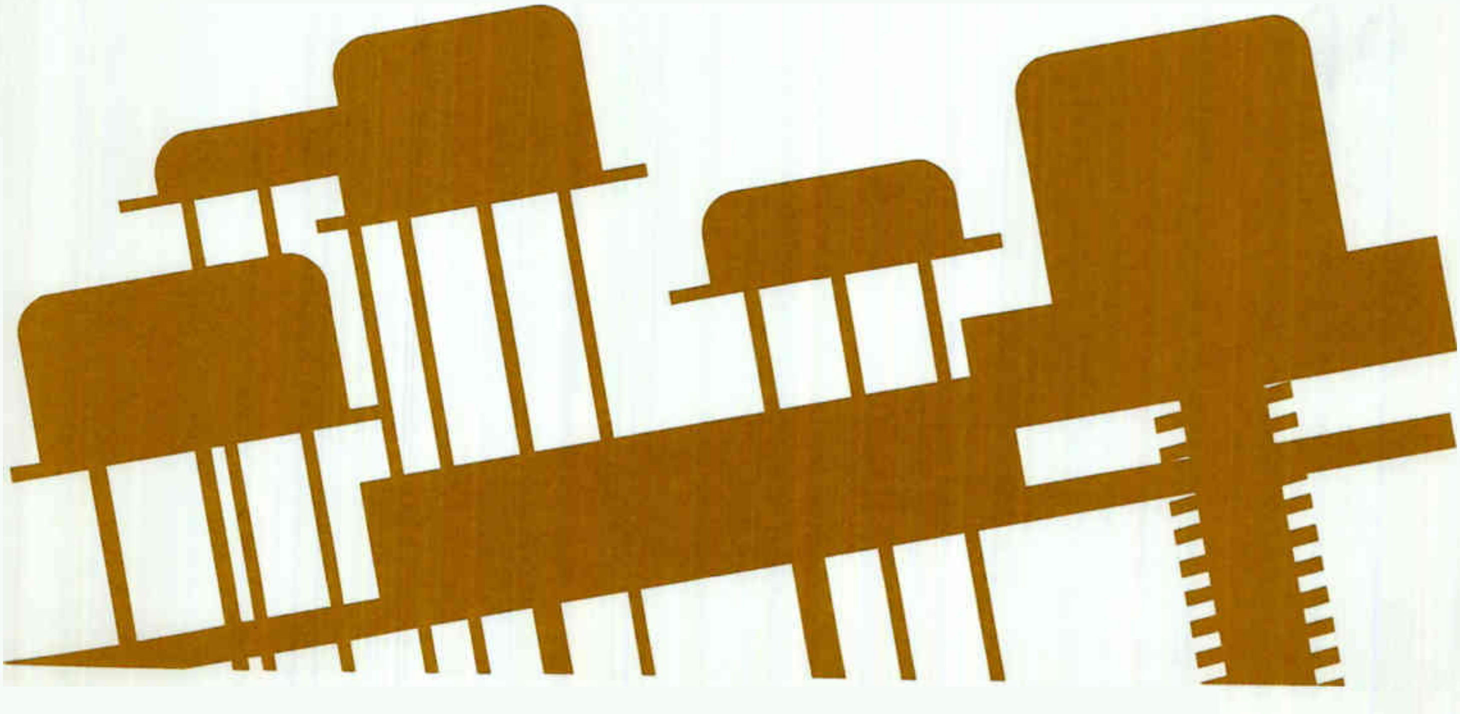
The NICR resistors, placed in series with the emitters, prevent this from happening. When a transistor tries to "hog" more than its share of current, the resistor induces a negative feedback which pulls it right back into the safe zone.

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

Test Planar Power

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

Planar is a patented Fairchild process



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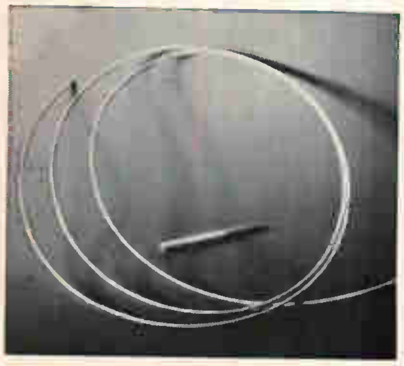
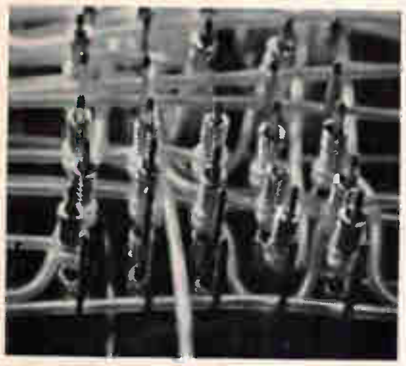
That's why it's used on...



cable jackets



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component sleeves

In all three cases, insulation of Kynar* was selected because of its outstanding toughness . . . resistance to cut-through and abrasion, dimensional stability and mechanical strength.

What's more KYNAR won't degrade with age or severe environmental conditions. It is resistant to a wide variety of solvents and provides excellent protection under conditions of flex and vibration at temperatures from —80° to 300°F.

If your design calls for an insulating material that's tough . . . really tough . . . ask your supplier about Kynar. Or, write Plastics Department, Pennsalt Chemicals Corporation, 3 Penn Center, Philadelphia, Pa. 19102

Kynar... the fluoroplastic that's tough!

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CHEMICALS • EQUIPMENT

Circle 35 on reader service card

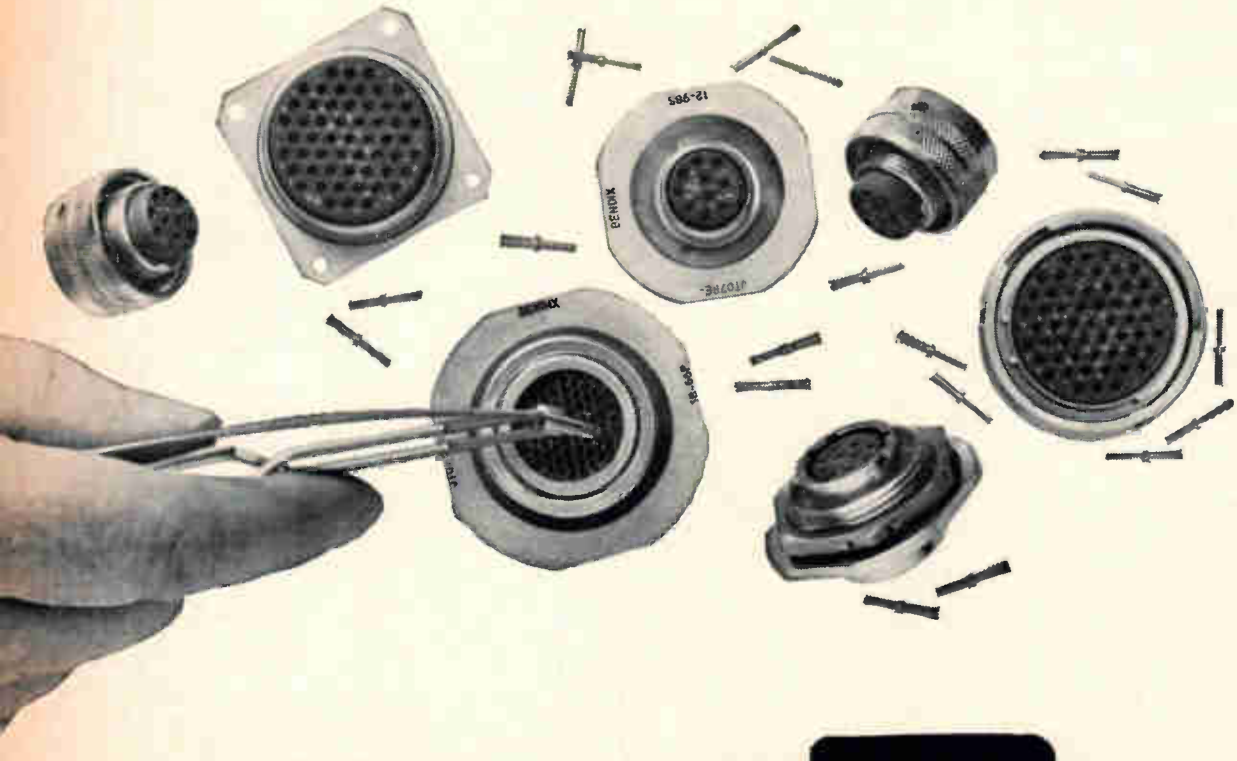
If it's possible to make a crimp type connector smaller and lighter, Bendix does.

That's why you'll find Bendix® crimp-type JT Pancake connectors the smallest, lightest now available. They reduce connector length up to 50%, weight up to 60%.

We're able to offer you a wider-than-ever series in rapid, off-the-shelf fashion, too. Included are wall mount, box mount, jam nut, straight plug and 90° plug. They're available in nine shell sizes—8 through 24, with standard temperature capabilities to 302°F. (Even high-temperature models to 392°F if need be.) And with over 28 different insert patterns, many of which are Pygmy® (Mil-C-26482) layouts.

Crimp-type Pancake connectors come in 16-, 20- and (Double Density) 24-contact sizes, with up to 128 contacts in a single connector. And you'll even find they out-perform all others because of a host of new design features.

We still haven't mentioned the connector you need for your application? Try our extensive JT Hermetic or Solder types. Or contact us in Sidney, New York. Phone: (607) 563-9511.



Scintilla Division THE Bendix CORPORATION

Circle 36 on reader service card

July 11, 1966

Electronics Review

Volume 39
Number 14

Military electronics

Jungle talk

Radio communication through dense foliage is so severely hampered by attenuation that troops in Vietnam must sometimes wonder if a network of jungle drums might not serve them better. There is one direction, however, in which the radio path is free and clear, even in Vietnam: straight up. High-frequency waves can be bounced off the ionosphere and picked up anywhere from a few yards to 200 to 300 miles away.

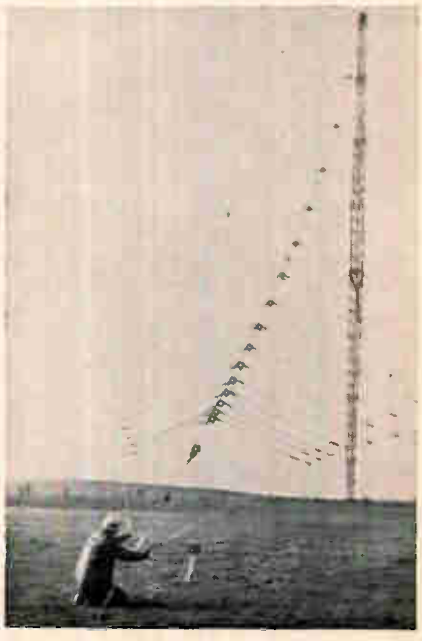
Skywave h-f antennas are used mostly for long-distance transmission, but Granger Associates of Palo Alto, Calif., introduced an antenna earlier this year specifically designed for communications under 300 miles. This broadband antenna, which operates from 2 to 20 megahertz, would be of small use to a field unit in Vietnam, though, because its radiators spiral out into a hexagon 200 feet in diameter, with 30-foot poles of Douglas fir at the vertexes and the center.

Scaled-down. Now, Granger Associates has followed up this permanent antenna, known as the series 798, with a short-range skywave model that operates at only 2 to 4 Mhz, but is somewhat more manageable. Like the rest of the company's 747CA models, which are designed for longer ranges, the new antenna is mounted on a single 75-foot tower; the radiators are strung on three Mylar rope catenaries. Even though the finished product is sizable (the land required is in the shape of an isoceles triangle of 300-foot base and 120-foot height), the entire antenna and all tools needed to erect it break down to fit into a 90-cubic-foot package that weighs about 700 pounds and could be flown in by helicopter. Five men can put up the antenna in two hours.

Clearly, even though the transportable antenna is nothing to pack around in a Jeep, it would provide an unstoppable link with the more secure outposts in Vietnam; and it could be used with mobile receivers.

Always in tune. Both the 798 and the 747CA are log-periodic antennas; that is, they are designed so that both pattern and impedance characteristics repeat periodically with the logarithm of frequency. Making the variation of pattern and input impedance small over any period gives operating characteristics that are nearly independent of frequency over the entire working range.

The horizontally polarized transportable antenna has a gain of 7 decibels at 2 Mhz and 11 db at 4 Mhz. The voltage standing-wave ratio is 2.1-to-1, not quite as good as the 2-to-1 ratio of the 798, and average power 10 kilowatts. The takeoff angle (between the direction of the signal path and the earth's surface) is practically 90° at 2 Mhz and 63° at 4 Mhz, but even at the higher frequency there is still plenty of energy directed straight up.



Skywave high-frequency antenna developed by Granger Associates fits into a 90-cubic foot package and can be assembled in two hours by five men. The antenna bounces signals off the ionosphere, thus skirting the problem of attenuation that's caused by dense jungle.

Medical electronics

Breath of life

For the thousands of people whose lives depend on the rhythmic pulses of their cardiac pacemakers, the surgical replacement of worn batteries is a procedure they have to face every other year. Even the development of the nuclear-powered pacemaker [Electronics, June 13, p. 42] won't be a complete answer because it would still have to be replaced surgically every decade or so and the generator cost would be very high. A team of biological engineers in Cleveland, however, is working on a relatively cheap, lifelong technique that taps the rhythmic action of the lungs for power.

Reporting at the Symposium on Biomedical Engineering in Milwaukee last month, researchers Carl C. Enger and F.W. Rhinelander of the Western Reserve University School of Medicine said they expect to test the technique on humans in a few years.

Power cycle. In the procedure—tested so far on dogs—one end of a tiny piezoelectric crystal is attached to a rib and the other end to the spine. When the dog breathes, his lungs expand and the rib cage rises; the mechanical action bends the crystal and generates a peak of 8 volts for each breathing cycle. The 22 microjoules output, Enger explains, is sufficient to drive a pacemaker.

Since each heart cycle occurs more frequently than the power-producing breathing cycle, the engineers devised a circuit to store current accumulated during breathing.

The decision to use piezoelectric elements to convert mechanical energy to electricity was based on three factors.

- The crystals produce no heat during energy conversion.
- They are extremely efficient.
- And they don't react with the body tissue.

Although the Cleveland engineers are designing the system for cardiac pacemakers, they see other applications. Enger notes that the rib-cage motion would generate enough power to stimulate some muscles that lack control due to diseased or severed nerves. Present pacemaker-like instruments that stimulate such things as bladder or limb muscles depend on relatively short-lived battery power.

Drive a heart. The work on the piezoelectric power source is also being extended to the development of a fully implantable artificial heart. In a project Enger is working on at the Cleveland Clinic, piezoelectric crystals are used in reverse: instead of being moved to generate power to pace the heart, they are being pulsed with current, causing them to contract. An instrument with such a motion, the researchers hope, will someday completely take over the blood-pumping action of damaged hearts.

In an early model, crystals are embedded in sandwiches of Silastic. The whole package looks like a canister about 4 inches long. So far it has adequately pumped oil of about the same viscosity as blood.

Enger doubts that the rib cage could generate enough energy to drive a full-scale substitute heart. "Too many crystals between the ribs and the spine," he cautions, "and the patient will be too stiff to breathe."

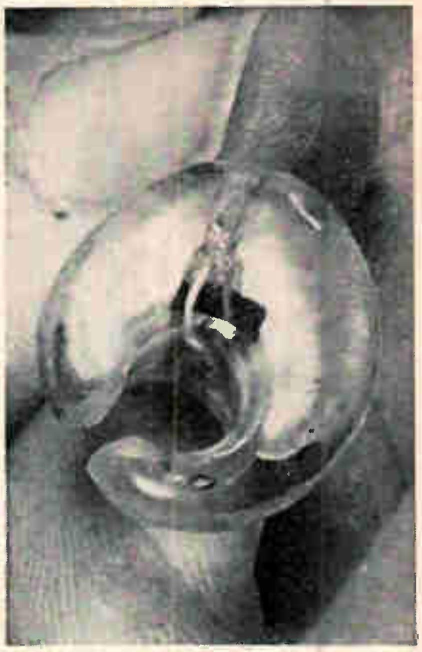
For a power source, he says, the team is considering a fuel cell. In one possible design, a small plastic reservoir with a one-way valve could be permanently placed inside the chest cavity; when the fuel runs out, the patient could inject a fresh supply with a hypodermic needle.

Other researchers, he adds, are considering using the body's own wastes—such as urine—as an element in the fuel.

Speed of the blood

Two doctors have developed a technique to measure the speed of blood flowing through an artery without cutting into the blood vessel. The key to the technique is a C-shaped electromagnetic sensor no more than 1 inch in diameter. The method is being applied to cases where a weak artery—in danger of rupturing—is slowly tied off to reduce the pressure; it could also be used for physiological research.

To take a measurement, an artery is surgically exposed and the tiny sensor placed around it. Then, a half ampere is passed through the iron-core electromagnet creating magnetic lines of force that



C-shaped electromagnet fits around artery and measures the flow of blood.

flow through the artery's walls and the blood. Since blood is a conductor (although not a very good one) any flow through the artery breaks the lines of force and generates a microvolt output in the sensor proportional to the rate of flow.

Then, a square-wave flowmeter picks up the output. The flowmeter —produced by Carolina Medical Electronics, Inc., of Winston-Salem, N.C.—filters random noise and enhances the weak signal generated by the sensor.

Dr. Merrill Spencer, director of the Virginia Mason Research Center in Seattle, designed the sensor, which was then developed by Dr. Adam Denison in cooperation with the Electromagnetic Probe Co. of Winston-Salem.

Avionics

Double-duty rotors

Helicopter rotor blades are doing double duty at the Bell Helicopter's Co.'s research labs in Hurst, Texas. Besides their usual function of providing lift, the blades are being tested as mounts for radar antennas. Military helicopters that are now in operation aren't furnished

Experimental radar antennas are being mounted in the rotor blades of Bell Helicopter's UB-1B.

with radar equipment.

Installing the slot array antennas at the edges of the whirling blades produces a scanning operation which requires no additional mechanical or electronic equipment. Placing the antennas out on the blades causes little or no shadow when radar is used for terrain-following, station-keeping and weapon control. In addition, the design doesn't require structure changes in the craft's fuselage and avoids the aerodynamic drag that would result if the antennas were installed on the underside of the helicopter.

Bell, a subsidiary of Textron, Inc., is performing the study under a joint Army-Navy contract. Detailed performance characteristics are classified.

The 15-foot-long antennas operate in the K_u band (15.35 to 17.25 gigahertz) and give approximately one-quarter degree azimuth beamwidth at 16.5 Ghz.

With one antenna, the scan rate is 5 hertz; with two antennas, it's 10 hz. Hugh W. Upton, chief electronics research engineer at Bell, says that a 20-hz rate is possible if antennas are installed in both the leading and trailing edges of the two main blades. So far, tests have been made only on antennas installed in leading edges, but Upton says they can also be placed in the trailing edges.

Weight edge. Leading-edge mounting holds a weight advantage over trailing-edge mounting. On the leading edge, the blade is thick enough for metal to be cut away; this results in a blade that weighs about the same as a standard blade. The trailing edge, however, is thinner and material has to be added when an antenna is installed.

Production cost, Bell estimates, would be about 10% greater than for standard blades.

An on-board radar—connected to the slot antenna—has a 0.1-microsecond pulse width and a 20-khz pulse repetition frequency; its power is 30 kilowatts and its storage tube is bright enough for daylight viewing. Power loss from the transmitter to the feed points amounts to 1.5 decibels.

During flight a certain amount of normal blade bending occurs, but for any given frequency, any bending of the antenna greater than one-quarter of the wavelength causes defocusing of the antenna. Bell reports no problem here, since its rotor assembly is semirigid with the blades firmly restrained at the hub.

Power supplies

A-c battery?

Batteries may soon provide a-c power for electronic equipment—without the complex and bulky gear that's needed to convert from d-c to a-c. Army researchers at the Electronics Command's power sources laboratory at Fort Monmouth, N.J., have developed the experimental battery that produces a pulsating output. The output voltage waveform is a triangular pulse superimposed on a d-c potential.

The experimental unit is about the size of two regular flashlight batteries. In early tests it produced a 0.8-volt pulse at about 400 milliamperes and flashed a lamp at a 15-hertz rate. The Army team that is working on the project says it can build up the frequency to at least 50 hz, which is a more useful rate. Efficiency of the cell varies from 45% at peak power to 25%.

Chemical reaction. The pulsing action is triggered by a fast-acting cyclic chemical reaction within the battery. The battery is powered by formaldehyde dissolved in a sulfuric acid electrolyte. These chemicals react with a submerged platinized platinum anode to form carbon dioxide and water, and with a lead-lead dioxide cathode to produce hydrogen. The formaldehyde breaks down to form two electroactive intermediates—formic acid, which has a potential of 0.6 to 0.9 volt, and hydrogen, which has a potential of 0.1 to 0.3 volt. The two intermediates are adsorbed at the platinum electrode; the more active hydrogen reacts first and during its period of oxidation a high-current density with a low potential is created. Then, when the hydroreaction has been completed, the formic acid oxidizes and the electrode is at a higher potential. When all the intermediates have been oxidized, the current falls off, formaldehyde reforms and the process begins again.

The pulse period, or frequency, is dependent upon the buildup of current density at the anode. And the current density, in turn, is a function of the electrode activity and the area of the electrode. In general, the larger the area, the higher the pulse frequency.

Communications

Quite a reception

Eavesdropping on Surveyor's telemetry signals with an 8-foot dish antenna was just a stunt. But the engineers from the Interstate Electronics Corp. of Anaheim, Calif., wanted to demonstrate the versatility of their new receiver, designed for the National Aeronautics and Space Administration.

In building the generalized concept receiver that NASA wanted, Interstate had to compete with 54 other companies, including industry giants—the Radio Corp. of America, Motorola, Inc., and the Collins Radio Co.

. . . master of some. The receiver wasn't meant to compete with elaborate space-tracking facilities—it doesn't have the bandwidth—but it can do an impressive number of things, including transmitting in certain applications. Possible receiver modes include: single-frequency superheterodyne monitoring, broadband surveillance, phase-locking with simultaneous lobing for tracking, conical scanning with another tracking mode, data demodulating for f-m and a-m to 100 kilohertz and phase modulation to 1.5 Mhz. Interstate is also working on a method of controlling the radio by computer logic—probably with a digital-to-analog converter.

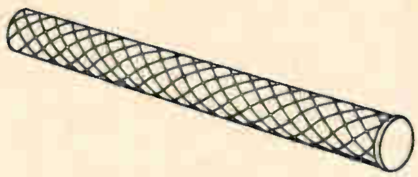
Any of these functions can be easily switched by interchanging plug-in circuit-board modules, with push-button tuning, to boot.

The solid state receiver is tunable from very high frequency (70 Mhz) to X band (10 Ghz). It has an f-m/p-m/a-m bandwidth of 10 Mhz and a doppler tracking bandwidth to 5 hz. Because of a box-within-a-box construction, radio-frequency isolation is greater than 160 decibels.

Antennas

A new twist

By adding a few new twists, a scientist at the Syracuse University Research Corp. has found that he can expand the bandwidth limits of a helix antenna from 2-to-1 to 9-to-1. Further, if each twist, or winding, is replaced by two wound in the opposite direction, he found that the contrawound helix antenna has a unique property: its polarization, bandwidth and gain can be controlled independently.



Contrawound helix antenna adds versatility and bandwidth.

In experiments by the developer Carl Gerst, a research engineer at the company's special projects lab, a contrawound antenna with eight windings was operated over a frequency band extending from 400 to 3,600 Mhz. Other ranges can be achieved, explains Gerst, by making a change in the antenna's linear dimensions.

Full control. Gerst found that by altering the relative phase and amplitude of the lines feeding the helix, he could produce any polarization—including linear, elliptical and circular. Neither the conventional single-wound helix nor the new multiwound design—without contrawinds—are that versatile.

Gerst says his experimental results substantiate his theory for the wide bandwidth characteristics of the multiwound helix. However, the theory for the more flexible contrawound antenna isn't as exact, although a number of antennas have been successfully tested. "I'm 95% sure the contrawound designs will work as well as the simpler multiwinding antenna," Gerst says, "but since we do not have a theoretical analysis of this antenna, we do need more experimental assurance."

Wider choice. Compared with other wideband antennas, such as the log-periodic dipole, the contrawound helixes provide more flexibility in choosing polarization, can be smaller and can operate at higher gains. The gain increases with length: when the helix is 3 wavelengths long, the gain is about 13 decibels above the gain of an isotropic antenna.

However, the log-periodic design has a simpler, two-line feed system. To attain the 20-to-1 bandwidths that log periodics can have, a helix would have 22 terminals—one for each winding.

Gerst says that the theory of multiwinding antennas indicates that as the frequency varies, the symmetrical arrangement of additional windings eliminates certain transmission modes that would otherwise attenuate rapidly, limiting the bandwidth.

The Air Force's Rome Air Development Center is sponsoring work on the antenna. Under study is a contrawound version that is mounted on a ground plane, such as a wing: the antenna is cut in half along its length and mounted on the metal surface.

Couplers. In an independent but related project at Syracuse, researchers are developing extremely wideband couplers—as great as 18-to-1—that can be used to feed the antenna. Gerst explains that a coupler has been tested successfully over an 8-to-1 bandwidth. The best commercially available coupler, he points out, has only a 5-to-1 bandwidth. The coupler combines two techniques of wideband design, but the physical spacing between the coupling elements is wider than in previous designs.

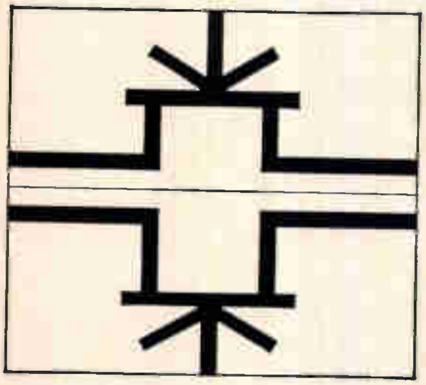
Consumer electronics

Jack-of-all-trades

To justify the cost of developing most monolithic linear circuits, the expense of design and debugging must be spread over a large production run. One way of doing it is to build a general-purpose amplifier chip that many users can buy in modest quantities; each user then adapts the IC by adding outboard chips containing thick- and thin-film networks.

The General Electric Co.'s semiconductor products department is taking another approach, equally attractive. GE sought a one-of-a-kind application where volume alone is high enough to support development work. It settled on a

Amelco FET 'DIFF AMPS' combine high input impedance with minimum tracking error!



Until now, poor tracking was the price of high input impedance when using field effect transistors. No longer! Now Amelco's 2N3921 matched FET Differential Amplifier is providing tracking better than 10μV/°C and input offset of less than 5mV. Best yet, the price for this outstanding performance is surprisingly low. And, if your requirements allow less stringent temperature characteristics, the 2N3922 with 25μV/°C tracking is even less expensive.

GUARANTEED VALUES 2N3921

TRACKING = 10 μV/°C
OFFSET = 5 mV
LEAKAGE = 0.25 nA
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Circle 41 on reader service card

consumer product, a rechargeable radio.

In production. The GE engineers concluded that most of the devices (active elements and some resistors) of a simple transistor radio could be built in one small semiconductor chip and the remaining components (all passive) could be attached to a printed-circuit board. The department, in cooperation with GE's Consumer Electronics division, developed the circuit and it's now on the production lines.

The radio measures 2 3/16 by 3 by 1 inch and the p-c board is about half that size. All the transistors, including the power-output stage, are contained within the 1/32-square-inch chip, which is bonded to a thin Kovar base. The base is welded to the frame of a dual in-line package similar to those made by several other IC manufacturers, and the package is connected into the p-c board by flow-soldering. The GE package is plastic and, unlike competitive packages, has a protruding end lag. The lag can be clipped or, as in the radio, tied to a heat sink.

The radio, due in retail stores this fall, comes with a nickel-cadmium battery and a recharger base. An optional feature will be a recharger that converts the product to a clock radio.

3-year warranty. The radio will carry an unprecedented 3-year warranty covering parts and labor, compared with standard 90-day warranties for all other GE radios.

GE envisions widespread applications of the microcircuit concept in other high-volume consumer products. A phonograph and portable television receiver using microcircuits will be available later this year, and the new circuits will be used in other GE radios, tv sets, phonographs and tape recorders by 1967.

Oceanology

Deep look

On the morning of Jan. 17 an Air Force B-52 bomber, laden with hydrogen bombs, and an aerial tanker collided over Palomares, a small town in the southeastern corner of Spain. The crash touched off a mammoth undersea search for one of the 10-foot-long silvery bombs that had dropped into the nearby sea. But it wasn't until April 7 that the 20-megaton H-bomb was fished from its resting place 2,850 feet down—and it cost the Air Force at least $7.4 million to do it.

The Navy, which rushed over the latest underwater equipment to aid the Air Force search, was criticized because it took so long to find the bomb and because it was ill-equipped to do this type of search. Navy spokesmen defend their efforts in the search, but admit they need "much better equipment to do such a job cheaply and more surely."

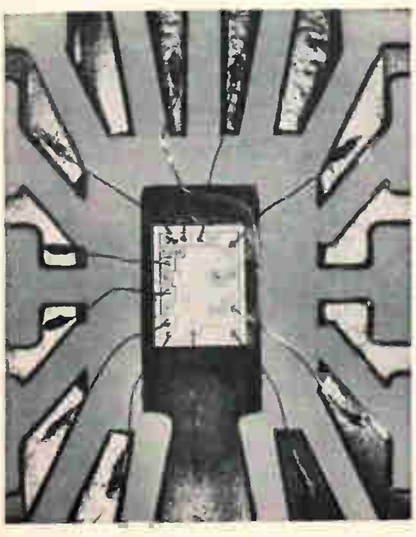
Find a bomb. The need for improved electronic equipment is also a major pacing item throughout the over-all oceanology area. A sonar system that can spot small items, for example, could aid in bottom mapping, sound-speed profiling and sound-propagation research, as well as in locating such objects as H-bombs.

The sensor used to find the H-bomb off Spain was similar to acoustic devices the Navy uses in mine detection and in mine warfare. The ocean-bottom scanning sonar operated at a frequency of 175 to 225 kilohertz and could spot a target at about 200 feet with a resolution of 1 foot.

Development work is well along at the Columbus, Ohio, division of North American Aviation, Inc., on a new type of sonar aimed at such jobs. The marine systems group is developing a liquid-filled sonar lens and a lightweight version based on the Luneberg lens principle. Both lenses act as a magnifying glass to form sharp output pulses and collect the return signal—and without the help of delay lines or complex beam-forming circuits.

In recent Navy tests the liquid lens sonar picked out a 3-foot sphere on the ocean floor 800 yards away. And it could pick up a 1-foot sphere at under 600 yards. The experimental model works best at a frequency of about 29.2 khz, said R.E. Stephens, engineering manager for the group.

Forms the beam. The lens is an



General Electric developed a jack-of-all-trades IC circuit, left, placed it in a plastic dual in-line package, above, and will use it in a rechargeable clock radio, right, for introduction this fall.

COMPONENT COMMENTS *From Speer*

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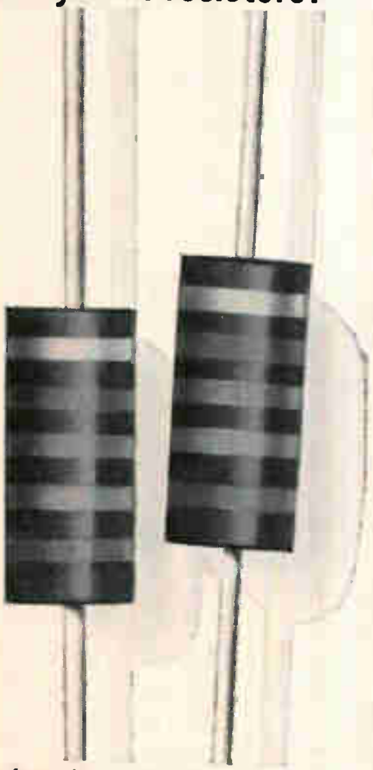

Let's face it, most buyers of insulated fixed carbon resistors don't need the established reliability assurance of MIL-R-39008. And don't want to pay for it. After all it's a costly business compiling "ER" data. The Life Failure Rate Level test is 10,000 hours at 50% rated wattage. Load life: 1000 hours at 100% rated wattage every six months. Quality Conformance: 2000 hours at 50% rated wattage every six months. And each lot must be tested for Load Life at 50% rated wattage for at least 250 hours. (For the "S" level, this means 35,000 units in a single style must be run for 12 months to accumulate the necessary 315 million test hours.)

So how does MIL-R-39008 benefit commercial users? Well, Speer doesn't build two products, one for MIL-R-39008 and another for general use. We build one. So when you buy from us there's a better than 90% chance you're getting more reliability than you pay for—even though your lot isn't run through the "ER" test series.

If you're interested in more information on this subject, we're offering a technical article on "How the New 'Tri-Service' Specification MIL-R-39008 Applies to Resistors." You can get a copy by filling out the coupon.

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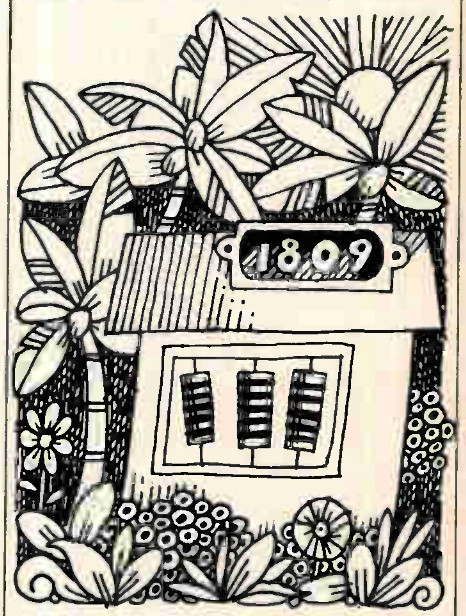
Get the Speer slant on MIL-R-39008 and temperature stability at the Wescon Show, August 23-26, at the Sports Arena. We'll be at Booth 1809—see us, see our resistors.



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18-inch diameter aluminum sphere filled with silicone oil. Voltage is applied to six transducers, each made up of a series of ceramic wafers, to get the movement to pulse the lens. The liquid lens forms the beam mechanically and the acoustic energy is bent like light. It loses no more than 20% in the back lobe and puts out a 6° beam. The transducers are "fired" one by one to scan an area 30° wide electronically. Sensitivity of the sonar is 18 decibels at 30 khz.

Working mostly on company money for the past 18 months, North American now is building an experimental four-transducer set for the Navy's mine defense laboratory in Panama City, Fla. The model, to be delivered by the end of July, will be mounted on a barge or platform but can also be mounted on a hull.

The first model will cost the Navy $54,000 and North American is hoping for a large follow-on order. The liquid-lens sonar can be used for hunting mines—floating on the surface or suspended below.

The four-transducer array can scan an area 20° wide. The signal return is picked up by a preamplifier which pipes it into an oscilloscope for viewing at the surface. The transducers, fabricated by the North American division, are put under compression and driven harder to get more power output.

First deep-sea tests for the Luneberg lens model is set for early September off Nassau in the Bahamas. The 5-foot sphere making up the lens of this set employs gas-filled rubber tubes to form the 5-foot lens when inflated. This lightweight approach is important since the Luneberg lens model is being developed for dropping from aircraft in the same way that sonobuoys are deployed.

Integrated circuits

Sticky problem

It was a real cliff-hanger—literally and figuratively. The Micro-electronics division of the Philco Corp. had to figure out how to get a strip of aluminum on a new breed of metal oxide semiconductor integrated circuit to climb a silicon resistor "cliff" some 3,000 angstroms high, without separating or failing to adhere.

Philco (more specifically, the Santa Clara, Calif., operation known as General Micro-electronics, Inc., before it was purchased by the Ford Motor Co. subsidiary last January) completed a special three-month research-and-development contract last month, and believes it now knows how to scale the cliff. That's good news for the National Aeronautics and Space Administration because the F and G flights of the interplanetary monitoring platform (IMP) series depend on how soon Philco can deliver 400 of the circuits for use in the telemetry system's coder and digital data processor. Philco has already delivered its first small batch of production circuits. But the company's timetable is tight. A NASA spokesman said, "If the present schedule is delayed much more than a week, we're in trouble."

Short insurance. NASA itself had asked for the special circuits, which differ from conventional MOS IC's in that they have silicon resistors deposited on the chip itself. The space agency wanted to make sure that the failure of one chip could not short out the power supply. The silicon resistor IC's filled the bill in two ways.

- Their own failures are opens, rather than shorts.
- Since they are in series with the circuit and have a high resistance, on the order of half a megohm, a short elsewhere on the chip would be blocked from the rest of the system.

Under a program that began in July, 1965, Philco built two kinds of silicon resistor circuits: a so-called "I-block," a two-bit accumulator with two binary stages and the resistor, and an "SI-block," a signal conditioner in front of the accumlator.

Won't stay put. The company ran into trouble when it tried to put the circuits into production. The first step is to deposit the silicon resistor on the silicon dioxide substrate; then a layer of KPR photoresist is added and the resistor paths etched. The development of the photoresist determines where the aluminum that completes the MOS devices will go; if the photoresist is deposited too thinly in spots, it cannot be developed adequately to ensure that the aluminum will not be moved.

The KPR is applied in a spinning process, which sometimes resulted in an uneven layer. Breaks in the aluminum pattern often resulted as it climbed over the silicon resistor.

A contact resistance problem also cropped up. Once deposited, the silicon loses its crystalline structure and lacks orientation. As a result, when the series connection between the aluminum and the resistor was made, Philco sometimes got a high-resistance contact, sometimes a rectifying contact and sometimes, it was discovered, no contact at all.

"We could have brute-forced the process and come up with the required number of circuits," says Philco's Donald Farina, manager of devices and circuit development, "but we wanted to come up with a workable process." In March, NASA agreed to the supplemental research - and - development contract, under which the company would get extra time to debug the circuits.

NASA also began work on the process itself, in the Goddard Space Flight Center laboratory in Virginia.

Cliff problem. Philco, which considers itself a leader in MOS technology and wants to keep it that way, is cautious about explaining exactly how it solved the cliff problem. But essentially, the solution was to change the spinning so the photoresist was deposited more evenly and the tangential force on the silicon resistor strips was lowered. It is equally reticent about the contact difficulty, although Farina does say the size of the contact was increased "slightly," from 10 square microns, and that the makeup of the aluminum alloy was changed.

Philco is now burning in produc-

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Circuitry is simplified and fewer components are required. Varicap-controlled tuning systems assure the performance characteristics required in the most sensitive communications and monitoring networks.

TRW Varicap diodes are true abrupt junction devices, produced by proprietary processes. This construction gives the designer maximum capacitance change with voltage; optimum uniformity and tracking and superior performance under all operating conditions.

Varicap Bulletin No. 101 discusses wide-range theory in detail. Get a copy from your authorized distributor or write TRW Semiconductors Inc., 14520 Aviation Boulevard, Lawndale, California (213) 679-4561.

Varicap is the trademark of silicon voltage-variable capacitors manufactured by TRW Semiconductors Inc.

TRW SEMICONDUCTORS

Circle 45 on reader service card

tion circuits. NASA has built about 30 that are flight-qualified. "Whoever gets 400 built first—those are the ones that will be flown," says John Lyons, assistant program manager for IMP.

Philco has built three other MOS circuits for NASA—a dual flip-flop and two simple gates that went into previous IMP instrumentation. The IMP program is a seven-satellite series to study cislunar and interplanetary radiation fluxes; three have been launched. The IMP-F launch, the first to carry the silicon resistor IC's, will be placed into a highly elliptical earth orbit some time before April.

Despite the difficulties with silicon resistors, the company says it is making money from the NASA program and, according to general manager J.P. Ferguson, "we'll be happy to work with NASA in the future."

Space electronics

High and mighty

A hitchhiker in the military communications satellite launch June 16 may outdo even the remarkable success of the seven satellite repeaters and the Titan 3C booster. The eighth satellite—an experimental gravity-gradient test vehicle is working as designed, something at least part of the technical community had not expected.

The satellite is stabilizing so well, in fact, that Air Force managers on the Initial Defense Communication Satellite Program sold their superiors the idea of buying an advanced model of the gravity-gradient satellite from the builder, the General Electric Co.'s Valley Forge Technology Center in Philadelphia.

The Air Force will try to get the improved gravity-gradient satellite on the second launch of the communications satellite program scheduled in August.

Higher up. Gravity-gradient stabilization had been demonstrated on such satellites as the Navy's Transit as early as 1964, but until now tests were carried out at 500- to 600-mile altitudes. The stabilization is based on the principle that a long object in space will align itself vertically with the earth. No one knew for sure if it would work at higher altitudes—as at the near-synchronous height used last month. Gravitational force decreases rapidly with altitude. At the synchronous altitude of 19,400 nautical miles, for example, gravity has only 1/200th the pull it has at 500 to 600 miles.

If it works well, gravity-gradient stabilization will probably be used in a variety of high-altitude satellites on meteorological, navigational, surveillance, data-gathering as well as communications missions. The Pentagon's Advanced Communications Satellite System —planned for 1969—is a candidate for the system. The Initial satellites are spin stabilized as are the commercial communications satellites. To be tested later this year are Sylvania Electric Products, Inc.'s despun antennas which counteract the spin and shoot a pencil beam back to earth.

Gravity-gradient supporters point out the simplicity of the system. There are no electronics or moving parts to wear out, and no need for thrusters unless a stationary orbit is needed, they say. Air Force officials are excited about gravity gradient because it means they could go to dish or steerable horn antennas, which are not as complex as the despun array system.

In either the gravity-gradient stabilized dish or the despun array, the payoff is a big one. The effective radiated power of a satellite would be raised by an order of magnitude over satellite antennas now flying. By beaming a stronger signal back to earth, the satellite can handle many more voice channels with the same sized transmitter, and smaller sized ground stations can listen in.

Space swinger. After two weeks in orbit the 104-pound gravity-gradient test satellite was down to about a 30° to 35° swing, or oscillation, and had already confirmed the practicality of the passive method of stabilization at higher altitudes. Two 52-foot rods, extend from the spacecraft, with a damper, or tip weight, at the end of each.

Final stabilization is expected 60 to 70 days after launch, quite a bit earlier than expected. The contract requirement was stabilization within ±8°, but it now looks like GE will achieve a "desired" 4°, William Van Patten, GE program manager, predicts.

The improved gravity-gradient system is being completed at GE and will provide three-axis stabilization, adding a rod to the system. Although the test satellite is kept pointed at the center of the earth, it has no preferred yaw position. The improved version will use mercury-fluid flywheels and may take sightings of the sun to orient the yaw axis and power the flywheels by solar cells. The improved stabilization system will have a rapid damping feature—five days to stabilize—and an improved pointing accuracy of 2° to 2.5°.

Far ranging

Researchers are turning to X-rays to guide craft to soft landings.

Last month the National Aeronautics and Space Administration awarded a $35,000 study contract to General Nucleonics Corp. to build a feasibility model of an altimeter that could help guide a spacecraft to a lunar landing.

X-rays offer decided advantages over optical or radar altimeters: they can pierce the plume of a retrorocket (radar and light beams are attenuated by the hot gases); special windows needn't be constructed in the spacecraft because X-rays can pass through the skin of a ship unobstructed; and they can make high-resolution maps of the terrain beneath the spacecraft.

The principle behind an X-ray altimeter is the same as that behind radar or optical systems: the time it takes for a pulse fired from the space ship to be reflected back is a function of the distance.

The altimeter that NASA wants must operate between 0 and 500 feet, and have an accuracy of ±2% below 10 feet and ±3% above 10 feet.

Beyond space. Interest in an

X-ray altimeter isn't limited to space. Some down-to-earth functions are being explored, also. The Air Force Flight Dynamics Laboratory at Wright-Patterson Air Force Base, Dayton, Ohio, is weighing an X-ray ranger for use on low-altitude airplanes. One model is scheduled for delivery this month by the Franklin GNO Corp. It will be flight-tested for use in an all-weather landing system and for terrain identification.

X-rays are especially suitable for military applications because the weak signal is nearly impossible to detect. In addition, since the signals are able to pierce foliage, the system could ferret out camouflaged bases and hidden guns.

Another design, for high-altitude use, is also under development by General Nucleonics. In this contract, a $263,000 award by the Air Force, the company is building an altimeter for the X-15; it's to be flight-tested early next year.

Still another company working on X-ray rangers is the Giannini Controls Corp. Its model is being considered as a fusing device to trigger a reentry missile when it reaches a predetermined distance from the ground.

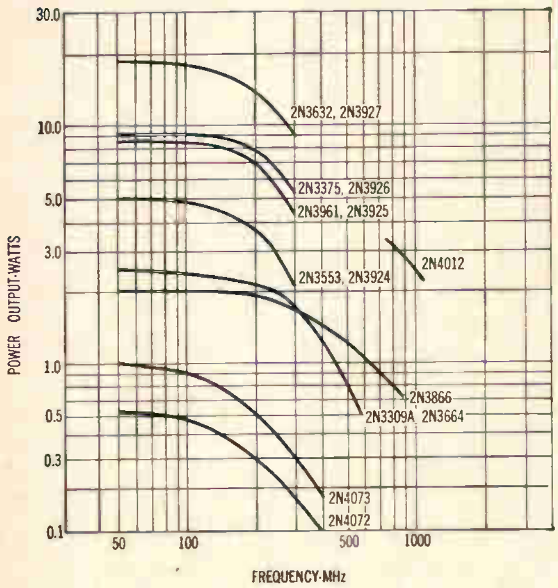
In high-level applications, the X-rays never reach the ground. When a craft fires a pulse, the atmosphere backscatters the rays; the thinner the atmosphere the less backscattering. By measuring the extent of backscattering, a craft's altitude can be calculated.

Electronics notes

- **Unique tanker.** A French affiliate of Royal/Shell put into service late last month the 65,000-ton Dolabella, first supertanker with fully automated engine room control. A single man on the bridge can operate the propulsion plant.
- **Successful bid.** A six-company consortium headed by the Hughes Aircraft Co. has been selected as the contractor for the $280-million air-defense network for NATO. The consortium underbid an international group led by the Westinghouse Electric Corp.

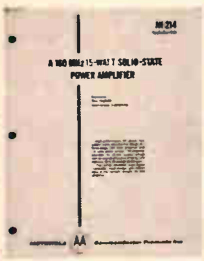
Circle 47 on reader service card

MOTOROLA'S BROAD RF POWER CAPABILITY MAKES YOUR SELECTION EASIER...



The power-frequency curves indicated here, cover only the EIA-registered device numbers available within Motorola's broad RF Power Transistor line. They are intended to help you narrow the range of possible choices for your specific application.

The power-output values shown are typical values achieved when operating within the maximum ratings for each device type with the unit performing at an efficiency level usable in most circuit applications.



HIGH-POWER, HIGH-FREQUENCY DESIGN TECHNIQUES SHOWN IN APPLICATION NOTE 214

A solution to the design errors caused by the use of small-signal design procedures for large-signal amplifiers is the thesis of this well-written technical report. The author employs large-signal transistor input-output admittance data in the network designs for a 160 MHz, 15-Watt Power Amplifier. You're sure to find Motorola Application Note 214 a valuable addition to your Semiconductor library. Write for it today, to Technical Information Center, Motorola Semiconductor Products Inc., P. O. Box 955, Phoenix, Arizona 85001.

A REPORT ON HIGH-FREQUENCY HIGH-POWER OUTPUT CIRCUIT DESIGNS USING MOTOROLA RF POWER TRANSISTORS

including types for high gain and efficiency combined with low input and output capacitance.

Motorola provides *one* source for a broad range of RF Power Transistors for applications at a variety of power output and frequency requirements. Now, you can write *one* order, look to *one* source for applications and engineering help . . . indeed, rely on *one* highly reliable source for all of your RF communications needs.

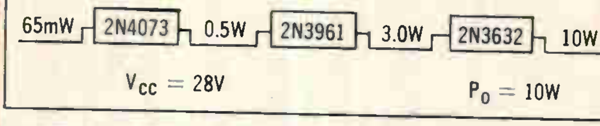
The chart below is indicative of the range of possible applications using Motorola RF Power Transistors in the driver and output stages.

13.6-Volt Supply	2N3927	2N3926	2N3925	2N3924
28-Volt Supply	2N3632	2N3375	2N3961	2N3553
Stage(s) or Function(s)	Final	Driver/ Final	Driver/ Final	Driver/ Final
APPLICATIONS:				
Military Communications (225-400 MHz)	10 W	5 W	2 W	1 W
Mobile Commun. (156-175 MHz)	15 W	7 W	6 W	4 W
Portable Commun. (156-175 MHz)	15 W	7 W	6 W	4 W
Beacon (243 MHz)	12 W	6 W	4 W	2 W

YOU CAN MATCH YOUR APPLICATION . . . TO A MOTOROLA POWER COMBINATION

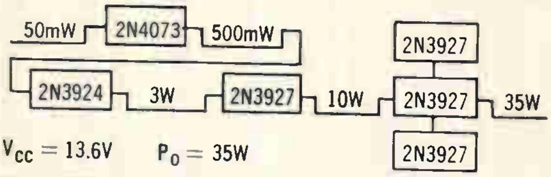
10 Watts Power-out at 175 MHz
For Military Communications

- Telemetry
- Beacons
- Radar
- Air to Air — Air to Ground



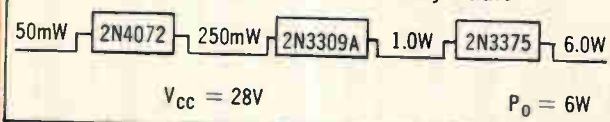
For 13.6 Volt Mobile Communications
35 Watts Power-out at 175 MHz . . .

- Police Radio
- Sonobuoy
- Field Radio



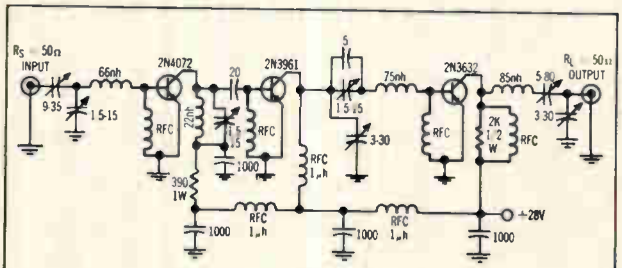
6 Watts Power-out at 175 MHz
For Portable Communications

- Walkie-Talkie
- 2-Way Radio



NOW—DESIGN A 160 MHz, 15-WATT SOLID-STATE POWER AMPLIFIER . . .

If your application calls for high power gain with reliability, in a circuit that's simplicity itself, this design may be your answer . . . Here's a circuit that provides 30.5 db power gain with an efficiency of 62%, operating on a 28-volt power supply. Motorola RF Power types 2N4072, 2N3961 and 2N3632 make possible this unique, 3-stage amplifier design, with suitable connecting networks.



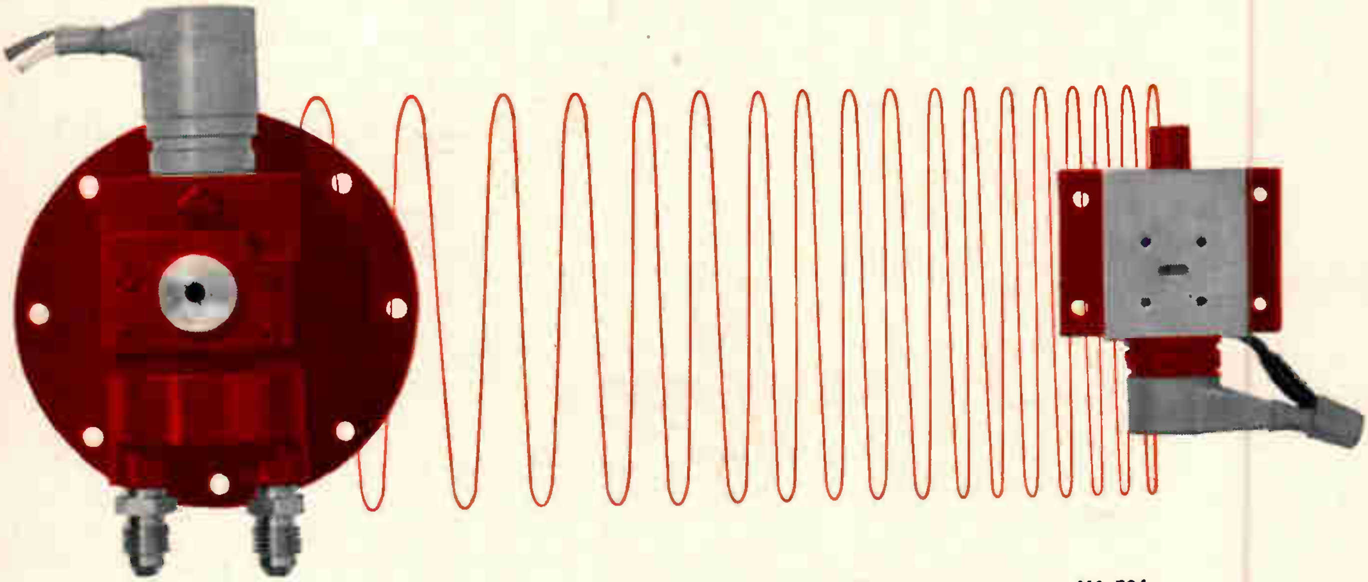
L_1 — 66nh, 6 Turns #18 Tinned Wire, 3/32" I.D. 1/2" L.
L_2 — 22nh, 2 Turns #18 Tinned Wire, 3/32" I.D. 1/4" L.
L_3 — 75nh, 4 Turns #14 Tinned Wire, 1/4" I.D. 3/8" L.
L_4 — 85nh, 3 Turns #14 Tinned Wire, 3/8" I.D. 3/8" L.
All capacitor values in picofarads.

MOTOROLA Semiconductors

—where the priceless ingredient is care!

Circle 49 on reader service card

Spanning the range of low-noise klystron oscillator capabilities



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

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

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

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

varian

A dour source of power

A powerful pair from Sierra

Happiness to some is sufficient lungpower to support a stirring skirl. To some members of the test engineering clan, it is stable power to support an RFI determination. Among the latter, many a dour face has brightened lately to performances given by Sierra's Model 470A power signal sources.

This powerful pair of Sierra sources delivers stable 55 to 80-watt power across frequency ranges of 200–500 mc and 470–1000 mc. Frequency stability is 0.005% per ten minutes below 500 mc; 0.002% per ten minutes above. Modulation can be provided from an internal 1 kc square wave, or from an external pulse source.

Other features include: 1) direct-reading, two-range wattmeter, 2) single-knob frequency tuning, 3) oscillator current metering, 4) automatic power tube protection under all load conditions, and 5) easy power tube changing (takes about two minutes). You can enjoy this highland performance at a thrifty lowland price of $2,650 for each model.

The product bulletins come scot-free. Write to Sierra/Philco, 3885 Bohannon Drive, Menlo Park, California 94025.

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PHILCO
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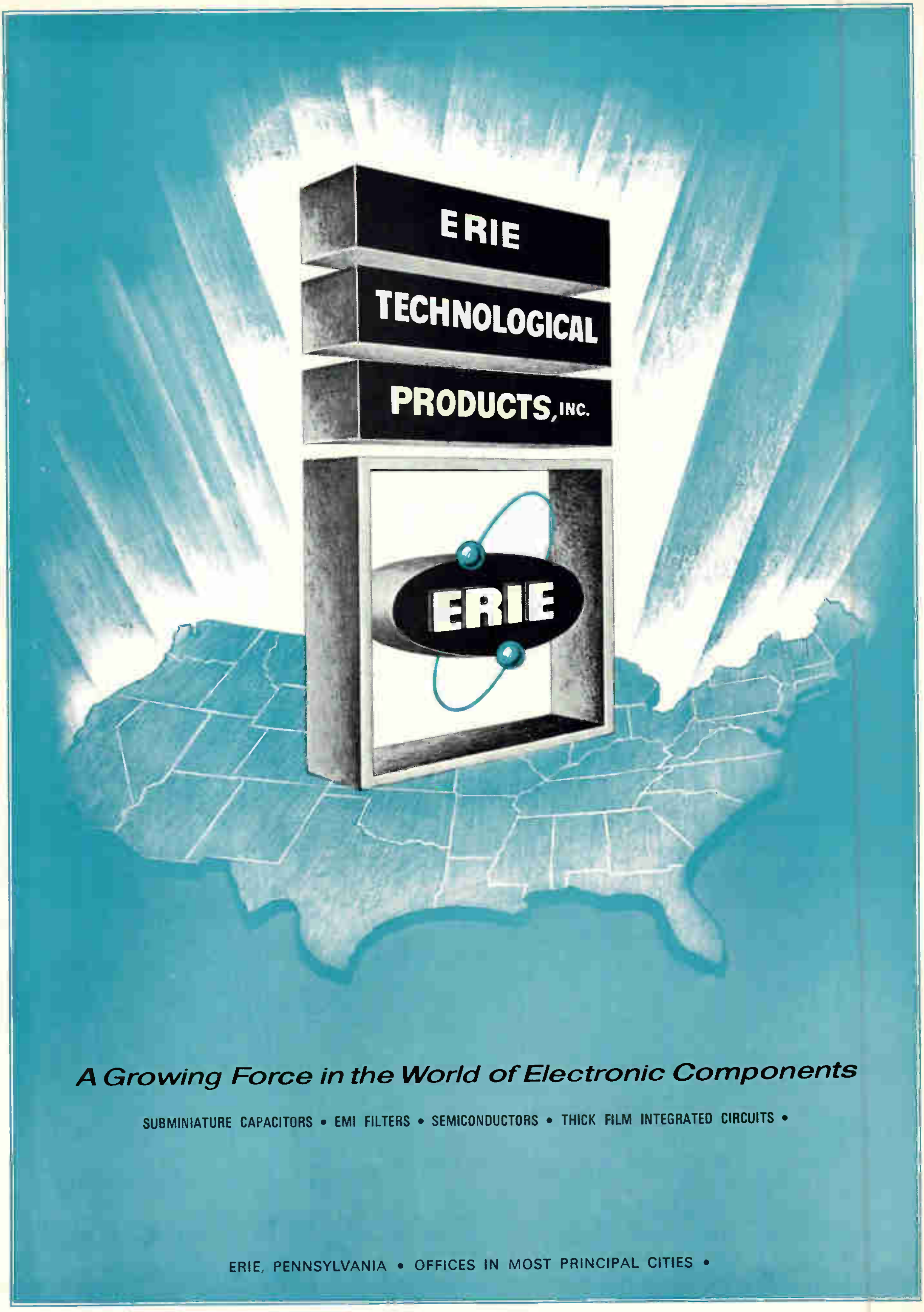
Circle 470 readers service card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Washington Newsletter

July 11, 1966

Lunar orbiter delay may prove costly for Boeing Co.

The space agency's lunar orbiter spacecraft has failed a "confidence" test and its launch has been delayed for at least a month—to mid-August. With the five spacecraft in the series costing the government about $150 million (50% more than originally estimated), project officials say they want to be "damn sure" of success before attempting the launch.

Lunar orbiter is being heavily counted on by the space agency to map the moon's surface so that astronauts of the Apollo man-on-the-moon program will know where to land [Electronics, June 27, p. 45]. Photographs snapped by the craft must be in hand for at least a year for analysis to pinpoint the best landing sites.

Late launch of the craft may hurt the Boeing Co., Seattle, the prime contractor. The contract carries elaborate penalty and incentive clauses. It seems likely that Boeing will pay a penalty, the amount to be negotiated. However, the slippage problem may be due primarily to difficulties encountered by the Eastman Kodak Co., Rochester, N. Y., the subcontractor for the $30-million complex camera system. An Eastman Kodak spokesman declined to comment.

Vietnam escalation pushes defense spending even higher

Defense spending is exceeding Pentagon budget estimates and probably will keep on climbing for the next six months as a result of the expanding war in Vietnam. Contract-letting is running close to budget projections, but rather than peaking as originally anticipated, probably will begin moving upward again early in 1967.

Though final figures are not yet in, **defense officials estimate that total expenditures for the year ended June 30 topped the budget estimate of $54.2 billion by $1 billion, and maybe more.** The volume of contracts awarded apparently came close to the $36-billion projection. This represented an $8-billion increase over the previous year.

The budget plan for the fiscal year now under way—submitted to Congress last January—predicted that contract awards would level off and decline slightly to $34 billion.

But it now appears that spending, for a variety of reasons, will exceed even the built-in increase anticipated in the $53.8-billion estimate. One reason is that the total size of the armed forces has swelled to nearly 3.1 million men—a level originally not expected to be achieved for another year—and will expand by at least another 100,000.

For budget-making purposes, the Pentagon originally assumed that the war in Vietnam would end in mid-1967. This fall that assumption will have to be reassessed. If it appears the war will continue beyond then—and few doubt that it will—the Pentagon will draw up a supplemental appropriations request to be submitted to Congress next January.

With the new funding authority, it will then begin to **contract for long lead time items—such as communications gear and avionics—to keep war production going beyond mid-1967.**

Pentagon shows military exporters how to succeed

The Defense Department is starting an intensive information program **to interest more companies in participating in the military export sales program and to spur those already participating to greater efforts.** It plans to conduct a series of briefings for industry and labor groups this fall in cooperation with the National Security Industrial Association

The Pentagon is also preparing background data for interested companies on U.S. trade relationships with several countries including Britain, Germany, Italy, Japan and Australia. And it is putting together information packets on such topics as the availability of export credit, the economic impact of military sales and the common market concept.

In still another move, the Pentagon is organizing a kind of complaint department for overseas customers. **The idea is to ensure that once a sale is executed, the U.S. producers will provide an effective follow-up with an adequate spare-parts program, technical assistance, maintenance services and the like.** Complaints have been mounting, and the new Pentagon trouble-shooting department will work with American sellers to iron out the wrinkles.

President says get blue-sky research down to earth

President Johnson's order to Federal research planners to press for immediate results is likely to mean more funds for applied research and less for basic research. The President said too much research is being carried on "for the sake of research alone."

Specifically, for the National Institutes of Health, to whom he addressed the order, **it means more effort in such areas as artificial organs, automated hospital design and other areas in which the electronics-aerospace industries are involved.** The edict won't affect the research programs of the Defense Department or the National Aeronautics and Space Administration. The Defense Department has been trimming its basic science funding in recent years.

National Science Foundation officials are looking to contract authority for applied science projects in pending legislation to provide them with a fast rate of growth. Up to now Congress has refused to push NSF budgets above $500 million a year because of the "blue sky" nature of the work it's been supporting—so far.

The future of Project Mohole—the one big contract operation run by the National Science Foundation—will remain in doubt until at least the middle of July. The Senate Appropriations Committee will take until then to decide whether or not to fight to restore House-cut financing for the deep-ocean drilling project. President Johnson has publicly requested restoration of the $19.5-million Mohole money, saying that to kill the project now would waste more than $30 million already invested. The Senate will probably be sympathetic—at least to the extent of supporting a stretched-out project—but won't act on the question until July 19 at the earliest.

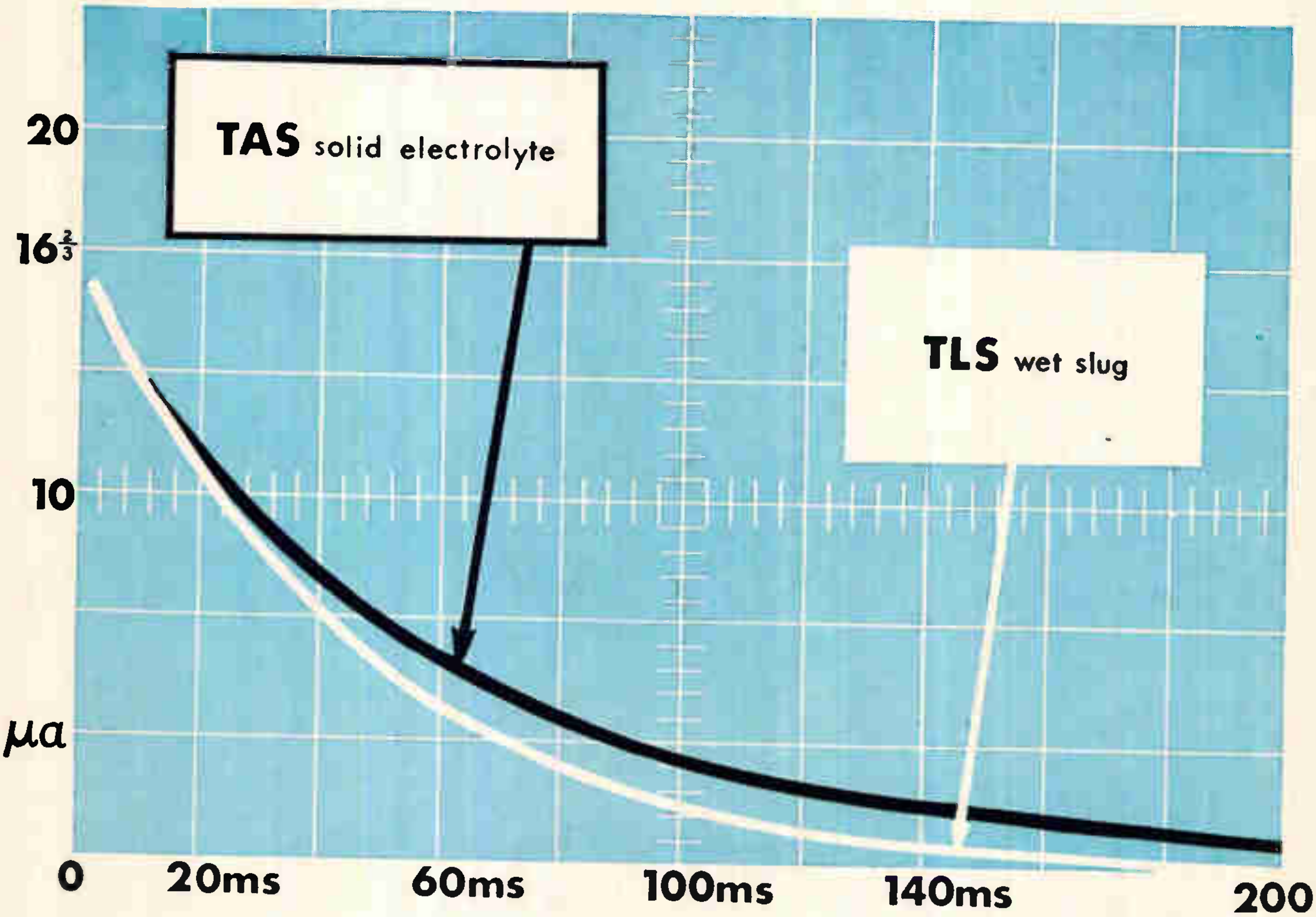
The Long view: tack patent rider on each bill

Senator Russell B. Long (D., La.) has chalked up another victory for public ownership of inventions that Federal funds help finance. The auto safety legislation, which passed the Senate and is working its way toward enactment, contains Long's language barring "give away" of patent rights based on more than "minimal" Federal contribution.

Anti-Long forces were able to defeat him twice in the past because the Senate Judiciary Committee was writing broad legislation governing disposition of such patent rights. But the Judiciary Committee refused to make concessions to the Long view. The committee bill would give administrators broad leeway to assign patent rights to contractors even before inventions are made. **However, the Senate supports the Long view that a bill-by-bill guarantee of public ownership of rights is the best approach.** The committee's bill will probably be defeated in the House, even if it sneaks through the Senate. Long so far has had no trouble tacking patent-rights riders to the saline water, coal research and other R&D legislation.

Why specify Mallory wet slug tantalum capacitors?

One reason: higher precision in timing circuits



Compare Charging Current-Time Traces reproduced from scope photographs.

Sweep speed: 20 millisec/div   Vertical sensitivity: 3⅓ μa/div

DC leakage of a capacitor acts as a parallel resistor. In an RC timing circuit, Mallory wet slug tantalum capacitors produce less time error than solid electrolyte types, because they have only about 10% as much DC leakage.

Want more reasons? Greater freedom from catastrophic failure—documented by millions of unit test hours. Up to 5 times more rating per unit volume—as much as 172,000 mfd-volts per cubic inch. Highest voltage and temperature ratings. We make all types . . . wet-slug, solid and foil. Ask us for recommendations. Mallory Capacitor Company, a division of P. R. Mallory & Co. Inc., Indianapolis, Indiana 46206.

50th ANNIVERSARY

MALLORY

Circle 53 on reader service card

AUTOMATIC OPERATION

for your Tektronix Type 561A or 564 oscilloscope — with Type 3A5/3B5 plug-ins

Now, with two Tektronix automatic/programmable plug-ins—a Type 3A5, with included P6030 Probe, and a Type 3B5—you can make DC-to-15 MHz measurements with new ease, and in any of these modes of operation:

AUTOMATIC SEEKING

In this mode, upon SEEK command from the probe or the plug-ins, the oscilloscope automatically presents an optimum display. The SEEK command to the plug-in units automatically controls the triggering settings and the time and amplitude settings, eliminating the need for continuous front-panel adjustments. Indicators on the plug-ins light automatically to show the time and amplitude settings. Measurements can then be made quickly and accurately from the CRT display. In AUTOMATIC SEEKING mode, the deflection factor is 10 mV/div to 50 V/div and sweep range is 5 s/div to 0.1 μs/div.

> **when plug-ins receive SEEK command**
>
> **Type 3A5** automatically establishes the optimum deflection factor. Indicators light to show readout with input coupling, such as .5 V/DIV, DC (coupled) WITH PROBE. (Coupling can also be DC or AC Trace Stabilized.)
> **Type 3B5** automatically establishes optimum trigger settings and automatically selects time per division setting. Indicators light to show readout, such as .2 μs/DIV, and to show NOT TRIG'D condition. (IF X10 or X100 Magnifier operative, readout is automatically corrected and indicates SWP MAG'D condition.)

REMOTE PROGRAMMING

overrides the SEEK command and Manual Operation. In this mode, both plug-ins can be programmed using the Type 263 Programmer, which accepts up to 6 plug-in type program cards. Each program card, after initial set-up, establishes the plug-in control functions required for a particular test or measurement . . . with actual measurements made conveniently from the CRT display, as usual. Automatic/Programmable Plug-Ins provide selection of eleven different programmable functions. Any number of programmers can be cascaded for applications requiring pushbutton control of more than six measurement set-ups. In REMOTE PROGRAMMING mode, the deflection factor is 10 mV/div to 50 V/div and sweep range is 5 s/div to 10 ns/div.

MANUAL OPERATION

In this mode, both plug-ins are controlled conventionally. Indicators on the plug-ins show the time and amplitude settings. In MANUAL OPERATION mode, deflection factor is 1 mV/div to 50 V/div (5 MHz bandwidth at 1, 2 or 5 mV/div and 15 MHz at 10 mV/div to 50V div) and sweep range is 5 s/div to 10 ns/div.

Type 3A5 Automatic/Programmable Amplifier Unit	$760
Type 3B5 Automatic/Programmable Time-Base Unit	$890
Type 263 Programmer (complete with 6 program cards)	$325

Oscilloscopes which accept both Automatic/Programmable Plug-Ins:

Type 561A Oscilloscope	$500
Type RM561A Oscilloscope	$550
Type 564 Storage Oscilloscope	$875
Type RM564 Storage Oscilloscope	$960

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

Tektronix, Inc.

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

Mktg Parts Dept

Tru-matic MACHINE & TOOL CO., INC.

Phone: 421-5000 421-5001

Paradise Road
EAST STROUDSBURG, PA. 18301

April 13, 1966

Tally Corporation
1310 Mercer Street
Seattle 9, Washington

Gentlemen:

We have an NC-425 Wiedemann punch press with a Pratt & Whitney tape control. The control has a Tally reader, Model 424-PR, Serial No. 409-0274.

We have had the machine two years. Usually we run two 9-hour shifts. The other day the motor froze fast. Actually what happened was the corregated belt was too tight and it caused the Oilite bearings on the drive shaft to become out of round and bind.

If possible I would like to get a Parts List for the reader and two bearings.

Congratulations on producing a good piece of equipment. This is the first trouble we have had. Under normal working hours, the Tally reader would work without fail for over four years.

Very truly yours,

TRU-MATIC MACHINE & TOOL CO., INC.

James Staples

James Staples,
Plant Superintendent

JS:mk

ELECTRONIC CHASSIS & ASSEMBLIES, CABINETS, AIRCRAFT MACHINED PARTS, FINISHING, WELDING

All tape readers break down. Only ours don't break down very often!

We're grateful for Mr. Staples' letter telling us about the built-in reliability of Tally equipment. Needless to say, the parts list and two bearings have been sent long ago. Mr. Staples tells us the machine was quickly restored to 18-hour-a-day service. Now that the drive belt has been properly adjusted, he expects his N.C. System to run with little or no trouble for many years.

Pleased as we were to hear from Mr. Staples, we are even happier that our correspondence from the user is minor compared to the number of perforators and readers we've shipped in the past few years. For as you know, in our business, no news is good news.

There are a lot of good solid engineering reasons why Tally readers are extraordinarily reliable. For all of them, please address Ken Crawford, Tally Corporation, 1310 Mercer Street, Seattle, Washington 98109. In the U.K. and Europe, address Tally Europe, Ltd., Radnor House, 1272 London Road, London, S.W. 16, England.

TALLY

Circle 55 on reader service card

Murray Siegel can't hold a job at Fairchild. He's had five in as many years. He's been a Circuit Designer, Senior Product Engineer, Integrated Circuits Applications Designer, Senior Marketing Engineer. Now, he's responsible for developing advanced applications for digital circuits. We have a lot of job-hoppers at Fairchild.

We need four more. If you want to move fast in the semiconductor business—and you have what it takes to get there — contact Jack Sheets at Fairchild Semiconductor, 313 Fairchild Drive, Mountain View, California.

We need an Applications Engineer with a B.S.E.E. and experience in digital circuit design to determine new product direction and to work with field salesmen in the development of integrated circuits for advanced computers.

Murray Siegel needs an Applications Engineer with a B.S.E.E. and two years experience in semiconductor circuit design to provide complete technical assistance in the development of integrated circuits for communications equipment.

We're also looking for an Applications Engineer with a B.S.E.E. and two years experience in designing timers and motor controls to coordinate Fairchild applications projects in the development of integrated circuits for consumer appliances.

And we need an Applications Engineer with an M.S.E.E. and experience in solid state circuit design to work with customers and Fairchild departments in the development of custom integrated circuits and discrete circuits for digital systems.

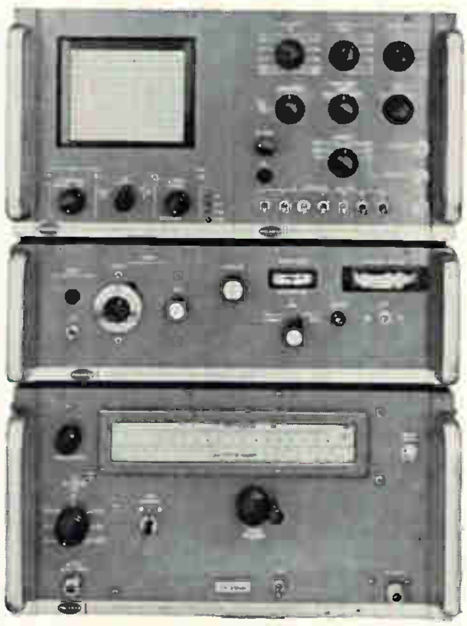
FAIRCHILD

SEMICONDUCTOR

A Division of Fairchild Camera and Instrument Corporation ■ An Equal Opportunity Employer (M&F)

We hate the numbers game

because we fall for it ourselves, sometimes. Sure, a volt is a thousand millivolts, and your gigacycle has the same thousand megacycles in it that ours has. Numbers **are** necessary, and we sell many of our instruments **simply because** our numbers are better; but **numbers alone** can't possibly describe the many reasons why one instrument design is superior to all the rest. Take our **2-Gc-Dispersion Modular Spectrum Analyzer** series, for example. When you sit down and compare the numbers, the POLARAD design wins by a tidy margin, in just about every department . . . but the numerical specifications can't tell you that **only the POLARAD design** is completely image-free . . . that **only the POLARAD design** has the foolproof harmonic-identifier push button . . . that the Model 2992-A is really a three-piece "starter set", from which, by adding only four more modules, from "open stock", you can build up **the most** complete spectrum analyzer capability ever offered . . . that with those seven, you can assemble 17 different spectrum analyzers! Check the features listed here—there's not a number in them, but they constitute a powerful set of reasons for **going the POLARAD route.** Call 212-EX 2-4500. One demonstration is worth 10,000 numbers.



This module alone is a complete Spectrum Analyzer with 100 Mc Dispersion.

Add Continuous Phase-Lock Frequency Stabilization with this Module . . . permits narrow-dispersion analysis of signals down to 1 Kc resolution!

Add this "Swept Front End" module for 2-Gc dispersion over 10 Mc—91 Gc.

MODEL 2992-A 2-Gc-DISPERSION SPECTRUM ANALYZER

- **TRULY QUANTITATIVE.** Built-in crystal markers. Choice of LIN-LOG-POWER display modes, all with excellent level-resolution, for optimum signal-amplitude accuracy.
- **WIDEST RESOLUTION RANGE**
- **WIDEST DISPERSION RANGE.** In calibrated steps or variable in a pair of continuous ranges.
- **ERROR-FREE.** Push-button Harmonic Identifier—foolproof, fast, positive! Image-free presentation over full rated dispersion on all bands—without exception!
- **LOWEST NOISE, HIGHEST STABILITY.** Obtainable at present state of the art . . . orders of magnitude better, due to phase-lock stabilization of front-end L.O., which eliminates spurious FM/jitter.

By the way, those rumors you hear are true. We can't give you better than about 60-day delivery, despite nearly tripled production on the 2992. We are shipping and manufacturing like mad, though, to try to catch up. (No manufacturer *enjoys* having instruments on the shelf. Backlogs are better.)

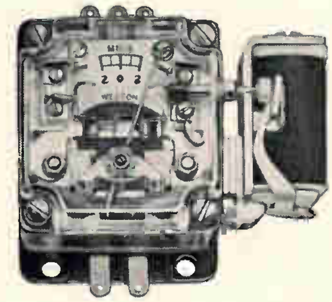
POLARAD

World Leader in Microwave Instrumentation

POLARAD
ELECTRONIC INSTRUMENTS
A Division of Polarad Electronics Corporation
34-02 QUEENS BOULEVARD
LONG ISLAND CITY, NEW YORK 11101

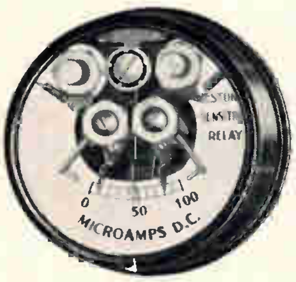
Circle 57 on reader service card

familiar faces from the world's broadest line of indicating relays



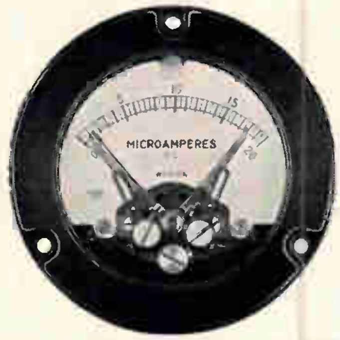
Model 813 Miniature—compact and lightweight; sensitive and Sensitrol (magnetic) contacts; single or double contact; ranges as low as 2-0-2 μa.

Model 1092 Sensitrol—low cost; all purpose; magnetically shielded; wide range adjustability; ideal for use in engineering breadboard circuits.

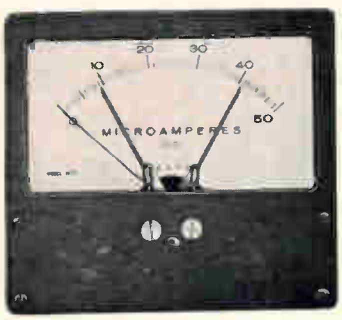


Model 705 Sensitrol—highly sensitive; surface or flush mounted; single or double, fixed or adjustable contact; ranges as low as 0.5-0-0.5 μa.

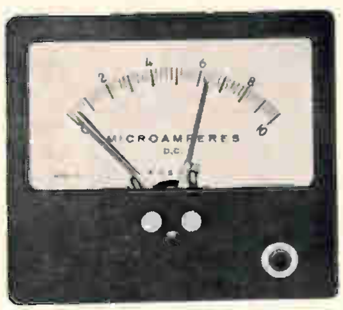
Model 723 Sensitrol—sealed; shielded; internal reset; solder terminals; single or double magnetic contact; ranges as low as 1-0-1 μa.



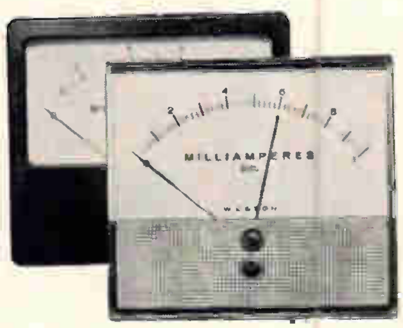
Model 1097 Ruggedized 3½" Relay —Load Current Contact Aiding type fully meets applicable portions of military ruggedized spec; sealed; long scale; shielded; solder terminals; single or double adjustable contacts.



Model 1075 Photronic—operates without physical contact; single or double adjustable set points; continuous reading beyond set point; taut band frictionless mechanism; solid state switching circuit; ranges from 10 μa.



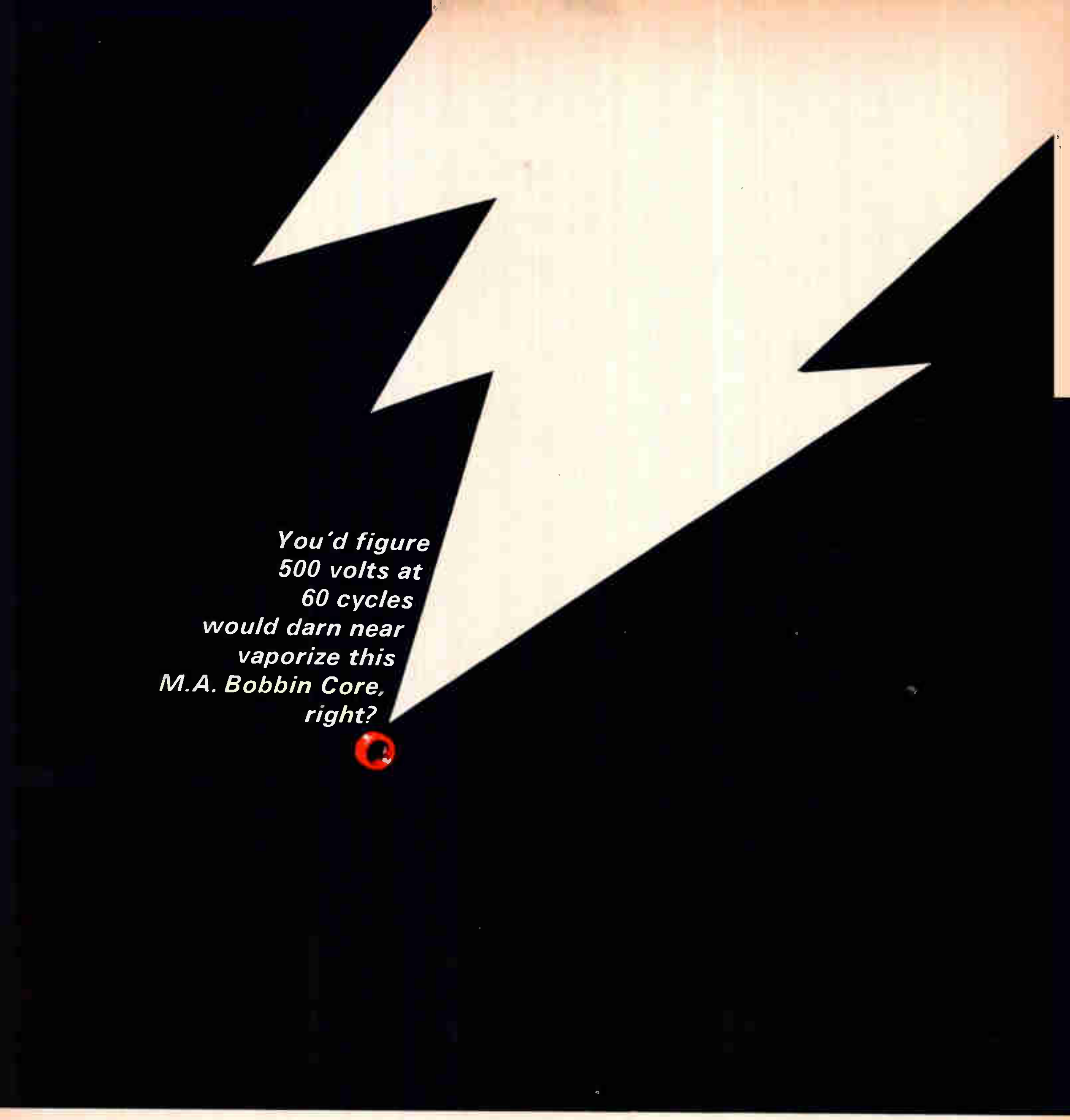
Model 1073 Mag Track—long scale; shielded; positive contact; combines Load Current Contact Aiding with magnetic attraction; self-contained reset; single or double adjustable contacts, ranges from 10 μa.



Model 1930/1940 Photronic—3½" and 4½" in either bakelite or plastic front; low cost; add-on power supply and solid state switching circuit; shielded; non-physical, adjustable contact.

Weston Instruments, Inc. • Newark Division • Newark, N.J. 07114

WESTON® *prime source for precision... since 1888*



Wrong! Its got GVB*. Even at more than 1500 volts, tests show no breakdown on M.A. bobbin cores with GVB. In addition to guaranteeing the core's ability to withstand at least 500 volts between bare winding and bobbin, GVB finish also seals the bobbin to withstand a ten-inch mercury vacuum.

It seals against potting material, provides a resilient, non-slip base for winding, and its epoxy skin protects the core against wire cuts. Abraded wire problems are eliminated and no prior taping is required.

GVB has proven itself on thousands of cores . . . and now Magnetics has applied it to the bobbin core, the miniature workhorse of computers, high frequency counters, timers, oscillators, inverters and magnetic amplifiers.

Made from ultra-thin permalloy 80 and Orthonol® (0.001″ to 0.000125″), Magnetics' bobbin cores are available in tape widths from 0.023″ to 0.250″ or wider on request. Core diameters range down to less than 0.100″ with flux capacities down to several maxwells.

For more information on GVB Bobbin Cores, write Magnetics Inc., Dept. EL-42, Butler, Pa. 16001.

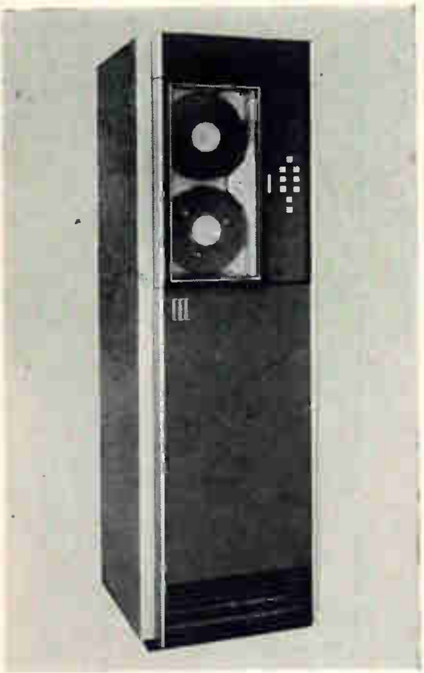
MAGNETICS inc.®

**Guaranteed voltage breakdown*

Circle 59 on reader service card

If you consider the cost... and the performance... and the versatility...

you won't consider any other.



For this is CEC's DR-3000 — the first truly universal digital magnetic tape system. It offers unequalled performance and versatility — at the lowest cost of any comparable digital tape system available today.

The DR-3000 series is designed to cover the full range of tape speeds and computer compatibility.

The following advantages sum up the reasons why this system has become the obvious choice for so many digital data processing requirements.

Compatibility. The DR-3000 will guarantee complete machine compatibility with any other DR-3000, or with any IBM-compatible tape system operating within IBM specifications. A complete selection of IBM-compatible accessories is available.

Operator convenience. The DR-3000 is the easiest of all to load due to a straight tape-loading path which requires no threading.

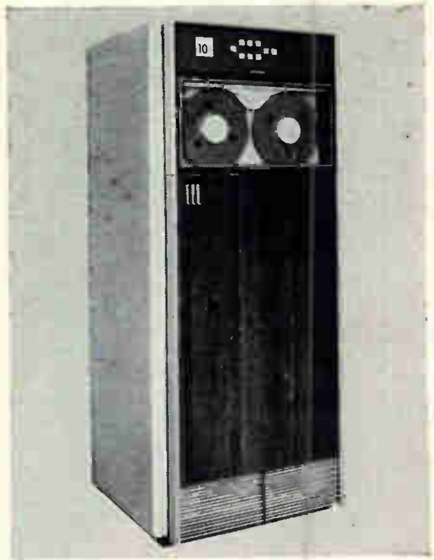
The entire operation takes less than 10 seconds. CEC's patented self-locking reel hubs with quarter-turn action provide fast, positive reel retaining. Front access only is required for all normal maintenance.

Formats. 7-channel 729 series or 9-channel 2400 series formats are standard, reading and writing at 200, 556, or 800 bpi — plus 1600 bpi phase-encoded format available on special order.

Versatility. High, medium, or low speed units feature major interchangeability of parts. The most compact system made, it will mount 2 or 3 to a rack—even fit through a submarine hatch. It is available in horizontal or vertical cabinets. Rugged construction for semi-mobile environments. It provides a complete selection of input/output logic levels. The DR-3000 is the ideal unit for most commercial or laboratory data processing systems.

Reliability. Only field-proven design concepts are used. Dual capstans with rugged drive actuators provide positive accurate drive. There are no belts or mechanical linkages to cause tape slippage or creep. Tape drive actuators are self-aligning for minimum skew and do not need adjusting. CEC-built all metal-front-surface read/write heads have achieved *over 12,000 hours* operational life in field environments. All electronics are modular and solid state.

Performance. The DR-3000 assures the most performance per dollar available today. Fast start/stop characteristics provide complete unrestrictive programming, high speed rewind. Air bearings virtually eliminate tape friction. Average steady state tape speed variations are less than ± 0.5%.



Transport Specifications:

Standard ½" tape, 7 or 9 channels • Tape speeds — 37½, 75, or 112½ ips • Standard IBM formats • Operates at 200, 556, 800 bpi NRZ or 1600 bpi phase-encoded (on special order) • Start time —less than 4 msec • Stop time — less than 3 msec • Rewind — 2400 feet in less than 2½ minutes • Bit dropout rate less than 1 in 10^7 • Maximum total skew — within full IBM machine-to-machine compatibility at all speeds • Average tape speed accuracy — within ± 0.5% of absolute • Cycling rate — 200 commands-per-second without programming restrictions • Power —1 kva • Size — 19" x 24½" x 13½" • Weight — 135 lbs.

For complete information about the DR-3000, call CEC or write for Bulletin 3000-X10.

CEC
Data Instruments Division

CONSOLIDATED ELECTRODYNAMICS

A SUBSIDIARY OF BELL & HOWELL/PASADENA, CALIF. 91109
INTERNATIONAL SUBSIDIARIES: WOKING, SURREY, ENGLAND AND FRIEDBERG (HESSEN), W. GERMANY

NEW MICROTRANSFORMERS AND MICRO-INDUCTORS

MIL-Spec Reliability, Laminated-Core Efficiency in a ¼-inch Cube!

Now — microtransformers and micro-inductors created especially for tight, hi-rel military/aerospace environments. The new Bourns Models 4210 and 4220 exceed the environmental requirements of MIL-T-27B and the transformer-reliability specifications of MIL-T-39013!

In performance, too, these models hit new highs. They are the only units to give you the efficiency of laminated-core construction. At 1000 cps the insertion loss is less than 3db. In high-frequency operation, the model 4210 is dramatically superior to the smallest solid-core units available. In square-wave operation, droop is as low as 5%, overshoot as low as 10% and rise time as little as 100 nanoseconds. In every performance category, Models 4210 and 4220 give you the industry's highest ratio of performance to size.

Like Bourns potentiometers, the 4210 and 4220 are subjected to the intensive testing of the exclusive Bourns Reliability Assurance Program. The big "B" on the cover means there's a full measure of reliability in the package.

We specialize in winding custom microtransformers and micro-inductors to meet your exact requirements, and we substantiate performance in our qualified test laboratory.

Write today for complete technical data!

Standard Specifications, Model 4210 and 4220

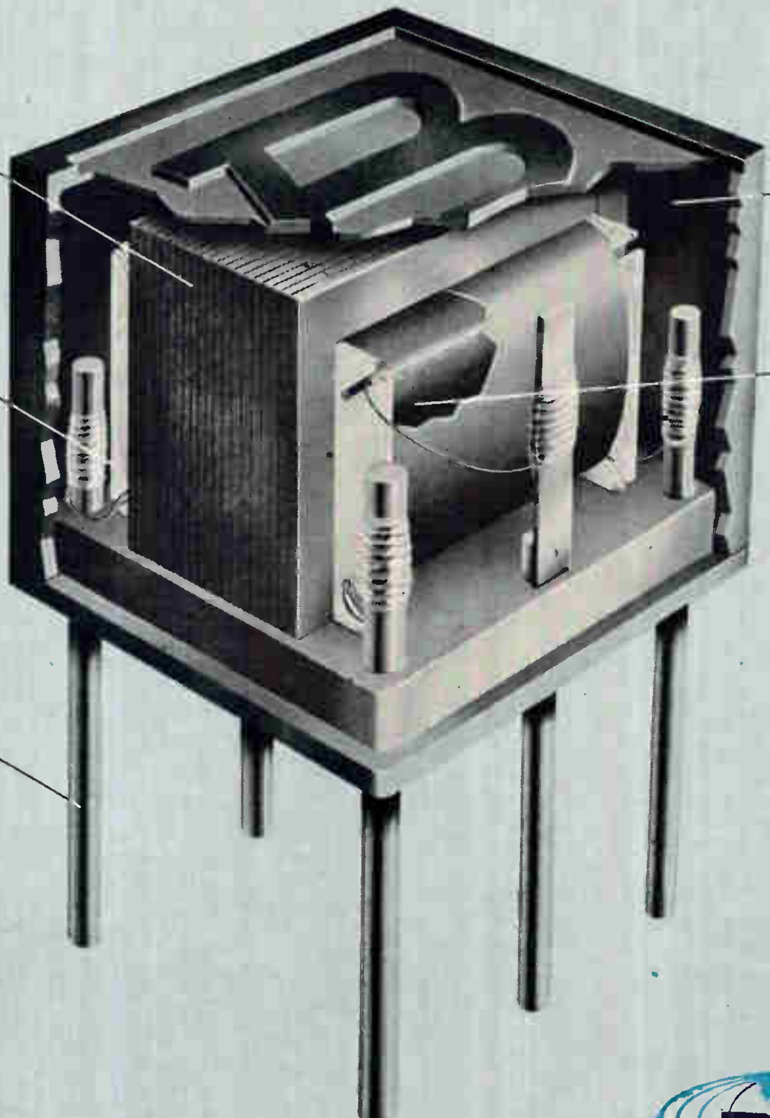
Size: .25" x .25" x .25"
Maximum operating temp.: +130°C
Frequency response: —2db, 400 cps to 250 kcps (Model 4210)
Power rating: 1 watt at 10KC (Model 4210)
Insertion loss: 3db max. (Model 4210)
Primary impedance range: 100Ω to 200KΩ (Model 4210)
Secondary impedance range: 3.2Ω to 10KΩ (Model 4210)
Turns ratios: to 15:1 (Model 4210)
Inductance range: .08 to 66 Hy (Model 4220)
MIL-Specs: designed to exceed MIL-T-27B and MIL-T-39013

Units shown actual size

Bourns Model 4210 Microtransformer

Bourns Model 4220 Micro-inductor

Standard Models available from stock!



BOURNS INC.

BOURNS, INC., TRIMPOT DIVISION
1200 COLUMBIA AVE., RIVERSIDE, CALIF.
PHONE 684-1700 · TWX: 714-682 9582
CABLE: BOURNSINC.

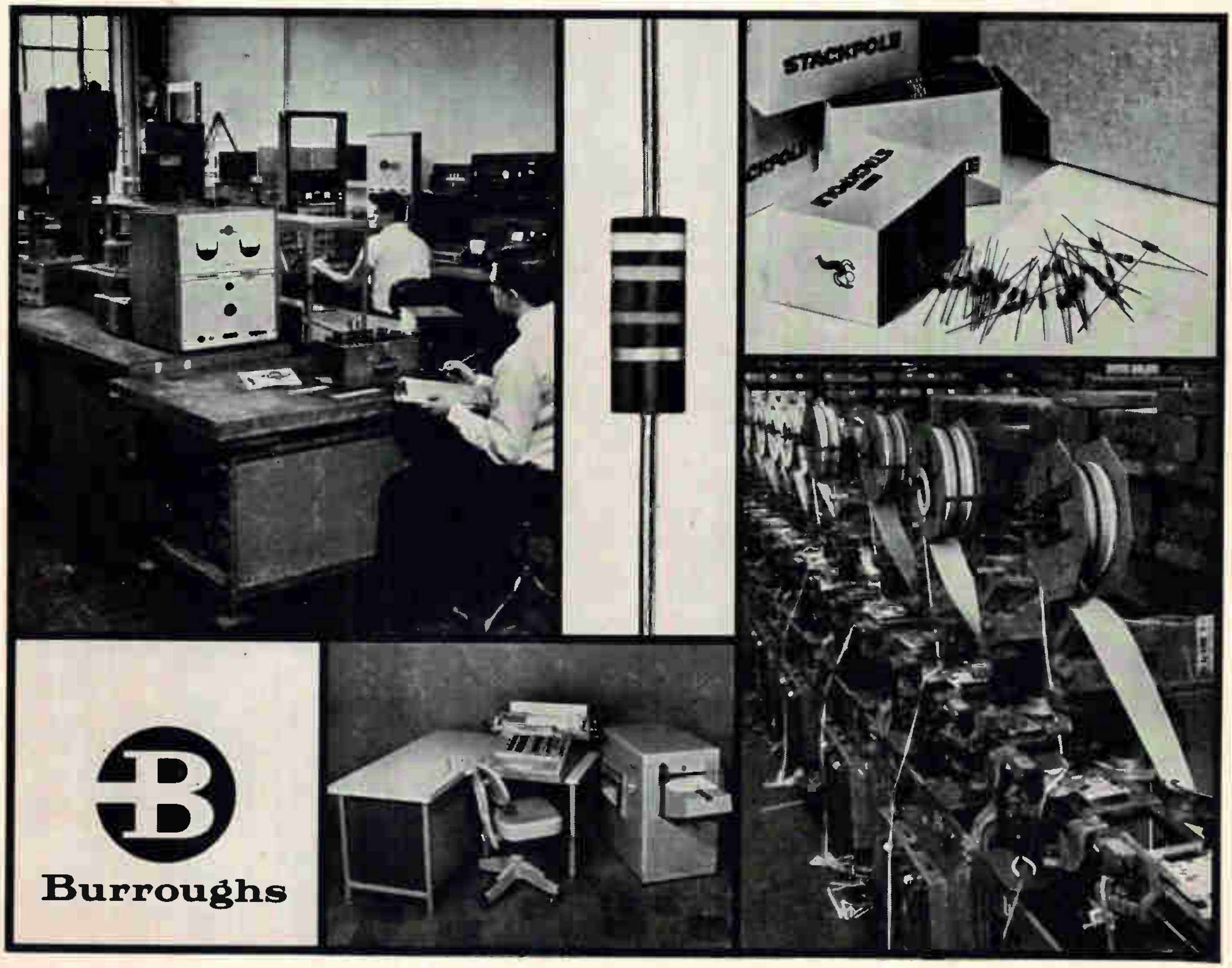
TRIMPOT® AND PRECISION POTENTIOMETERS — RELAYS — MICROCOMPONENTS: TRANSFORMERS, INDUCTORS, RESISTORS AND CAPACITORS

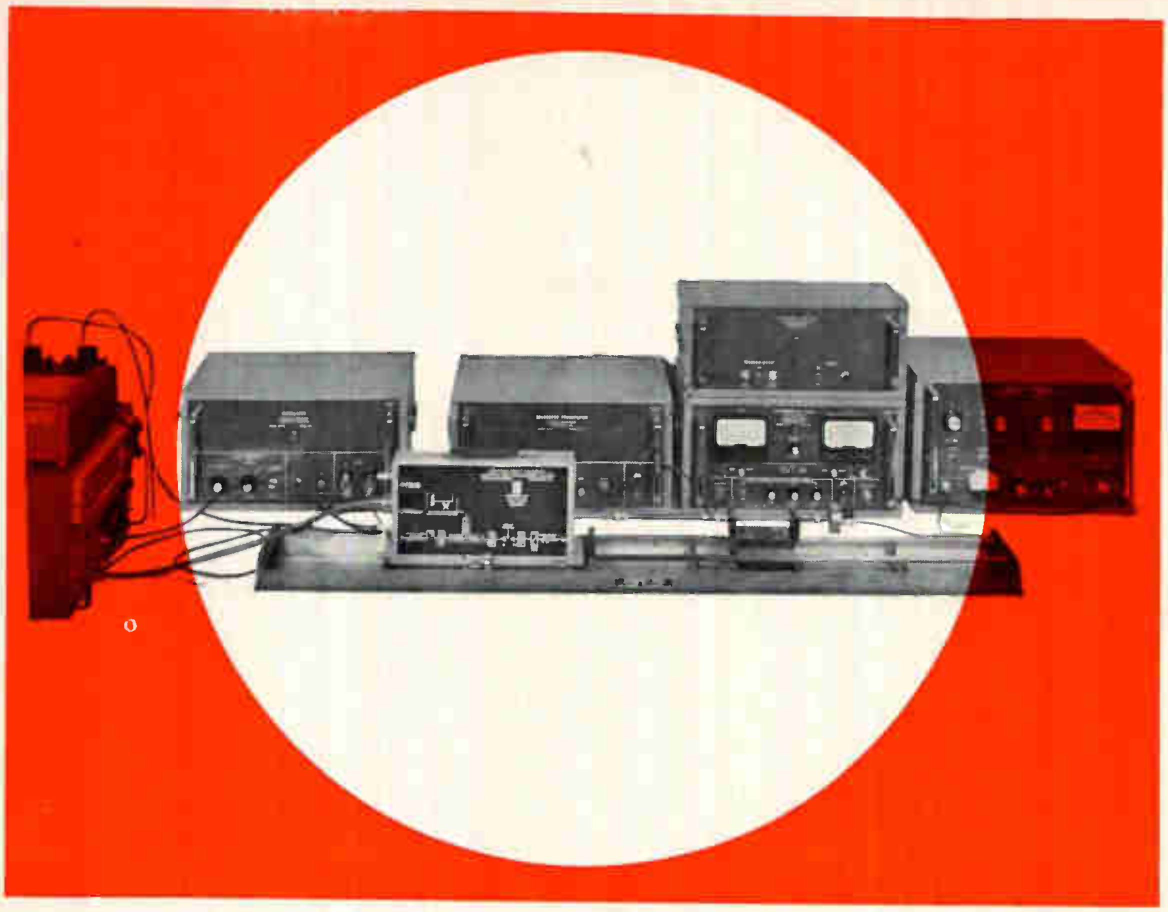
Six months of evaluation testing by Burroughs engineers revealed four things about Stackpole commercial resistors.

Quality, performance, value and service.

STACKPOLE
ELECTRONIC COMPONENTS DIVISION

At their Plymouth, Michigan, Evaluation Testing Laboratory, Burroughs engineers put Stackpole resistors through the paces. What they discovered was a commercial resistor that more than matched their demanding requirements. Stackpole commercial resistors are manufactured carefully and backed by prompt delivery and service. Such attention to quality assures trouble-free machine or hand assembly and lifetime operation. These are but several reasons why Burroughs selected Stackpole commercial resistors for use on their E 2100 Direct Accounting Computer. Dependability, performance and accuracy are essential to Burroughs. Stackpole, too. For the full added-value story, write: Stackpole Carbon Company, Electronic Components Division, Kane, Pa. 16735.





A HIGH RESOLUTION SWEPT-FREQUENCY INSERTION LOSS MEASUREMENT SYSTEM... WITH FIXED FREQUENCY MEASUREMENT ACCURACY

Now, in an adaptation of the widely accepted ₩ Dual Channel Insertion Loss Measurement System, Weinschel Engineering offers swept-frequency measurement of insertion loss to accuracies associated up to now only with fixed frequency measurements. The new ₩ 1850 system greatly speeds precise insertion loss measurement of microwave component characteristics over octave ranges.

For use in coaxial systems, the ₩ 1850 has available 4 microwave heads for octave ranges for use with an instrument package composed of proven ₩ Dual Channel System Instruments. Existing ₩ Dual Channel System Instruments can be adapted for use in the ₩ 1850 Swept System. Use of the dual channel arrangement with the selected and matched RF components composing the microwave head permits resolution of .02 db/cm for small dynamic ranges and accuracies of .02 db for small insertion loss values. Insertion loss variations are displayed on a graphic recorder.

For additional information or a demonstration of the ₩ 1850 System contact your local Weinschel sales engineer or Weinschel's home office.

SPECIFICATIONS

IMPEDANCE: 50 ohms

FREQUENCY RANGE: 0.5—12.4 Gc (4 bands)

SIGNAL: 100% square wave modulated at 1 kc

INSERTION LOSS RANGE: Up to 30 db

SYSTEM ACCURACY (includes resolution and repeatability):
.02 db for values to 1 db
.03 db for values to 10 db
.05 db for values to 20 db
.07 db for values to 30 db

MAXIMUM DYNAMIC INSERTION LOSS VARIATION: 6 db

RESOLUTION: to 0.02 db/cm for small dynamic ranges

SENSITIVITY: Variable to ± .005 db

STABILITY: > 0.01 db/hr.

VSWR AT INSERTION POINT:
<1.05, 0.5— 4.0 Gc
<1.1, 4.0—12.4 Gc

INSERTION POINT CONNECTORS: Type N (other connectors available)

REQUIRED ACCESSORIES: Sweep Oscillator and recorder

PRICE:

Model 1850E—Instrument Package (Includes BA-1D, BA-5, MO-1C, MB-1, ND-2 Mod., ND-2Z, and interconnecting cables) $4,900.00

Model 1850-1
0.5—2 Gc Microwave Head $2,090.00

Model 1850-2
1.0—4 Gc Microwave Head $2,090.00

Model 1850-3
4.0—8 Gc Microwave Head $2,090.00

Model 1850-4
8.0—12.4 Gc Microwave Head $2,090.00

DESIGNERS AND MANUFACTURERS OF PRECISION MICROWAVE EQUIPMENT

WEINSCHEL ENGINEERING

GAITHERSBURG, MARYLAND
TEL.: 301/948-3434
TWX: 301-926-3730

SANTA MONICA, CAL., 1318 Second St.
TEL.: 213/394-1154
TWX: 213-879-0490

Circle 65 on reader service card

HOW CAN YOU BEAT ODDS LIKE THESE IN FINDING THE DISPLAY LIGHT YOU WANT?

You're looking for one very special display light or switchlite. Control Switch makes over 2,900...the broadest line you can tap at any one manufacturer. Check the items below for an idea of our diversification. Then . . . get a real reference file by sending for all the literature listed.

Goof-proof Switchlites

One to four lamps and colors. Four-lamp Quadlite* monitors up to nine conditions by combining flashing and steady lights. All re-lamping from front. Extra compact designs. Round lenses from ⅝" diam.; square units from ⅞". Over 1,800 styles in all.

See literature offer—Bulletin 54-A, 55-C, 63.

World's tiniest indicator lights

Type L10,500 (top), only .200" diam. L10,600 (center), only .383" diam. and L10,400 (bottom) only .219" diam. Operating life, 16,000 hours at 28 v; 60,000 hours at 5 v. All with 100% moisture-proof integral lamp and lens assembly molded to stainless steel assembly. Available with RFI radiation shielding. (See RFI item at right).

See literature offer—Bulletin 60

Multi-color indicator lights

From two to four lamps and colors. Four-lamp Quadlite* monitors up to nine conditions by combining flashing and steady lights. Twinlite* monitors two conditions simultaneously in different colors. All re-lamp from front. Choice of five colors, plus clear. Compact for tight, symmetrical stacking.

See literature offer—Catalog 120

See-able billboards

Over-sized. Two lamps for extra clarity. Operators get the message for sure. Captive lens housing can't be reversed or interchanged. Single or split lens. Split lens can be any of six colors, lighted independently. Choice of 6, 14, or 28 v incandescent or 115 v neon. Press-to-test types included.

See literature offer—Catalog 120

*Trademarks

Single lamp/color indicator lights

Virtually every size and type you could want. Subminiatures with lenses as small as 0.200" diam. and cases to fit holes as small as 13/32" diam. Types include edge-lit, water-tight, moisture-proof, back or front panel mounting, press-to-test and others . . . even lighted legends and numerical read-outs!

See literature offer—Catalog 120

RFI-shielded indicator lights

New! Especially designed to reduce RFI and EMI emission from filaments of lamps in otherwise well-shielded panels. Metal mesh in lens attenuates emissions in the important 0.15 to 1,000 mc range. Special conductive gasket provides electrical conductivity between shield and case in removable lens types. Standard sizes with 115 v neon lamps, subminiatures with long life 5 or 28 v incandescent lamps.

See literature offer—Bulletin 62

Human engineering advances for extra safety

Control Switch designers are deep into human engineering for the development of switch and light features that take the guesswork out of panel equipment operation. Advances include a broad range of toggle, pushbutton and special-actuator switches as well as switchlites and indicator lights. Write us about your specific needs.

Get this complete literature packet

You are welcome to any or all of the literature listed here. If you get the complete set, you'll have the handiest, most comprehensive light reference file available from any single source. Just check numbers on the Reader Service Card as shown for each item at the right.

Reader Service Card #	
450	Integral Switchlite Bulletin 63
451	Twinlite Bulletin 55-C
452	Indicator Light Catalog 120
453	RFI-shielded Light & Switch Bulletin 62
454	Quadlite Bulletin 54-A
455	Light and Switch Condensed Catalog 100
456	Subminiature Indicator Light Bulletin 60

CONTROLS COMPANY OF AMERICA®

CONTROL SWITCH DIVISION

1420 Delmar Drive, Folcroft, Pennsylvania 19032

60% higher surge rating

23% higher current[††]

1400 volts steady state

New 110-AMP thyristor SCR with exclusive Westinghouse CBE design widens your design options. This new Westinghouse Type 254 (JEDEC 2N4361-2N4380 series) thyristor SCR is rated at 110 amps RMS. This makes it an ideal replacement for older thyristors such as the 2N1792 and 2N1909 series. But it can do much more. It can be run at higher case temperatures. You can use a smaller lower-cost heat sink with it. Or you can use it in higher current applications with present sink designs.

Type 254 is ideal for cycling loads. Use it for inverters, motor controls, starters, and primary controlled power systems. Its 1600-amp surge rating, combined with the industry's highest I^2t rating, allows optimum fuse co-ordination. Steady state blocking voltages go through 1400 volts with a 1500 volt transient rating.

Key to these increased high temperature capabilities is Westinghouse's exclusive CBE design. (Compression-Bonded Encapsulation.) It eliminates solder joints. The result: elimination of thermal fatigue and a 30% decrease in thermal impedance. Such features also make possible the ✤ guarantee symbol shown here. It is the symbol that says this device carries the exclusive Westinghouse Lifetime Guarantee.†

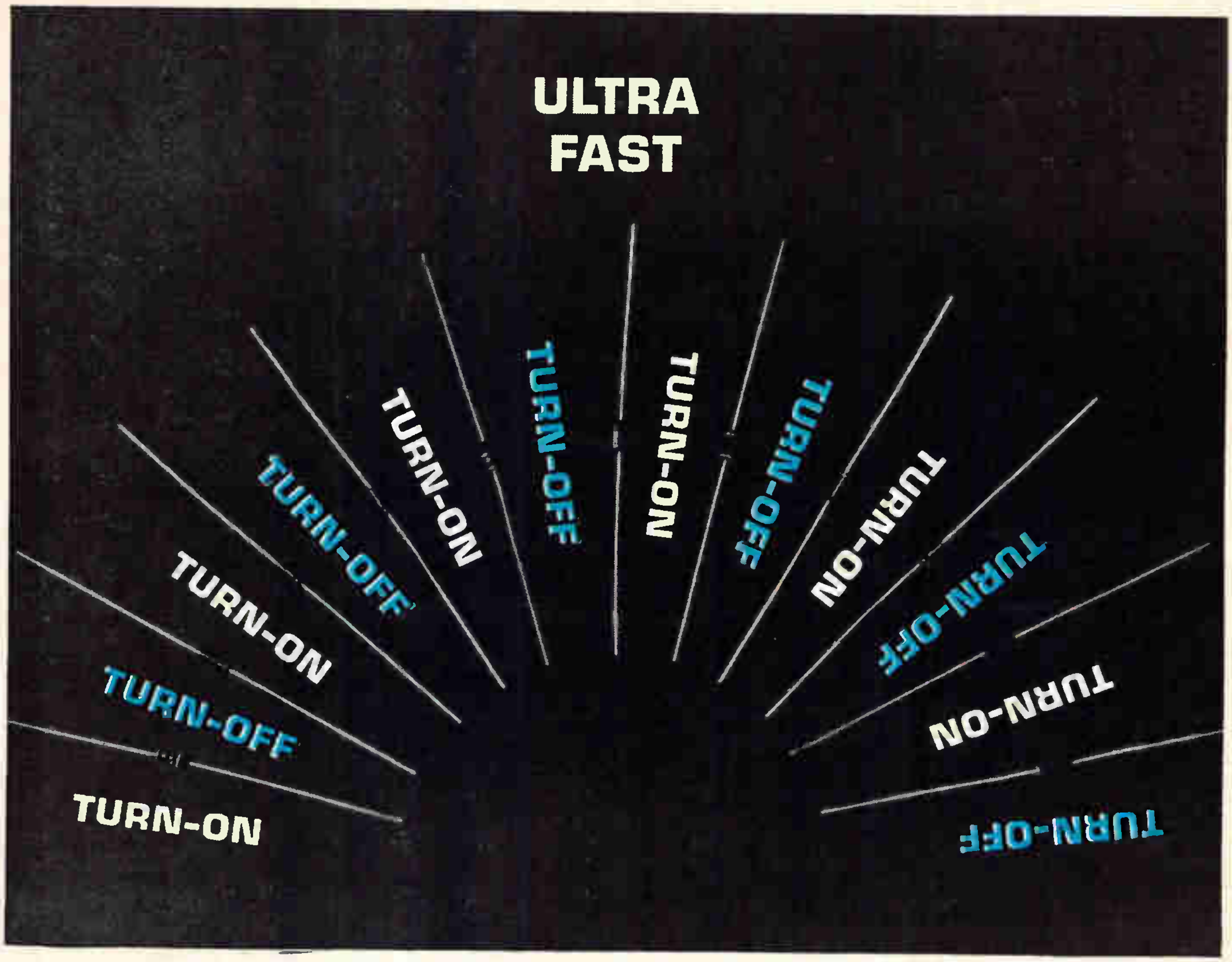
Get all the data on this higher performing thyristor now. Call your Westinghouse salesman or distributor. Ask for Technical Data 54566P3. Westinghouse Semiconductor Division, Youngwood, Pennsylvania. SC-2063

†Westinghouse warrants to the original purchaser that it will correct any defect or defects in workmanship, by repair or replacement f.o.b. factory, for any silicon power semiconductor bearing this symbol ✤ during the life of the equipment in which it is originally installed, provided said device is used within manufacturer's published ratings and applied in accordance with good engineering practice. This warranty shall constitute a fulfillment of all Westinghouse liabilities in respect to said products. This warranty is in lieu of all other warranties expressed or implied. Westinghouse shall not be liable for any consequential damages.

††At 82°C case temperature

You can be sure if it's Westinghouse

Circle 67 on reader service card



specify hot carrier diodes from hpa

For high-speed switching in ultra-fast computers, sampling circuits, test equipment or UHF and VHF mixers and detectors, you owe it to yourself to investigate low-noise, high-reliability 2300 Series Hot Carrier Diodes from hp associates. All devices in this series have minority carrier lifetimes of less than 100 picoseconds. Using the latest advances in metal-silicon technology, these devices offer increased forward current and higher breakdown voltage. Dperating and storage temperature range −60°C to +125°C. Power dissipation at 25°C is rated at 125 mw. Peak pulse power rating is 5 ergs. They also meet the requirements of MIL-S-19500C.

Write today for application information and complete data, including life test data, hp associates, 620 Page Mill Road, Palo Alto, California 94304, Tel. (415) 321-8510.

TYPICAL DEVICE SPECIFICATIONS

Device	Forward Current I_{F_1}	Forward Current I_{F_2}	Breakdown Voltage BV_R	Leakage Current I_R	Capaci-tance Co	Effective Minority Carrier Lifetime* τ	Price 1 to 99 / 100 to 999
hpa 2301 Min.	50 mA	1 mA	30 V				$8.50 ea.
Max.				300 nA	1 pf	100 ps	6.35 ea.
hpa 2302 Min.	35 mA	1 mA	30 V				7.75 ea.
Max.				300 nA	1 pf	100 ps	5.80 ea.
hpa 2303 Min.	35 mA	1 mA	20 V				7.15 ea.
Max.				500 nA	1.2 pf	100 ps	5.35 ea.
Test Conditions	V_F= 1 V	V_F= 0.4 V	I_R= 10 μA	V_R= 15 V	V_R=0 f=1.0 MHz		

*These diodes are too fast to measure in conventional circuits utilizing standard reverse recovery time measurements. Therefore, the effective minority carrier lifetime is specified as τ instead of Trr. Devices are hermetically sealed in a miniature glass package 0.160" long, 0.070" in diameter, color coded.

HEWLETT PACKARD hp HP ASSOCIATES

Circle 69 on reader service card

Semiconductor Report

NEW PRODUCTS, DESIGNS AND APPLICATIONS FROM MOTOROLA

REMEMBER FOUR NEW LOW-COST PNP/NPN TRANSISTORS ...AND YOU CAN FORGET 35 OTHER TYPES!

Here are four, new low-cost UNIBLOC* plastic transistors that offer such broad performance versatility and complete specifications that you can use them to replace some 35 other current types.

For general purpose switching and amplifier service covering all commercial/industrial applications in the 10 to 100 mA range and from audio to 100 MHz frequency range, these four Motorola types, the NPN 2N4123 and 2N4124 and the PNP 2N4125 and 2N4126, cover practically *all* your application requirements!

THESE — 2N4123, 2N4124, 2N4125 and 2N4126 replace all these —		
2N2711	2N3393	2N3845A
2N2712	2N3394	2N3854
2N2713	2N3395	2N3854A
2N2714	2N3396	2N3855
2N2715	2N3397	2N3855A
2N2716	2N3398	2N3856
2N2921	2N3721	2N3856A
2N2923	2N3843	2N3858
2N2924	2N3843A	2N3859
2N2926	2N3844	2N3860
2N3390	2N3844A	2N3900
2N3392	2N3845	2N3901

And, think how this simplifies your transistor selection and inventory control problems, too!

Here are the kind of specs you get with these new performers:

	2N4123/5	2N4124/6
High BV_{CEO}	30 V	25 V
h_{FE} selected to 2 ranges	50-150	120-360
Low saturation voltages — $V_{CE(sat)}$	< 0.3 V	< 0.4 V
Low C_{ob}	4 pF max	4 pF max

In any quantity, the prices are right for economy:	1-99	100-999
2N4123 & 5	$ .52	$ .35
2N4124 & 6	.60	.40

As with all Motorola plastic transistors, you get the added assurance of rugged Unibloc transistor construction — the solid, single-piece, pressure-molded package that offers unusual physical strength for internal leads and connections, plus improved heat transfer characteristics . . . the package doesn't leak ever!

One other point, they have Motorola's patented "annular" device structure which assures you maximum reliability and stability.

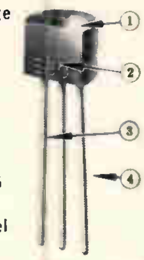
Your local Motorola district office or franchised distributor have units available for immediate evaluation. For complete technical details, write: Technical Information Center, Motorola Semiconductor Products Inc., Box 955, Phoenix, Arizona 85001.

HIGH SPEED LOW-COST NPN LOGIC SWITCHES CHARACTERIZED ON "DESIGNERS" DATA SHEET

A pair of new low-cost NPN plastic Unibloc transistors have been characterized with limit curves which are directly applicable to "worst case" saturated switching circuit designs — giving sufficient information to permit the design engineer, in most cases, to design entirely *from the data sheet alone!*

The devices (types 2N4264 & 65) are specified in a Motorola Designers Data Sheet* at both 10 mA and 100 mA levels and feature a very low storage time of 20 nsec. Although they offer the economy of plastic devices (prices range from \$.40 to \$.45 in 100 quantities), the units offer performance matching that of other higher-priced units. For example:

The Rugged "UNIBLOC" Package



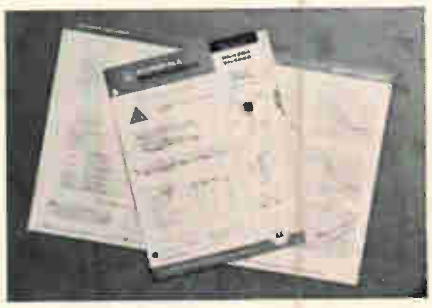
① "Unibloc" package eliminates use of separate preformed header and poured cap

② "D" shape lays flat for easy PC board mounting

③ In-line leads easily adaptable to TO-18 or TO-5 lead pin circle

④ ½-inch, gold-plating nickel leads permit reliable solder connections

	2N4264	2N4265
BV_{CEO} (@ 1 mA)	15 V	12 V
h_{FE} min(@ 10 mA)	40	100
f_T min (@ 10 mA)	300 MHz	300 MHz
Output Capacitance	4 pF	4 pF
Input Capacitance	8 pF	8 pF
Turn-On (@ 10 mA)	25 nsec	25 nsec
Turn-Off (@ 10 mA)	35 nsec	35 nsec



DESIGNERS DATA SHEET SHOWS "WORST-CASE" LIMIT CURVES

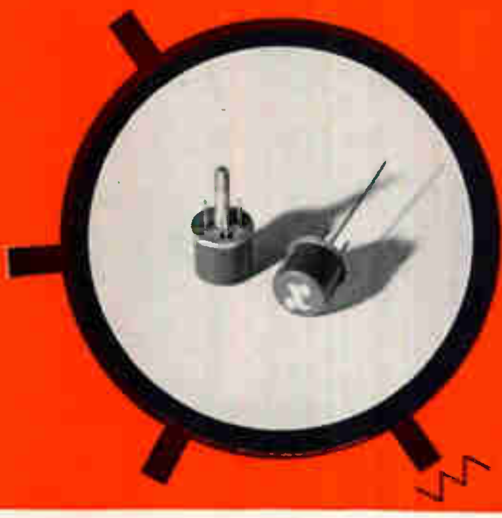
In addition, the rugged, high-pressure, single-piece molded-plastic encapsulation of Unibloc devices provides a uniform, dense and solid package, free of voids (and leaks). Also, they feature Motorola's exclusive "annular" device structure for optimum reliability.

For more information on these high-performance, fully-specified, low-cost devices, circle the reader service number below.

*Trademark of Motorola Inc.

MOTOROLA Semiconductors

—where the priceless ingredient is care!



40 to 400 Mc in a single SUBMIN PLUG-IN hybrid

Taking Advantage of Printed Circuit RF-ology

The submin plug-in ISO-T's above are the first of a new generation of Adams-Russell hybrid devices which permit taking practical advantage of PC-board RF-ology. Other submin plug-in hybrids, frequency converters, phase-shifters and null-T's will soon be available for use as circuit elements in much the same way that transistors are now used. The Adams-Russell ISO-T's above (MTV-50) are reduced in size for packaging in a standard TO-5 case. Units are available with either ground-pin leads or with ground studs for use with printed circuit test boards.

Lead Length Limitation

Because Adams-Russell submin plug-in hybrids are so broadband (Figure 2), their connections to the circuit are a very important consideration in obtaining maximum performance. In high frequency circuits the problems associated with lead lengths are often a limiting factor. When the actual hybrid circuitry is immediately introduced into a transmission line of the proper characteristic impedance, the full potential of the hybrid circuit performance would be available. Practically, this can be most nearly accomplished by connecting the output leads of the submin plug-in package into strip-transmission line with the shortest possible lead length. As feed-through leads of the header are 50 ohms impedance, and these feed-throughs are connected directly into matched transmission line, there is only a minor discontinuity at the interface.

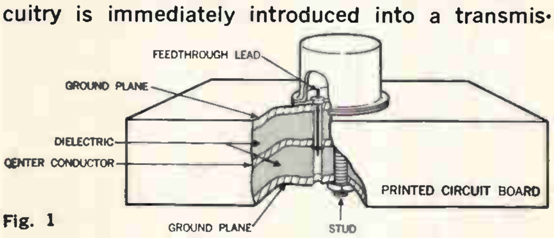


Fig. 1

If, for mechanical reasons, a short lead is not feasible, then the series inductance of the leads must be taken into account in circuit performance. This lead inductance may be compensated for by a shunt capacity, but in so doing, the cutoff frequency of the ensuing lowpass filter must be considered.

A threaded stud, also supplied on MTV-50 units, provides the ground for all input and output leads. (For non strip transmission line applications, a center pin ground is available.) The stud must be connected to the ground plane in the transmission line to complete the RF circuit. Figure 1 shows the recommended procedure for utilizing the full potential of the Adams-Russell submin plug-in ISO-T and other hybrid devices in PC-board and strip transmission line circuits. Deviations from this procedure are, of course, allowable as long as the resultant degradation of performance is acceptable. At lower frequencies lead length is of lesser importance.

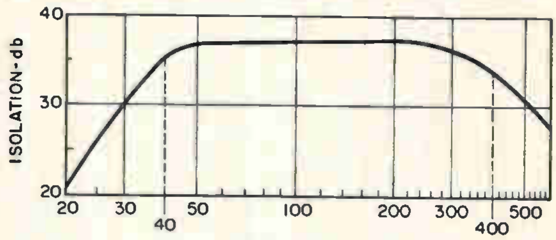


Fig. 2

The conservatively rated specifications below are typical values based on standard, submin plug-in, ISO-T's.

SPECIFICATIONS

Frequency Range	40-400 Mc	Amplitude Balance*	0.1 db (max.)
Insertion Loss	0.5 db (max.)	VSWR	1.3 to 1
Isolation	30 db (min.)	Impedance	50 ohms
Phase Balance*	1.0° (max).		

*Differences measured between isolated ports

Diameter	3/8"	Weight	2 grams
Height	11/32" excl. pins	Lead length	3/16" (max.)
		Stud	2-56 thread

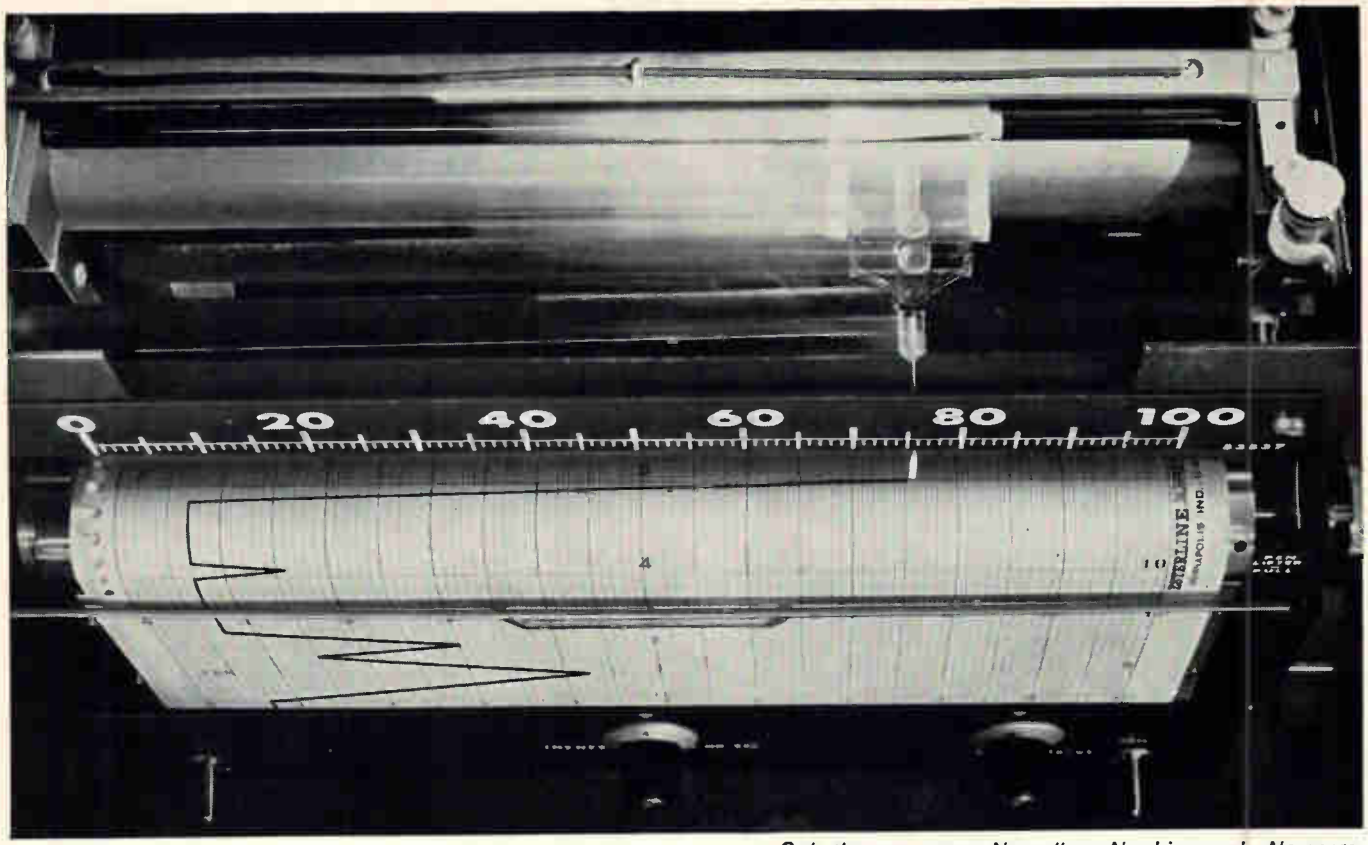
Submin Plug-ins Enroute

Other submin plug-in hybrid devices are on the way from Adams-Russell. Your inquiry will bring price and delivery information, plus the assurance that you'll be among the first to know when they arrive.

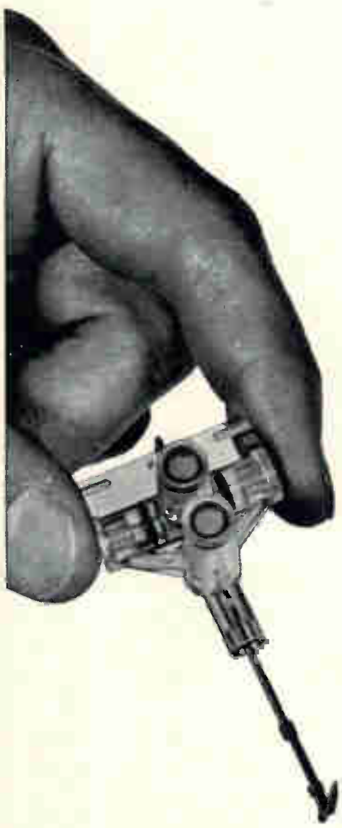
ADAMS-RUSSELL CO., INC.
280 BEAR HILL ROAD • WALTHAM, MASSACHUSETTS 02154
(617) 899-3145

EXPORT SALES — Technical Resources, Inc. • 600 Main Street • Waltham, Mass.

Circle 71 on reader service card



Only the pen moves. No pulleys. No drive cords. No gears.



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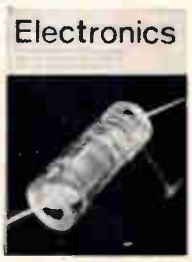
Technical Articles

New twist for backward diodes: help from low-noise amplifier: page 74

As microwave mixers and detectors, backward diodes exhibit superior noise performance over conventional point contact diodes. But the inherently low impedance of the device at intermediate frequencies is a frustrating problem. Now, a three-stage amplifier has been developed that makes backward diodes completely compatible with the requirements of doppler radar systems.

Many colors are better than one: page 84



A single laser beam actually contains light of many colors simultaneously. The device shown on the cover—a voltage-tunable Q-spoiler—provides a way to select and control any one color of the multicolor laser beam. Coupled with a digital beam deflector, this capability permits new methods of high density data storage and brighter display systems.

Harmonic testing pinpoints passive component flaws: page 93

Based on the principle that internal flaws produce nonlinear effects in all types of components, a fast, nondestructive testing method has been developed. The new technique can detect failure-producing defects that elude conventional component-screening procedures.

Ultrahigh-speed IC's require shorter, faster interconnections: page 103

If digital systems are to benefit fully from hard-won increases in circuit speed, wiring delays between circuits must be reduced. Shorter wiring is only a partial solution—attention must also be given to overcoming crosstalk, which occurs in various forms in high-speed systems.

Coming July 25

- **Holography: a versatile research tool**
- **Design innovations in a new oscilloscope**
- **Welding IC's to etched nickel boards**

New twist for backward diode: help from low-noise amplifier

Design enables diodes to function as mixers and detectors in microwave systems despite problems of low impedance at intermediate frequencies

By Russell O. Wright

Solid State Products Operation, Philco Corp., Spring City, Pa.

A new amplifier goes a long way toward solving a frustrating problem in designing microwave systems: how to take advantage of the superior noise performance of backward diodes as mixers and detectors while overcoming their very low impedance at intermediate frequencies.

The amplifier has already been designed into the landing radar on the lunar excursion module (LEM) of the Apollo program. Potentially, it could find widespread use in high reliability systems of minimum size and cost.

The need for the amplifier is spurred by the increasing use of backward diodes in continuous-wave doppler radar systems, where the intermediate output frequency ranges from 1 kilohertz to 100 kilohertz. A major advantage of the diode is its very low inverse frequency (l/f) noise, compared with that of conventional point-contact diodes. Use of this capability, however, requires an i-f amplifier which exhibits a low-noise figure at the required frequency while operating into impedances ranging from 40 to 400 ohms.

At audio i-f's (frequencies below 100 khz) the problem is especially severe, since the magnetic effects of impedance transformers may cause critical errors in doppler systems.

The high-output impedances of vacuum tube circuits made it impossible in the past to operate into low source resistances without transformers.

Transistor circuits compatible with low source resistances exist, but the base resistance values of the transistors make it difficult to achieve low-noise figures with source resistances on the order of 100 ohms. In addition, without careful design, the optimum source resistance for a fixed emitter current and the optimum emitter current for a fixed source resistance will differ significantly.

To obtain low-noise figures at frequencies below 1 Mhz for source impedances ranging from 50 to 100 ohms, the transistor selection and circuit design criteria differ from those of conventional amplifiers. Transistors must have low base resistance and high beta values at low emitter current levels, which correspond to low l/f noise. Furthermore, the emitter operating current level must be compatible with the expected low source resistances. The new amplifier design was based on these considerations.

3-stage amplifier

The circuit of the amplifier, shown on page 75, is being produced in two forms: with conventional discrete components and as a hybrid integrated circuit. The amplifier was designed with more than one feedback path to reduce output impedance and improve gain. The design goal for the output impedance was 100 ohms. As it turned out, the circuit was capable of providing impedances as low as 2 ohms.

The i-f amplifier contains three direct-coupled pnp silicon transistors. The first two stages are

The author

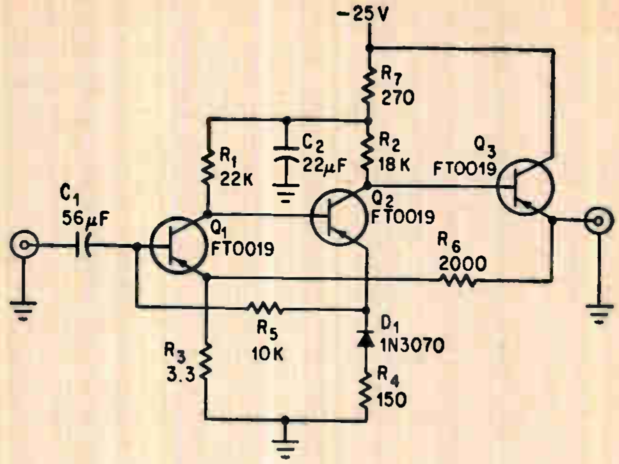
Russell O. Wright has worked in microwave applications since joining Philco in 1958. He is manager of the microwave department and is responsible for the development and production of microwave diodes and other microwave components.

common emitter circuits; the third transistor is used as an emitter follower. The d-c bias point and amplifier voltage gain are determined by two feedback loops. The bias point is stabilized by the first feedback loop, consisting of R_4 and D_1 in the emitter circuit of transistor Q_2, which provides the base bias voltage for Q_1 through R_5. The loop provides d-c feedback and also temperature compensation because the effect of variation on the voltage drop across D_1 essentially cancels the base-to-emitter voltage shift of Q_1. The a-c gain established by the loop for Q_1 and Q_2 must be in excess of the over-all required gain. The over-all amplifier voltage gain is determined by the second feedback loop consisting of R_6 and R_3. The amplifier voltage gain A_v is principally determined by the ratio of R_6 to R_3 or:

$$A_v \simeq \frac{R_6}{R_3}$$

Because the amplifier gain as determined by the first loop is not infinite, the actual gain is somewhat lower than calculated from the equation. The gain will vary slightly with temperature because of changes in the a-c resistance of D_1.

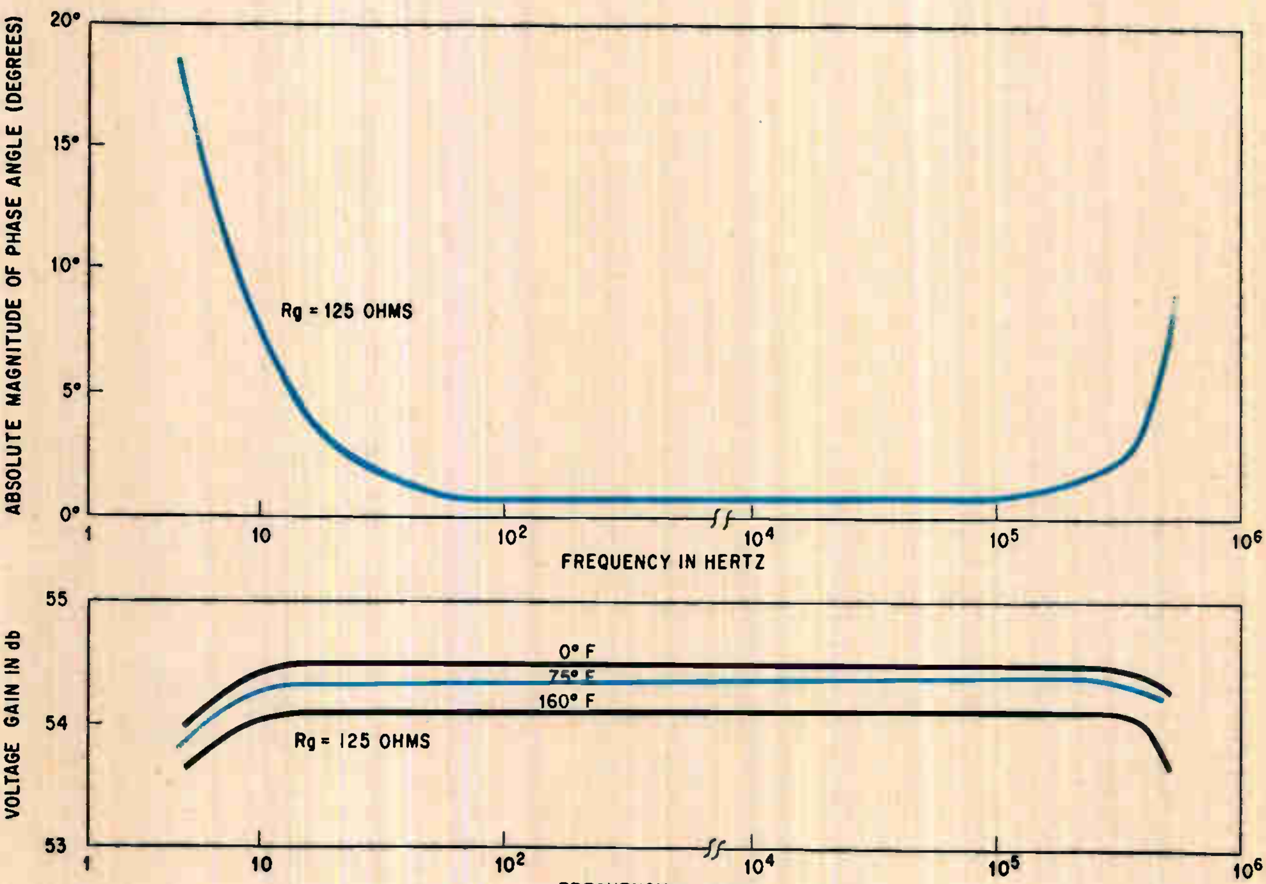
The over-all amplifier gain may be varied by adjusting the value of R_6. Increasing R_6 produces an increase in gain and a decrease in the emitter current of Q_3. Any variations in resistor R_3 would affect the noise figure of the amplifier.



Three-stage intermediate-frequency amplifier has low-noise and low-output impedance. These characteristics make it ideal for use with mixers and detectors which utilize backward diodes.

Many high-sensitivity microwave receivers use balanced receiver circuits. In them, both amplifier sections must be matched over a given range of operating conditions. A high degree of gain and phase matching was obtained for two amplifiers built without any attempt to match components.

As is demonstrated below, over the frequency



Voltage gain and phase shift versus frequency. From 5 hertz to 350 khz the voltage gain is essentially constant. The indicated phase shift is caused by the input-coupling capacitor.

range of 5 hertz to 350 khz the voltage gain of a single amplifier stage is flat to within 0.3 db when the nominal room-temperature gain is 54.3 db. Variation from 0°F to 160°F results in a gain variation of only 0.3 db. The low-frequency phase shift is entirely due to the input-coupling capacitor, since the amplifier itself is direct-coupled. The high-frequency phase shift is attributable primarily to the collector-to-base capacitance of Q_2.

From the curves atop page 77 showing the amplifier gain as a function of source resistance, it can be deduced that the input impedance is approximately 2.2 kilohms. The impedance is determined by the values of the components in the two feedback loops. The first loop, or d-c control loop, tends to reduce the input impedance; the second loop tends to increase it. The actual impedance is the result of the combined effect. If desired, the impedance may be increased by increasing R_5; this will also produce some change in the temperature compensation of the d-c bias. Under no circumstances does the distortion level exceed —47 db at the maximum required output voltage of 2.8 volts rms. The distortion measurements reflect a fairly high impedance load.

The output voltage level is limited by the emitter current of Q_3. The peak output voltage swing cannot exceed the static d-c output level of the preamplifier, typically 4.8 volts at room temperature. Also, the peak output current cannot exceed the emitter current of Q_2.

Noise figure

Of greatest interest is the noise figure as a function of source resistance at an audio frequency level. The test frequency chosen was 10 khz. To

Why backward diodes?

Both the Nike X and Apollo systems find a place for the unique properties of the backward diode. In Nike X, it solved the need for a temperature insensitive detector diode for a pump level control in a parametric amplifier. Apollo's lunar excursion module (LEM) relies on a landing radar which employs the c-w doppler principle for the velocity-sensing and altimeter functions. Only backward diodes could meet the required low-noise figure.

The microwave backward diode is an alloy-junction device that operates on the principle of quantum mechanical tunneling. In the comparison figure at the right the negative resistance of tunneling devices is evident. In microwave applications, its circuit components are designed to permit stable operation in the negative resistance region. By appropriate biasing, the devices can be used as oscillators or amplifiers.

In a tunnel diode operating as a frequency mixer, the negative resistance is used to achieve conversion gain. However, good stability and low-noise performance are difficult to obtain at high frequencies.

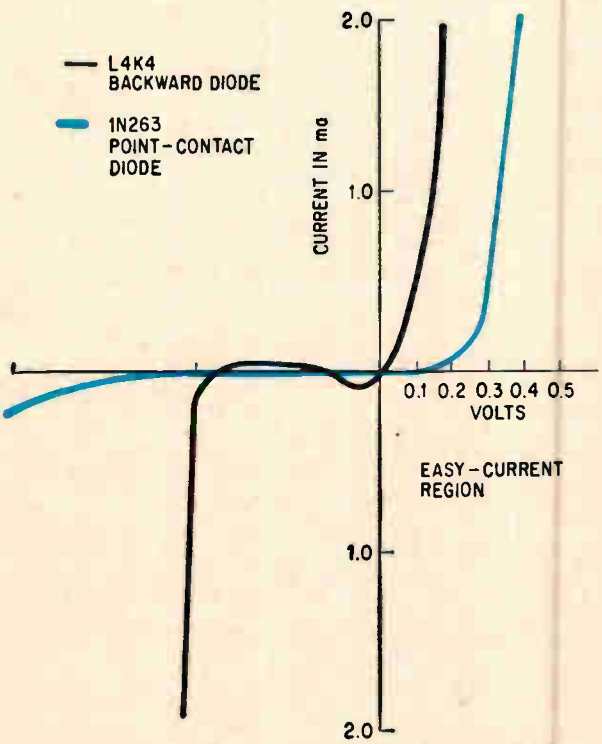
If the peak current of the tunnel diode is reduced to 50 microamperes or less, the value of the negative resistance increases. However, the magnitudes of the values of the circuit components required to achieve amplification or sustain oscillation become impractical.

However, the diode can still be used for mixing or conversion, although without gain, if operated in its positive resistance mode. At low peak current, it behaves like a conventional diode, except that the current-voltage characteristic is reversed—hence the name "backward" diode.

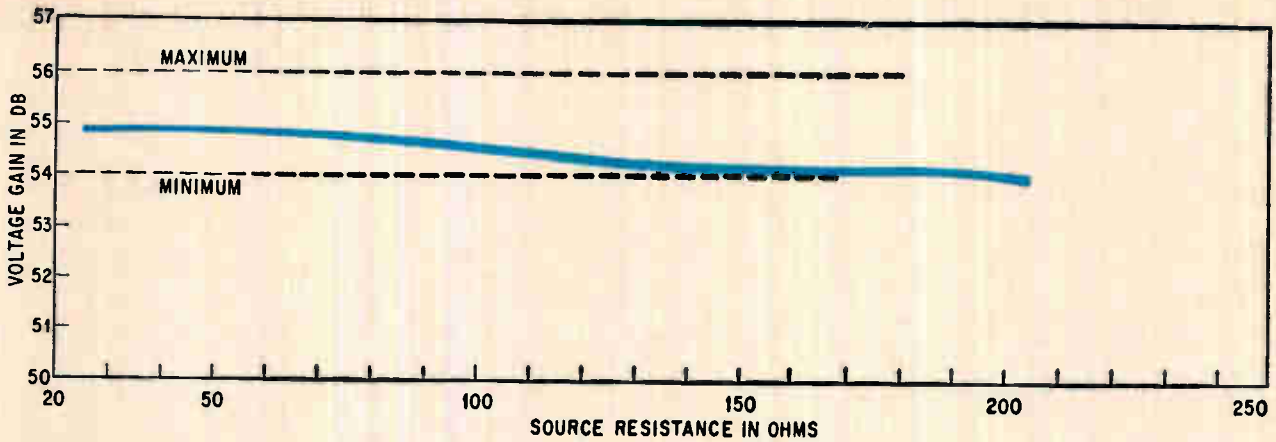
Inherently, the diode has higher current sensitivity than conventional point-contact diodes. Also the backward diode is operated near zero bias, where the parasitic junction capacitance in the diode is near minimum value. The conventional diode operates best at a condition of slight forward bias, where the junction capacitance is increasing. The backward diode can thus tolerate a higher junction capacitance at zero bias than can a conventional diode at high frequency.

One of the backward diode's major advantages is its very low 1/f noise. As a result, backward diodes permit the design of simplified c-w doppler systems where the transmitter and receiving frequencies are identical, with noise figures near those of conventional superheterodyne systems. This is an important characteristic in velocity-sensing and altimeter applications.

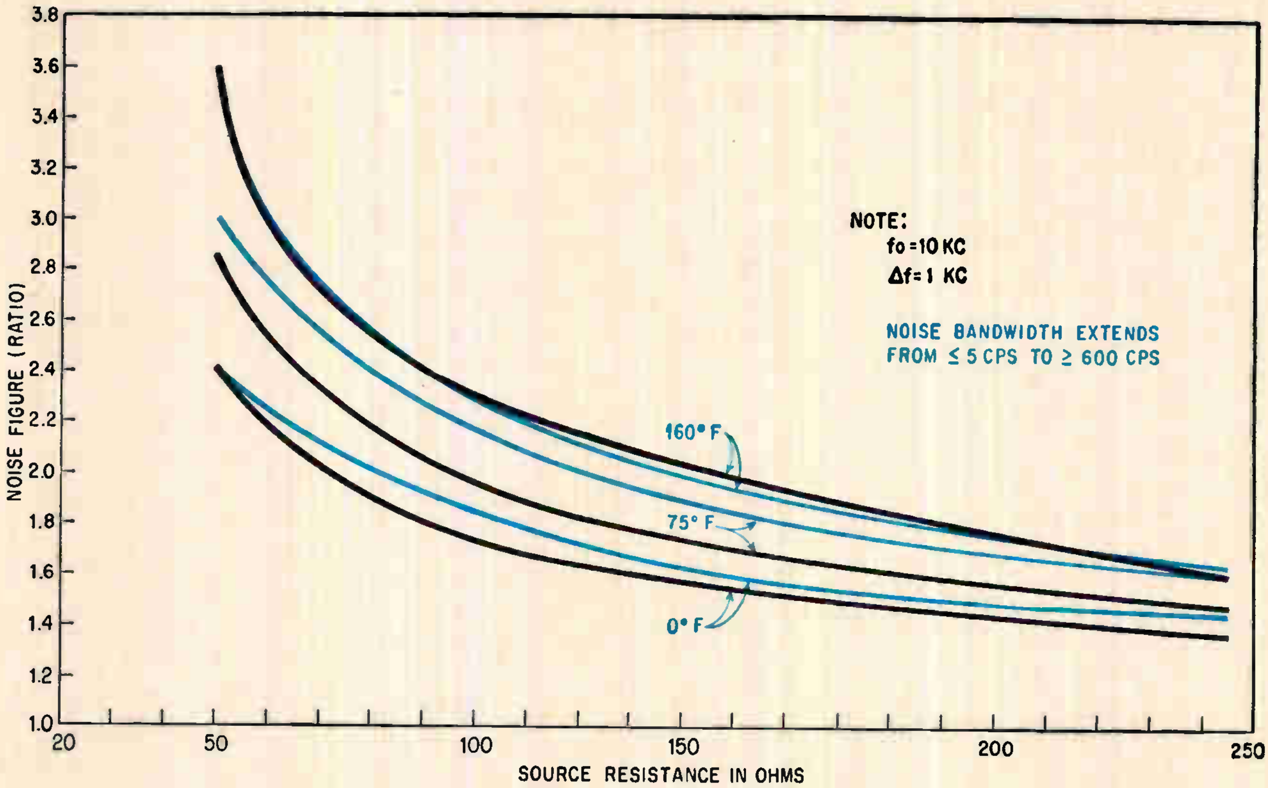
The diode's very low i-f impedance is its major disadvantage. To utilize the backward diode effectively in velocity sensing and altimeters, it is necessary to have an amplifier that can work directly into low impedance and still have low noise figures. The amplifier described here was designed expressly to answer this need.



Comparison of backward diode and conventional diode current-voltage characteristics. Easy direction of current flow for the backward diode occurs at negative bias, opposite to behavior of point-contact diode.



Voltage gain for the amplifier circuit drops off as source resistance increases.



Narrow-band and wideband noise figures of the amplifier as a function of source resistance at three operating temperatures. The wideband noise figures (color) are slightly higher. Narrow-band figures never exceeded the design goal of 2 at less than 140°F.

simulate operating conditions, the performance as a function of temperature from 0°F to 160°F was measured, as shown in the graph above. Measured were a narrow-band or spot-noise figure at 10 khz with a 1-khz bandwidth and a broadband figure with a bandwidth extending from 5 hertz to 600 khz. At the nominal source impedance of 125 ohms, the noise-figure ratio at 10 khz varied from 1.62 to 2.18 as the temperature varied from 0°F to 160°F. The design goal was a noise-figure ratio of 2 (3 db), which is achieved at 125 ohms for all temperatures less than approximately 140°F. At room temperature and below, the ratio does not exceed 2 for source resistances of greater than 95 ohms.

The wideband noise-figure tests gave results close to those obtained at 10 khz, typically with a slightly higher noise figure.

Normal room temperature and liquid-nitrogen temperature—achieved with the resistor enclosed in liquid nitrogen in a dewar flask—are convenient test conditions. For accuracy, the room-temperature resistance source must be operated in an oven at a controlled temperature above ambient.

To reduce size, the amplifier can be built with hybrid integrated-circuit techniques.

A hybrid amplifier is ideal where it is necessary to combine the preamplifier and the mixer diode in a single package close to the receiving antenna. The signal-processing circuits in the i-f system can then be separated from the antenna without cable losses.

Circuit design

Designer's casebook

Designer's casebook is a regular feature in Electronics. Readers are invited to submit novel circuit ideas, packaging schemes, or other unusual solutions to design problems. Descriptions should be short. We'll pay $50 for each item published

Triangle waveform generator resets automatically

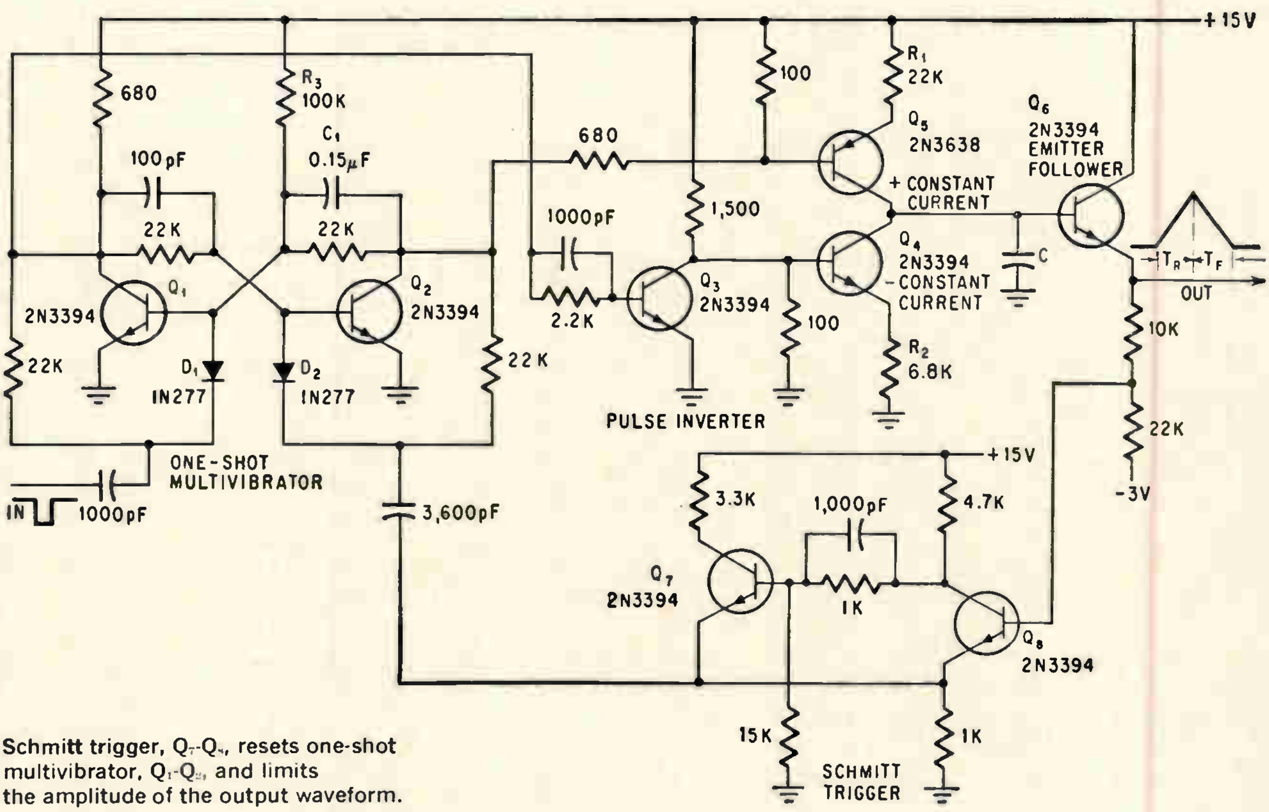
By Robert G. Teeter

RF Communications, Inc., Rochester, N.Y.

For synthesizing waveforms of predetermined shape, a triangular wave generator is very useful. The circuit of a generator which produces a single triangular pulse each time it is triggered externally is shown below. The output pulse has constant peak amplitude with no flattening and independently adjustable rise and fall times.

When an input pulse has triggered the one-shot multivibrator, Q_1-Q_2, to change state; the pulse appearing on the collector of Q_2 triggers Q_5 full on and the capacitor C charges. This linearly increasing ramp is buffered by the emitter follower Q_6 to minimize loading effects. When the increasing ramp reaches approximately 6 volts peak, the Schmitt trigger Q_7-Q_8 fires, coupling a pulse to the one-shot multivibrator. The multivibrator flips, turning off the positive constant current source Q_5, and turning on the negative constant sink Q_4. This action linearly discharges the capacitor and the circuit is ready to repeat the cycle. The time constant of the one-shot multivibrator is made much longer than the output triangle width. This assures that the one-shot is always in the proper initial state to accept the input pulse.

Resistors R_1 and R_2 can be varied to control the rise and fall times respectively. If the capacitor, C, is set at 0.01 microfarad, R_1 and R_2 can be varied to produce rise times (and fall times) from 100 to 900 microseconds. With R_1 at 22K ohms, R_2 at 6.8K ohms and C at 0.01 μf, the rise and fall times are both 800 μsec. With these values, the input pulse repetition rate can be varied from 20 to 50 pps without distorting the waveform.



Schmitt trigger, Q_7-Q_8, resets one-shot multivibrator, Q_1-Q_2, and limits the amplitude of the output waveform.

High MOS impedance benefits pH measurement

By Daniel J. Soltz

Honeywell, Inc., Industrial Division, Fort Washington, Pa.

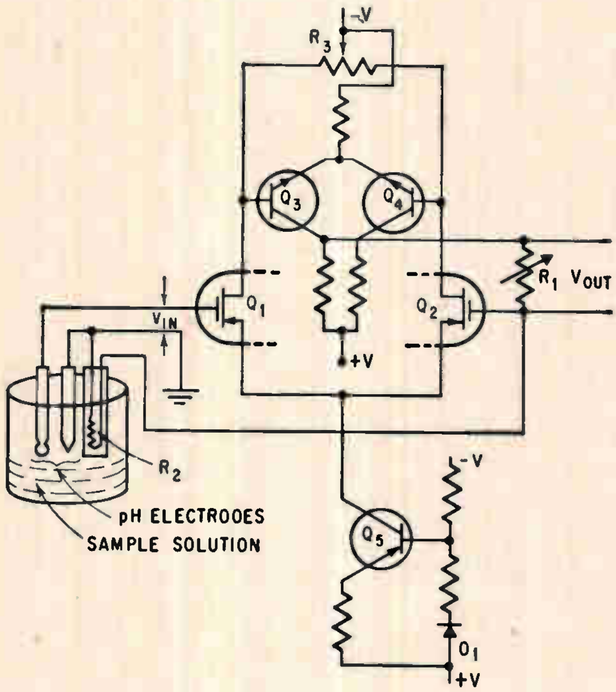
The extremely high input impedance and stability of metal oxide semiconductor (MOS) field effect transistors permits design of a simple solid state amplifier to aid in the measurement of the alkalinity-acidity content (pH) of solutions. Because it is small, the amplifier, with its input impedance of 10^{14} ohms, can be built right into the pH measuring electrodes. The amplifier output impedance is less than 5,000 ohms; consequently, readings may be obtained through long cables.

The very high input impedance is obtained by the use of commercially available dual MOS-FETs on a single chip. The devices are p-channel enhancement types connected in a differential mode for amplifier stability. Gate leakage current, usually a problem in junction-type FETs with temperature changes, is much lower in MOS-FETs at room temperature and remains constant as temperature increases.

Transistor Q_5 forms part of a constant current source which fixes the operating bias of Q_1 and Q_2. Diode D_1 compensates for Q_5's base-emitter voltage variations with temperature.

In the output stage of the amplifier are two matched npn silicon transistors, Q_3 and Q_4, connected differentially to form a symmetrical load for the input stage. Over-all amplification, A, essentially is a function of resistors R_1 and R_2, so

$$A = \frac{\text{volts out}}{\text{volts in}} = \frac{R_1}{R_2}$$



In the **pH amplifier** the high input impedance of MOS transistors Q_1 and Q_2 approximately matches the impedance of the standard pH electrodes. Potentiometer R_1 adjusts the amplifier gain and R_3 zeros the amplifier output at a pH of 7, pure water's acidity-alkalinity.

the gain can be adjusted to any value from 0 to 10 by changing R_1. R_2 is a temperature-dependent resistor which, when immersed in the sample solution, compensates proportionately for variations of the electrode temperature. The input signals are about 60 millivolts per pH unit. The pH unit scale varies from 0 to 14. A pH of 7 corresponds to 0 output volts and the amplifier output is adjusted to this value by potentiometer R_3. The voltage is positive below a pH of 7 and negative above it.

AND gate protects system should the voltage fail

By Alan Shapiro

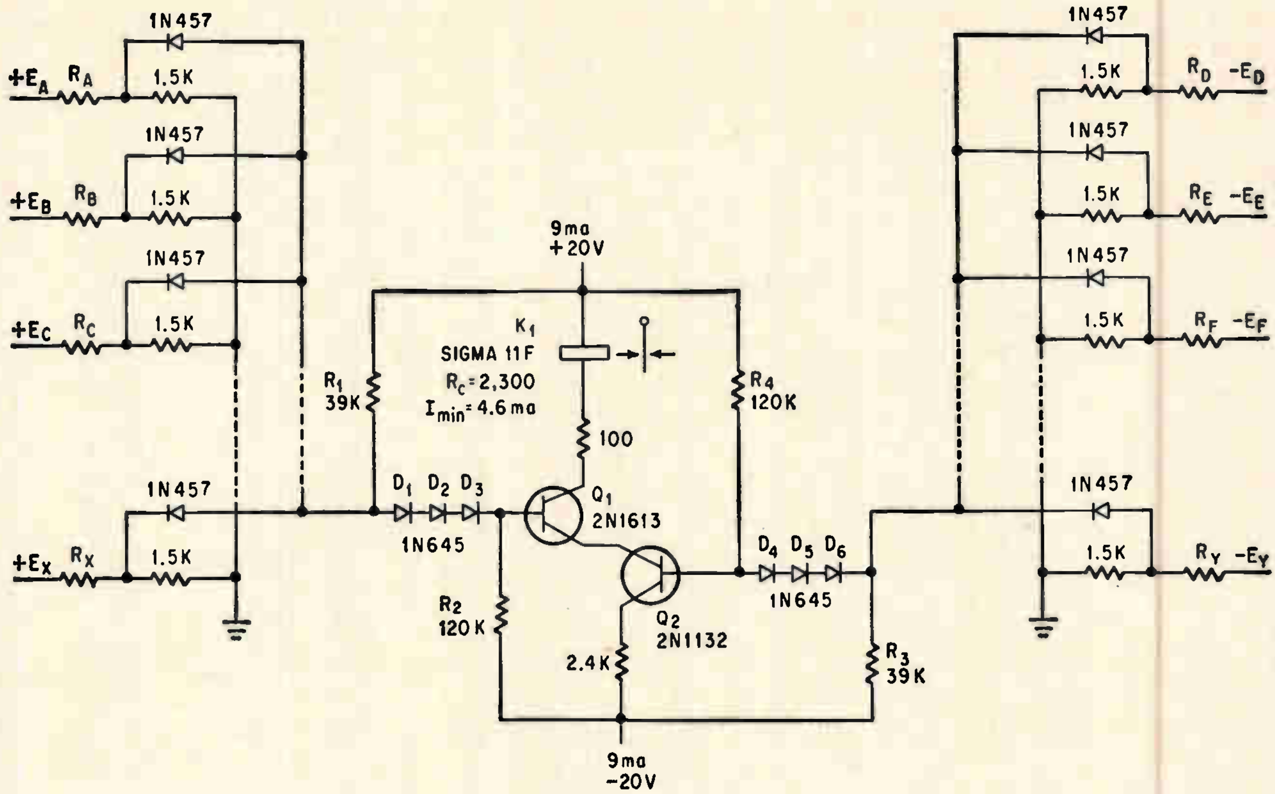
Beta Instrument Corp., Newton Upper Falls, Mass.

If a critical voltage supply fails, this simple AND circuit detects it and energizes an interlocking relay to prevent damage to the system's components. The circuit draws only 2 milliamperes from each monitored voltage source, which may be as small as 3 volts, and of either polarity.

Values of resistors R_A through R_Y are chosen so that 2 milliamperes flow through each 1.5-kilohm resistor. This reverse-biases each of the associated diodes D_A through D_Y. Base current of the transistors Q_1 and Q_2 is sufficient to saturate them and energize the relay, K_1. R_2 and R_4 act as bleed resistors which keep diodes D_1 and D_6 forward biased.

Should one of the monitored voltages fail, the corresponding diode becomes forward biased, and the voltage at the anode of D_1 or the cathode of D_6 drops to about one volt. This cuts off either Q_1 or Q_2 and the relay becomes deenergized, opening the interlock circuit.

If the —20-volt supply for the AND circuit



Simple circuit monitors d-c voltages of either polarity. As long as all the voltages are present, the relay is kept energized. But if one voltage should be absent, Q_1 or Q_2 is turned off and the protective relay is opened.

should fail, the high impedance presented to the emitter of Q_1 cuts it off. Similarly, Q_2 cuts off if the +20-volt supply fails.

The circuit's response time is the sum of the relay actuation time and the voltage decay time. The voltage decay time can be reduced significantly by adding a zener diode in series with the corresponding dropping resistor, R_A through R_Y. The zener voltage should be less than the difference between 3 volts and the value of the voltage to be monitored.

The number of circuits that can be monitored is limited by the sum of the leakage currents through the 1N457's. When this exceeds approximately 100 microamperes, the transistors Q_1 and Q_2 may remain on under any conditions.

Low-cost strobe built with scr in trigger

By Arthur C. Eberle

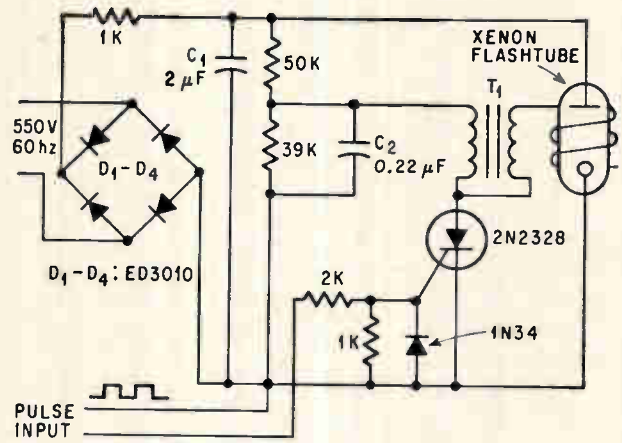
Columbia Gas System Service Corp. Columbus, Ohio

By using a silicon controlled rectifier in the triggering circuit, a low-cost general-purpose stroboscope can be made by modifying an automobile engine-timing strobe. The unit is triggered by low-powered transducer pulses and can be built for one-quarter the cost of a commercial laboratory strobe.

A timing light with a xenon-filled flashtube mounted in a pistol grip housing can be purchased for about $20 with a built-in power supply adequate to drive the strobe synchronizing circuit. After the circuit is mounted inside the housing, the modification is completed by wrapping 10 turns of No. 18 bare copper wire around the flashtube. One end of the wire is connected to the secondary tap of the photoflash transformer, T_1, and the other end is left unconnected. The finished unit in its gun-type housing is more easily handled than conventional strobes which are often bulky.

In the circuit, capacitors C_1 and C_2 are charged by the power supply to about 500 and 200 volts respectively. An incoming pulse causes the scr in the triggering circuit to fire, discharging C_2. The resulting surge of current produces a 6-kilovolt pulse at the secondary of T_1. This ionizes the xenon gas in the flashtube, providing a conductive path through which C_1 discharges, and a 100-microsecond flash of light is produced. The ringing of T_1 and C_2 turns off the scr, preparing it for the next pulse.

A special feature of this circuit is its ability to respond to low-power pulses; it was initially designed to be triggered by a photodiode when commercial strobes proved to be too insensitive. It can be triggered by a 10-microsecond pulse of 3-volt amplitude at a current of 5 milliamperes. An input of 25 pulses per second is possible before the photoflash transformer saturates and the circuit ceases to respond. Tests of response time made with a IN2175 photodiode showed a circuit delay of about 10 μsec and a flash duration of 100 μsec.



Incoming pulse triggers the scr discharging C_2 into T_1, producing a 6-kilovolt pulse to ionize the gas. C_1 then discharges, producing a 100-μsec flash of light.

Series gating reduces components in counter

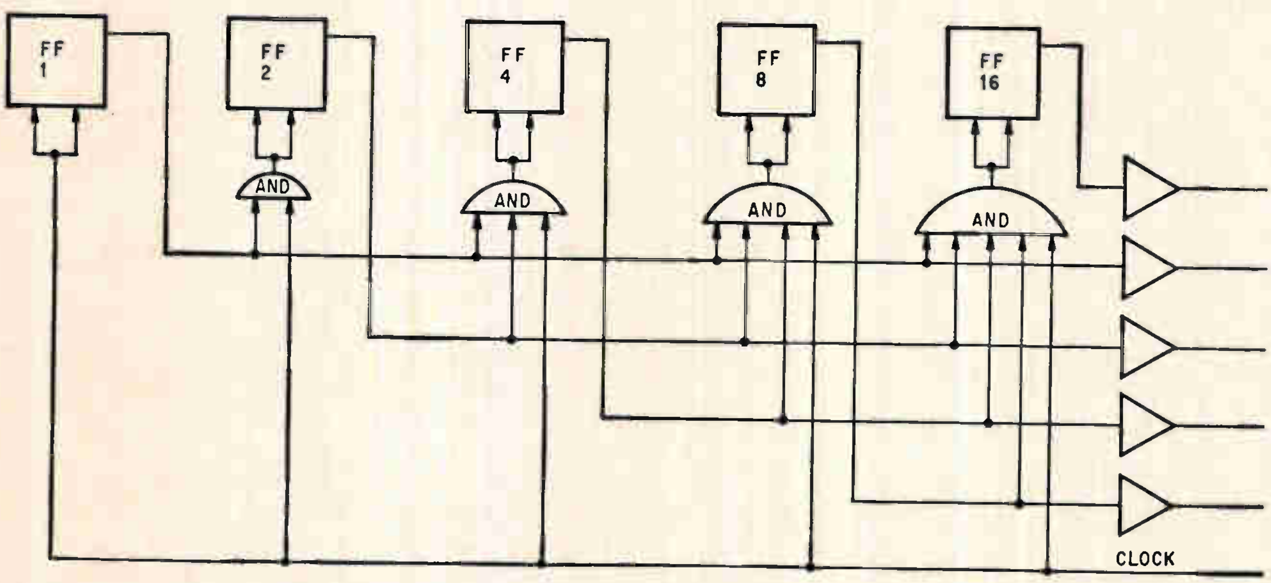
By Robert C. Sanford

Electrac, Inc. Anaheim, Calif.

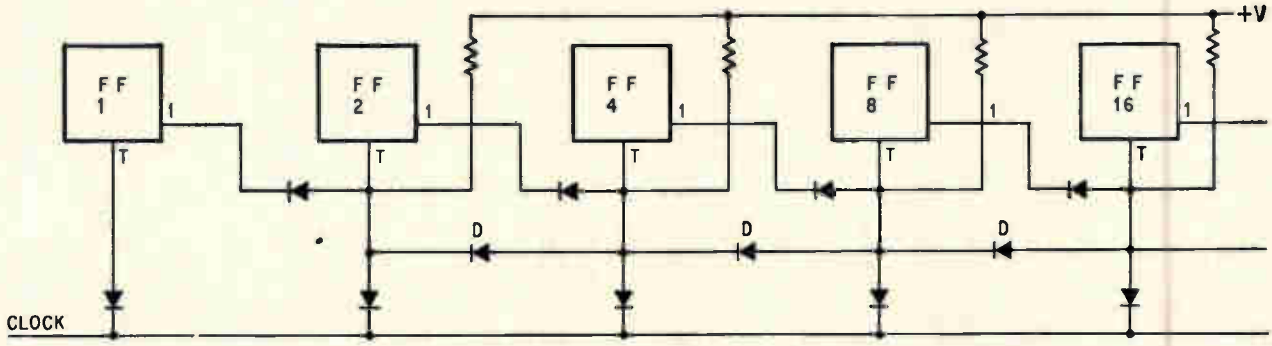
Parallel binary counters are used in computers or other applications where the delay time of a conventional counter cannot be tolerated.

In the standard parallel-gated counter shown below, counter logic prohibits any flip-flop from changing to the logical 1 state unless all preceding bits are in a logical 1 state; each bit must be gated by inputs from all preceding bits. Thus, the most significant bit of a 20-bit counter would be gated by 20 diodes, one for each preceding bit, plus one for the clock. The preceding bit gate would contain 19 diodes, the one before would contain 18 diodes and so on until the second bit, which would contain two diodes. A total of 209 diodes is required. Two-stage noninverting amplifiers would be required in most cases to drive the gates.

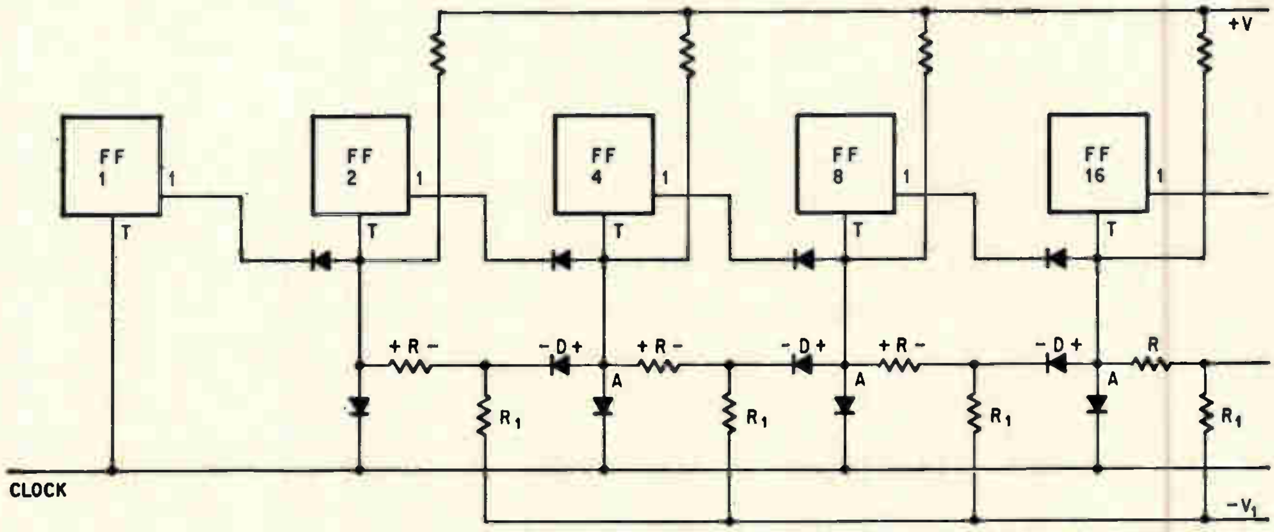
The series-gated parallel counter, on page 82, requires much fewer components than the standard parallel counter. Each flip-flop drives only one



To change the state of a flip-flop to logical 1 in the stand ard parallel-gated counter, each AND gate requires information from every preceding bit, all of which must b e in a logical 1 state.



Cumulative voltage drops across the diodes limits the number of permissible bits in this series-gated parallel counter.



Voltage across resistor R compensates for the drop across series diode D, thereby maintaining a fixed triggering level at point A for each bit. When this compensation occurs point A is at logical zero.

diode in each gate. A 20-bit series-gated parallel counter required 58 diodes and no amplifiers. When each flip-flop is in a logical zero state, it clamps the following stage so that it cannot be set to a logical 1. If the selected flip-flop is in the logical 1 state, but some preceding flip-flop is in the zero state, the zero will be propagated through the series diodes to clamp the succeeding stages to zero.

Voltage divider network R and R_1 above compensates for the series diode voltage drops. Choose resistor values so that the voltage at gate junction A represents a desired logical 1 level. When the voltage at A indicates logical zero, voltage drops across each R and D are equal and opposite.

Unijunction controls spacing between pulses

By Arthur M. Ridenour and Francis Turco

HRB-Singer Inc., State College, Pa.

In a unijunction circuit, it is often desirable to generate a train of pulses with constant pulse width but with variable spacing. To do this a circuit has been designed in which the time between pulses is linearly voltage-controlled over a 20-to-1 range. Unlike other unijunction circuits, the period rather than the pulse repetition frequency is varied linearly in the circuit at the top of page 83.

In the new circuit, the unijunction's trip point and hence the time between pulses is varied by adjusting the voltage V_{CONT}. Until the trip point is reached the output at the 330-ohm resistor will be approximately at the level of the control voltage. When the capacitor charges to the trip point, the unijunction transistor conducts and the output voltage drops. The unijunction immediately turns off and the cycle repeats, generating a pulse every time the unijunction transistor momentarily conducts.

During the nonconducting portion of the cycle the output voltage V_o is

$$V_O = V_{CONT} \frac{R_{B1} + R_{B2}}{R_2 + R_{B1} + R_{B2}} \quad (1)$$

where R_{B1} and R_{B2} are the unijunction's base-1 and base-2 internal resistances such as in the lower schematic on the right. Since $R_{B1} + R_{B2}$ is generally much larger than R_2, the output is approximately at the level of the control voltage. When the unijunction conducts, R_{B1} becomes very small and the output voltage drops to

$$V_O = V_{CONT} \frac{R_{B2}}{R_2 + R_{B2}} \quad (2)$$

Since R_{B2} is usually larger than R_2, the output voltage at this time will be above ground potential.

Linear control over pulse period is held by charging the 10-microfarad capacitor with a constant current source consisting of the zener diode and transistor circuit Q_1. Since the zener maintains a constant voltage across the transistor's emitter circuit the emitter and collector current will be constant. Consequently, the capacitor charges linearly.

With the given circuit values, the time between pulses as a function of control voltage is shown in the graph. The time, Δt, required to charge to a specified trip voltage is given by

$$\Delta t = \frac{\Delta VC}{I} = \frac{(V_T - V_{min})C}{I} \quad (3)$$

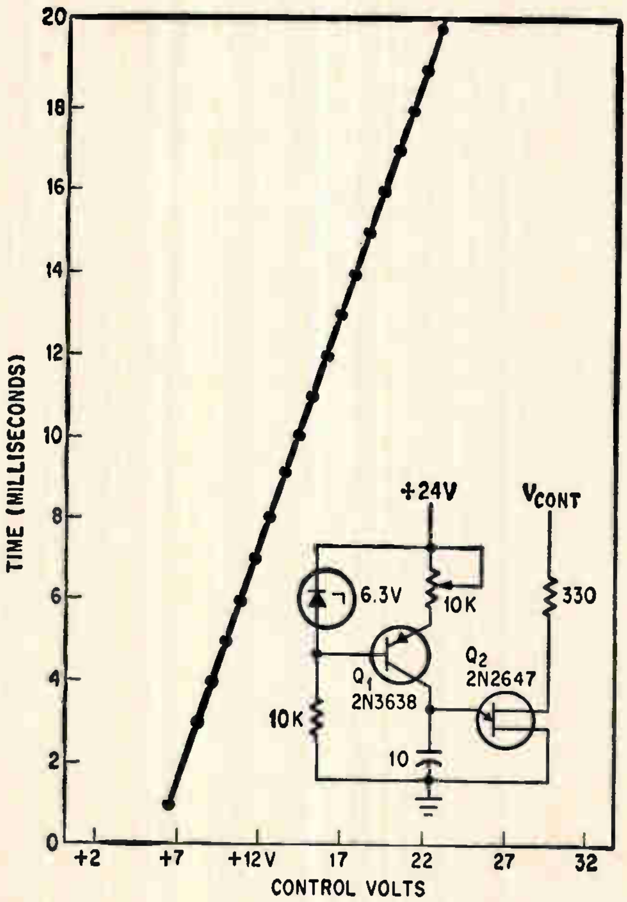
Thus, the slope of the curve can be varied either by varying the charging current, I, or the value of capacitor C. In this equation V_T is the trip point voltage and V_{min} is the minimum voltage to which the capacitor discharged.

The natural pulse width of the circuit is about 20 microseconds, but longer pulse widths may be obtained by connecting a one-shot multivibrator to the output.

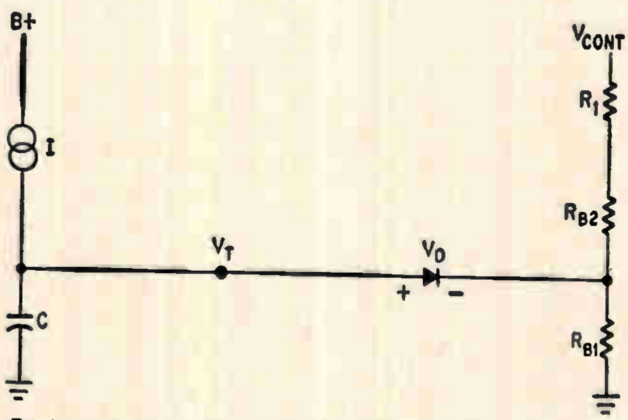
Although the linearity of the circuit is good, it is affected by the current-dependent internal resistances of the unijunction transistor. This resistance affects the minimum voltage to which the capacitor discharges and therefore affects ΔV in equation 3. Improved linearity can be achieved by synchronously discharging the ramp on the emitter of the unijunction through an external circuit. This allows the minimum capacitor voltage to be determined by the external circuit rather than by the unijunction transistor parameters.

From the equivalent circuit, the trip point voltage V_T may be expressed as

$$V_T = V_D + V_{CONT} \frac{R_{B1}}{R_{B1} + (R_1 + R_{B2})} \quad (4)$$



Pulse spacing is controlled by the unijunction circuit. A negative output pulse 20 μsec side is developed when Q_2 conducts. Experimental pulse-spacing values as a function of control voltage are shown on the graph.



Equivalent circuit represents Q_1 as a constant current source I and Q_2 by the diode V_D and resistors R_{B1} and R_{B2}.

Substituting into equation 3

$$\Delta t = \frac{C}{I}\left[V_D + V_{CONT} \frac{R_{B1}}{R_{B1} + (R_1 + R_{B2})} - V_{min}\right] \quad (5)$$

Since all the terms except V_{CONT} on the right side of equation 5 are approximately constant, the time between pulses is proportional to the control voltage.

Many colors are better than one

Capacity of optical memories and versatility of displays can be multiplied when a laser reading and writing beam is switched from one color to another at electronic speeds with new device

By Millard A. Habegger and Thomas J. Harris
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The multicolor capabilities of laser beams have not yet been exploited, but the possibilities for new ways of coding, multiplexing, storing and regenerating data as pure or mixed colors are fascinating.

Computers could optically access tens of millions, perhaps billions, of data bits stored in small chips of color film. Brighter, more meaningful displays could be projected electronically by controlling the colors, intensity and spatial positions of a laser beam. The laser's potential in optical communications and data processing is just beginning to be explored.

The missing link in multicolor schemes has been a suitable color selector, a device that would limit a laser's multicolor output at any given instant to one discrete color, or wavelength, and then switch at electronic speeds to other selected wavelengths.

Such a device, shown on these pages and on the cover, has been built and demonstrated. It operates in microseconds, while other wavelength-selection techniques reported in recent years have generally lacked the speed needed in practical electronic systems.

The new device is a Q spoiler that is voltage turnable and wavelength dependent. Typically, a Q spoiler is an optical device placed within the resonant structure of a laser so that the net gain is insufficient for laser action. However, in this case the Q spoiler is employed with a laser that has gain at several discrete wavelengths.

The undesired wavelengths are elliptically polarized, introducing reflection losses that are higher than the gain. For minimum loss, the desired lasing wavelength is linearly polarized. Therefore, it will be emitted at an intensity high enough to be useful. The magnitude of an electric field in electro-optical crystals that are part of the Q spoiler determines which wavelength is linearly polarized.

The color selector complements two previous developments that are also prerequisites for an optically accessed, multicolor storage system. One of these is a means of writing multicolor information into a film storage with a density of one million to 10 million bits per square inch. The other is a system that digitally deflects a laser beam to any selected spot in the storage medium, so that the beam can be used for writing and reading. The deflector-memory system provides a reading rate of 10 million bits a second. Only a color selector and beam deflector combination is required for a visual-display system.

One laser, many colors

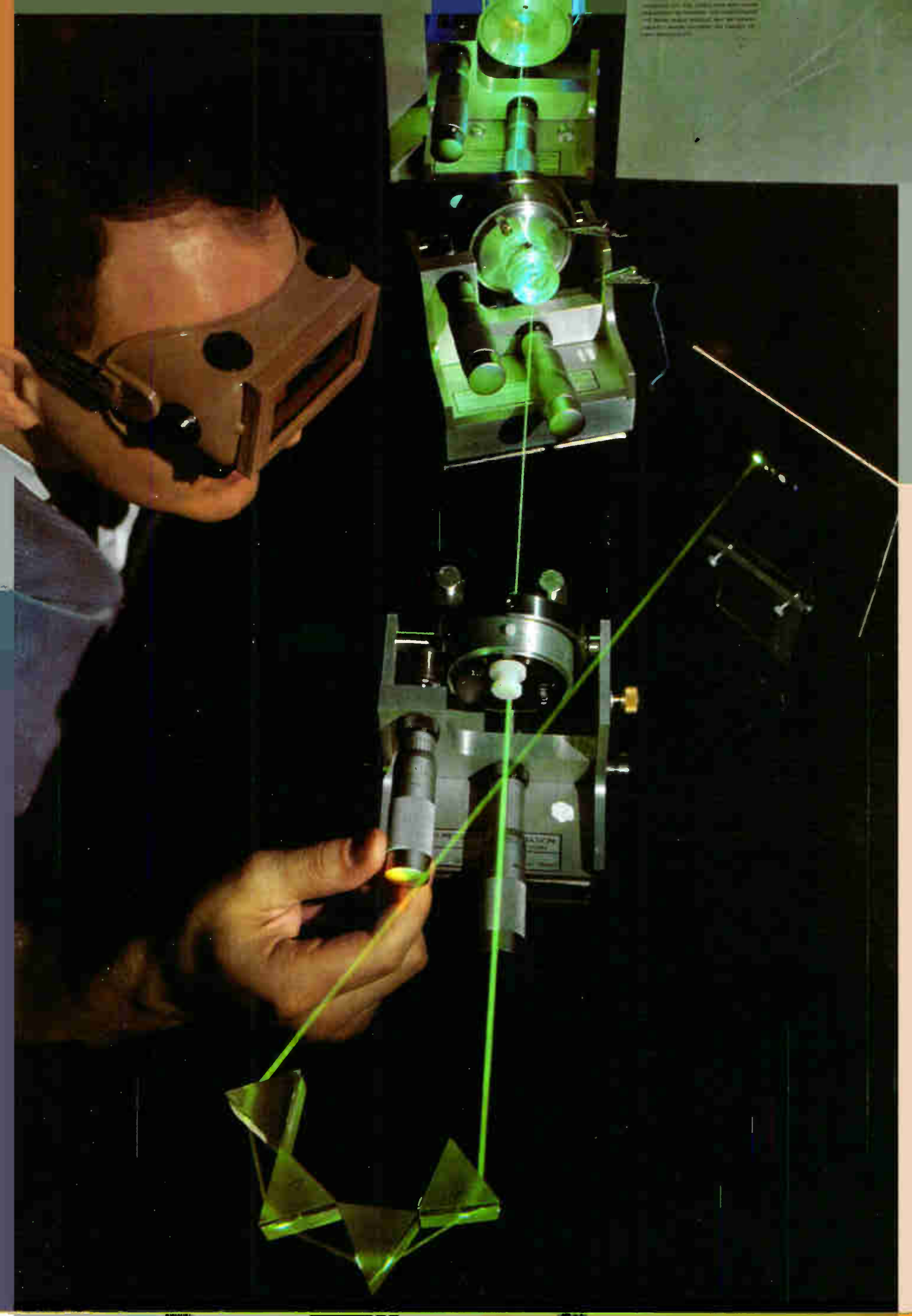
Although the beam's brightness, coherence and high degree of collimation makes the laser unique as

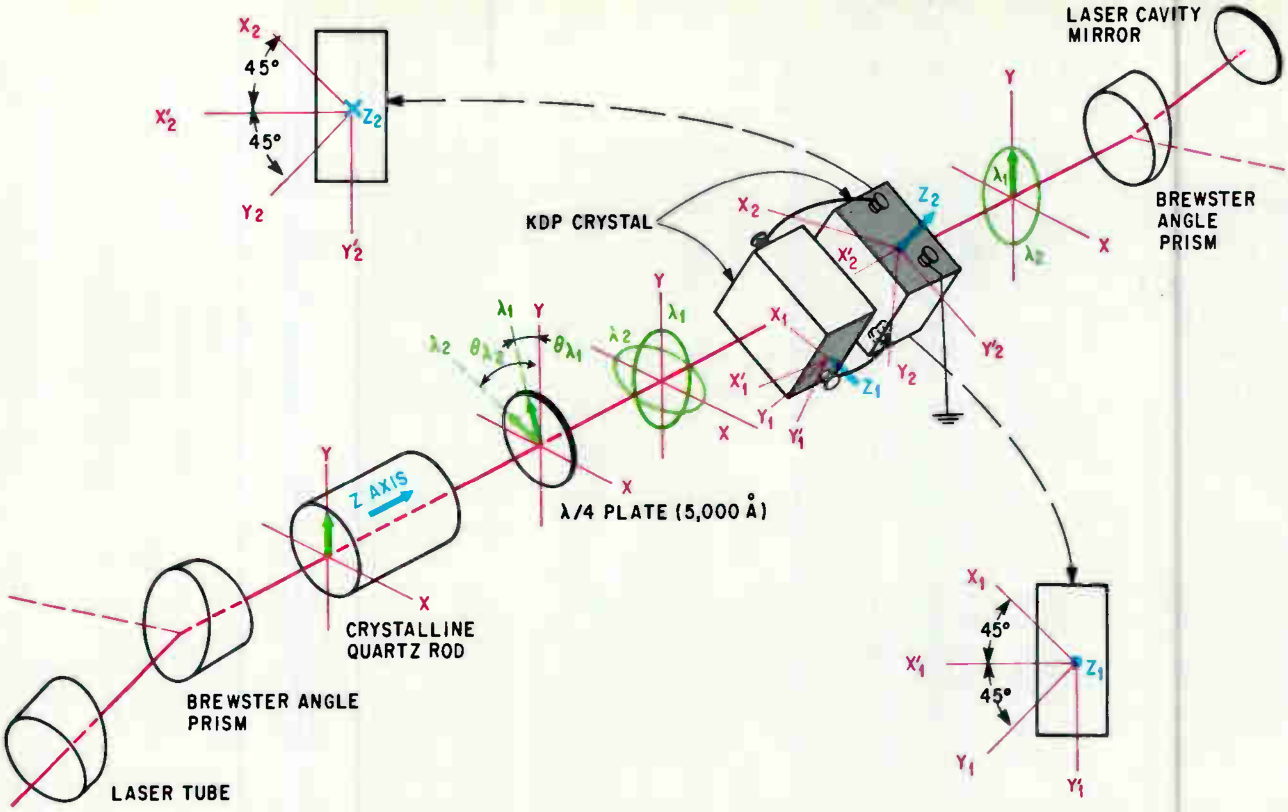
The authors

Millard A. Habegger, physicist at the IBM Systems Development Laboratory, is working on computer applications of the laser. Before joining IBM in 1964, he was a research assistant at Purdue University where he earned his doctorate in solid state physics.

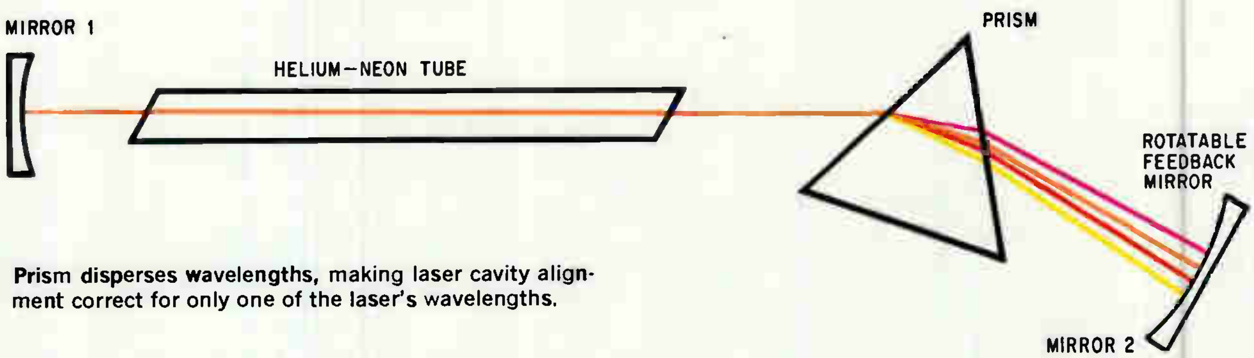
Thomas J. Harris is advanced optics manager at the Poughkeepsie, N.Y., laboratory. While at IBM he has investigated applications for lasers and techniques for controlling the parameters associated with laser beams.

Wavelength selector causes an argon-ion laser to emit green light, the light traveling around the optical path. Normally, the laser emits mixed colors; five colors were photographed on the screen by multiple exposures.





As light passes through the optical components of the Q spoiler, light of one wavelength, λ_1, is linearly polarized; light at another wavelength, λ_2, is elliptically polarized, causing reflection losses.



Prism disperses wavelengths, making laser cavity alignment correct for only one of the laser's wavelengths.

a light source; it is similar to an electronic oscillator in other respects. It requires an amplifying medium and feedback to the input of part of the amplified signal. The gain must be greater than the loss in the feedback loop or it will not oscillate.

Lasers frequently have gain or emission at several different wavelengths or colors. An argon-ion gas laser, the type employed in the experiments with the Q-spoiler color selector, produces two strong emissions and six weaker lines simultaneously. The two strong lines are visible as blue and dark green, corresponding to wavelengths of 4,880 and 5,145 angstrom units. The photograph on the preceding page illustrates the laser oscillating in the green line. The weaker emissions are at wavelengths of 4,579, 4,658, 4,765, 4,965 and 5,017Å. The colors of four possible emissions are shown on the screen with the 5,145-Å green line.

There is, at present, no continuous-wave laser that emits a beam containing substantial power distributed throughout the visible spectrum. In the future, such a laser might by constructed by mixing several gases in a single laser tube and obtaining oscillations from transitions in each gas. However, many existing lasers can oscillate at several wavelengths.

If the feedback mirrors of a helium-neon laser are highly reflective throughout the visible spectrum, the oscillation will occur at 6,328 Å — bright red — and not at any other visible wavelength. However, a prism placed in the laser cavity as in the diagram shown above can remove the dominance in the 6,328-Å line and cause oscillation at another wavelength.[1] The prism disperses the wavelengths so that the laser-cavity alignment is correct for only one wavelength.

Rotating the prism or the feedback mirror can give oscillation at 5,940, 6,046, 6,118, 6,293, 6,351, 6,401 and 7,305 Å as well as 6,328 Å. Switching wavelengths could be done in a millisecond if a piezoelectric transducer rotates the prism or mirror. Higher speeds are not possible because of the mass of these optical components.

Wavelengths have been selected by other techniques, too, such as using a feedback mirror with selective reflectivity,[2] placing a set of interference plates in the optical resonator,[3] placing a methane-filled cell in the optical resonator of a helium-neon laser,[4] or having one of the end reflectors a special prism that makes the collimated output parallel for all wavelengths.[5]

Continuous sweeps through a small range of wavelengths have also been obtained by applying electric or magnetic fields, or pressure, or by changing the temperature of the laser's active media.[6–9] High hydrostatic pressure continuously shifts the wavelength of a lead-selenide, pulsed-injection laser.[10] But applying high pressure is not a practical dynamic tuning technique and high fields or forces are difficult to sweep rapidly.

The Q spoiler

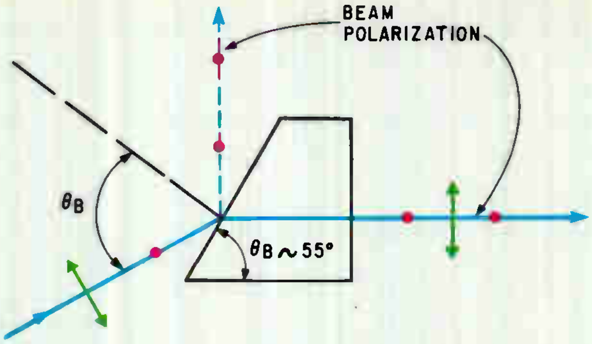
For many applications, discretely spaced wavelengths are preferred, at which the active media have gain and which can be selected by changing the parameters of the optical resonator. Hence, the effort to develop an electronically tunable, wavelength-dependent Q spoiler.

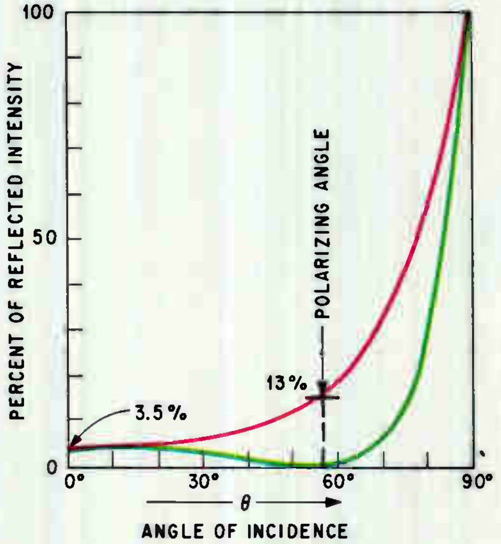
When the selector device is placed in the optical resonator, the switching speed from one wavelength to another is limited only to the rate at which the optical resonator and active media can change resonant modes.

The gains of the transitions in continuous-wave gas lasers, range from a few percent up to 80%. The fixed optical losses, scattering, reflections and absorption in the Q spoiler must be lower than the minimum gain in the system. The combination of optical elements diagrammed above left introduces more loss than the available gain for each line except the desired one.[11]

The Q spoiler consists of a crystalline-quartz rod, quarter-wave plate, KD*P (potassium didenterium phosphate) electro-optic crystals and Brewster-angle windows (prisms) made of fused quartz. These optical elements are stacked tightly against each other with a film of silicone oil between them for refractive index matching. The Brewster-angle windows are needed to reduce reflection losses for plane-polarized light. The reflection from a fused-quartz surface is illustrated at the right, above. There is practically no reflection of light that is incident at the Brewster angle θ_B when this light is linearly polarized parallel to the plane of incidence (plane formed by the normal to the surface and the incident ray). The reflection for an orthogonal polarization will be approximately 13%, as indicated by the graph right, below.

After the light passes through the Brewster-angle window, it propagates along the z axis of the quartz rod. Plane-polarized light will have its plane of polarization rotated as it traverses the rod. The amount of rotation per unit length of rod due to optical activity depends on wavelength. The planes of polarization





Intensity of light reflected from a dielectric surface, such as glass, depends upon the angle of incidence and beam polarization. The red dots and curve indicate polarization perpendicular to the plane of this page.

for two arbitrary wavelengths λ_1 and λ_2 after the light has passed through a length of quartz are shown in the diagram of the Q spoiler at the left. These planes make angles $\theta_{\lambda 1}$ and $\theta_{\lambda 2}$ with respect to the y axis.

The light then enters a crystalline-quartz, quarter-wave plate whose optic axis is parallel to the y axis. This plate introduces a 90° phase shift between the polarization components along its x and y axes. The light leaving the plate will have an elliptical polarization according to the equation

$$\frac{x^2}{A^2 \sin^2 \theta_\lambda} + \frac{y^2}{A^2 \cos^2 \theta_\lambda} = 1$$

The elliptically polarized light enters two KD*P electro-optic crystals. The transverse Pockel's effect in these crystals introduces a phase shift between two polarization components, as has been described.[12] Normally, the longitudinal electro-optic effect is used rather than the transverse effect, but the transverse effect is used in this case to keep the losses to a minimum. The electric field in the two crystals is along the z axes, which are rotated 90°

relative to each other and 45° with respect to the optic axis of the quarter-wave plate. This geometry cancels the temperature dependance of the electro-optic crystal birefringence. The light travels down the x^1 axis of each crystal.

Voltage tuning

For an applied electric field E_z, the phase shift φ_λ between a component, A sin ωt (ω is 2πf), along the z axis of one electro-optic crystal and a similar component along the z axis of the other electro-optic crystal is

$$\varphi_\lambda = \frac{\pi d E_z}{V_{\lambda/2}}$$

where d is the length of the light path in each crystal, and $V_{\lambda/2}$ is the half-wave voltage as customarily defined for the longitudinal electro-optic effect.

After the light has passed through the electro-optic crystal, the components along the orthogonal z axes are

$$Z_1 = \frac{1}{\sqrt{2}} A \sin(\omega t - \theta_\lambda)$$

$$Z_2 = \frac{1}{\sqrt{2}} A \sin(\omega t - \theta_\lambda + \varphi_\lambda)$$

By placing an appropriate electric field on the electro-optic crystals such that

$$\varphi_\lambda = 2\theta_\lambda$$

the light of wavelength λ will again be linearly polarized along the y axis. Light of all other wavelengths will remain elliptically polarized.

The second Brewster-angle window of the Q spoiler introduces reflection losses for all polarization components which are not parallel to the plane of incidence. Components of the elliptically polarized light will be reflected out of the laser cavity. The light emerges from the Q-spoiler cavity and propagates to the feedback mirror. The beam is reflected back to the Q spoiler's Brewster-angle window which will introduce additional loss in all polarization components not parallel to the plane of incidence. If the resulting losses are sufficient, there is an output at only the selected wavelength.

Four photographs showing the Q spoiler in an argon-laser cavity are shown at the right. Each photograph shows a different wavelength being selected as the appropriate voltage is applied to the electro-optic crystals. The light intensity through one of the laser mirrors as a function of the applied voltage is shown in the graph on page 91. A transition time of 8 microseconds was measured in switching from the 5,145-Å to the 4,965-Å line. Shorter switching times are expected with better voltage-control circuitry. Switching times from below threshold to equilibrium of 20 to 100 microseconds were reported for a Q-spoiled helium-neon laser.[13]

Optically accessed memories

The simplest concept of an optical memory is to divide a photographic film into small, discrete areas. Each area can be either opaque or transparent to represent the binary ones or zeros of basic computer language. The memory can be read with a light beam directed with a light deflector to any selected area, while a photosensitive device behind the film gives an electrical signal indicating the presence or absence of light, corresponding to a one or zero.

If each area were addressed with light beams of different colors, the storage capacity of each area would be increased by the number of colors that could be stored. An optical memory able to store several colors can be constructed by the Lippmann process, with a panchromatic photographic emulsion on a metallic mirror.[14]

Light that has a coherence length — the length of the wave train over which the waves in the beam are exactly in phase — greater than twice the thickness of the emulsion passes normally through the emulsion, reflects from the mirror, and returns through the emulsion. This sets up standing waves in the emulsion with a node at the metallic mirror surface as in the right side of the diagram on page 91. Silver ions form in the regions of the antinodes of the standing wave.

If the light were not coherent or if the coherence length were too short, then weak, scattered antinodes would result and the ion formations would be ill-defined or nonexistent.

When the film is developed, a periodic structure of layers of reduced silver is set up. Because of the periodic variation in index of refraction, interference occurs in the reflected light; constructive interference occurs only for the wavelength which originally sets up the layers during exposure. Hence the reflected light wavelength is a reproduction of the exposing light wavelength.

Furthermore, if several anharmonic wavelengths are used to expose the same region of the emulsion, each will set up a separate layer structure, as shown by the two colors in the left side of the diagram, provided the grain size is sufficiently small. Broadband light energy, reflected from the emulsion, will contain all the original wavelengths. Conceivably n color sources spaced appropriately over the band of sensitivity could provide n information bits, one per color, at each spatial location. A density of 10^6 to 10^7 bits per square inch can be obtained.

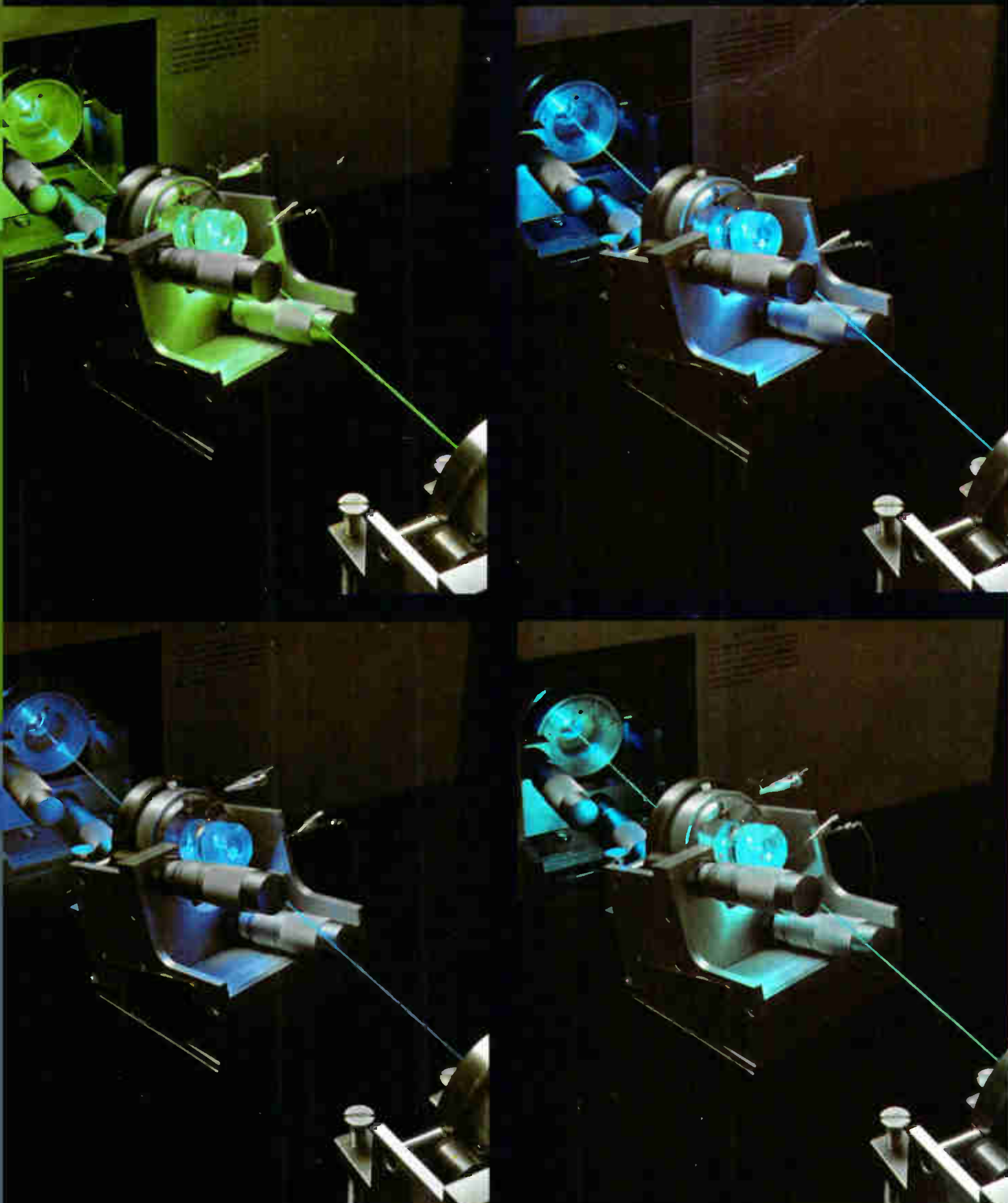
A laser or combinations of lasers that have emissions suitably distributed over the wavelength region of film sensitivity are useful for exposing the memory at high speed because of their high brightness and coherence.

The Lippmann process results in a read-only type of memory — a multicolor analog of black-and-white microfilm. A read-write optical memory is possible if the storage medium is reversible, such as a photochromic material.

A short-wavelength beam directed with a light deflector to the appropriate area in the medium would write into the memory by exciting the material and causing local changes, such as a change in color, density, or index of refraction.

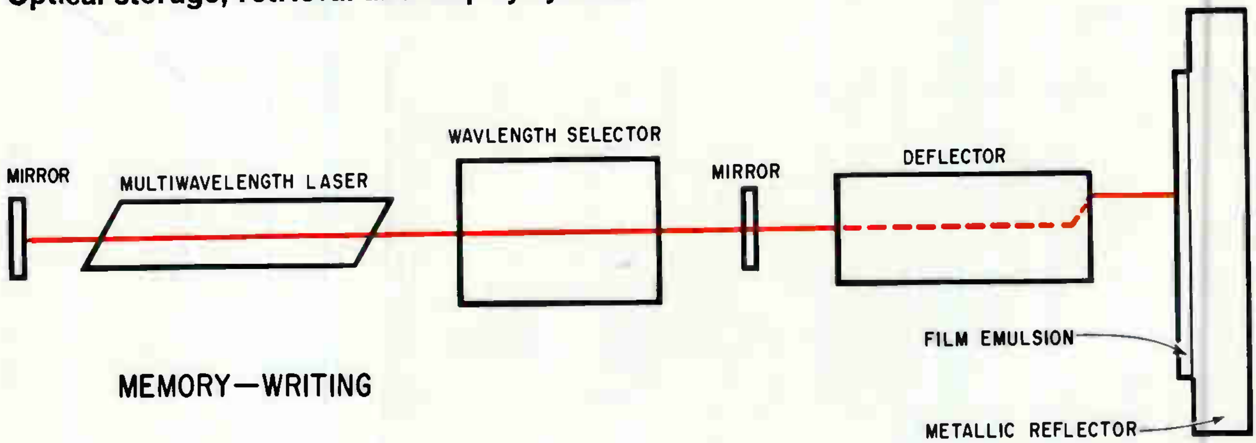
A beam with longer wavelength, such as an infrared beam, directed to the same area would erase the

Same laser emits four colors

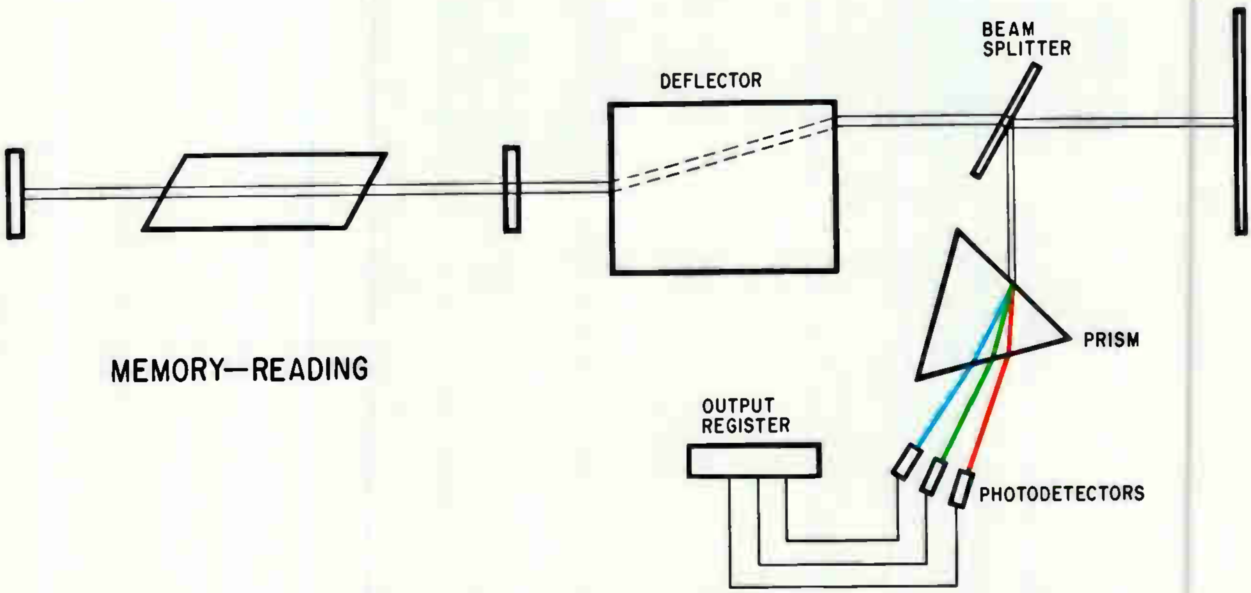


These beam shades—corresponding to wavelengths of 5,145, 4,756, 4,579 and 4,965 angstroms—were produced by varying the voltage of a Q spoiler in an argon laser's resonant cavity. The beams emanate from the laser tube, upper left in each photo, pass through the wavelength selector in the center and are reflected by the mirror.

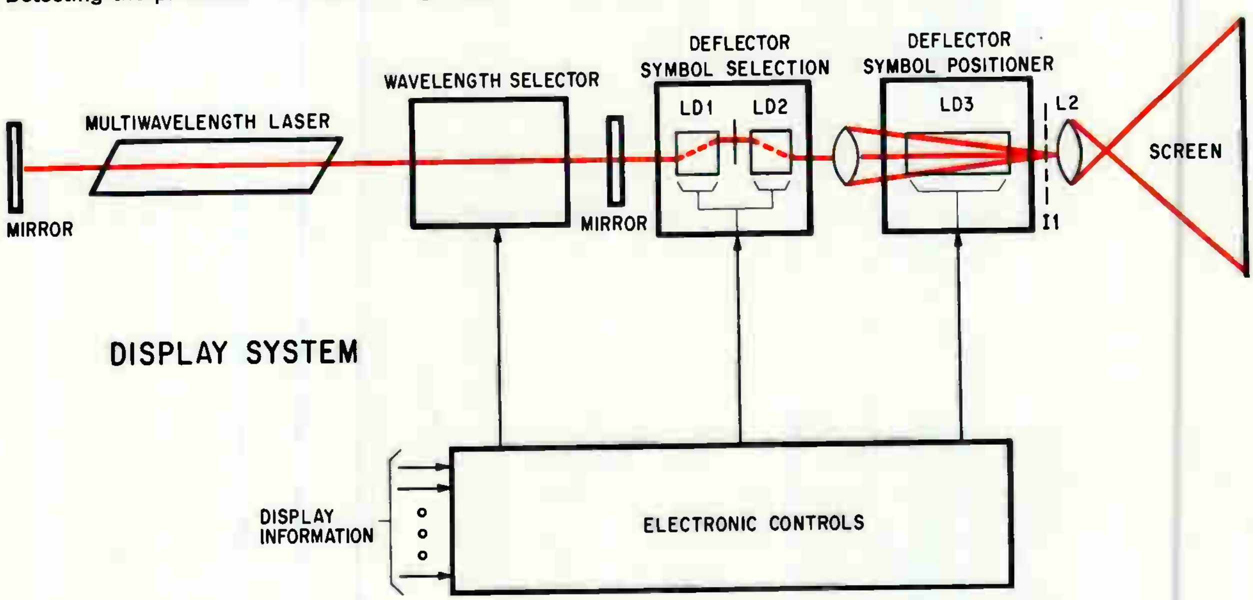
Optical storage, retrieval and display systems



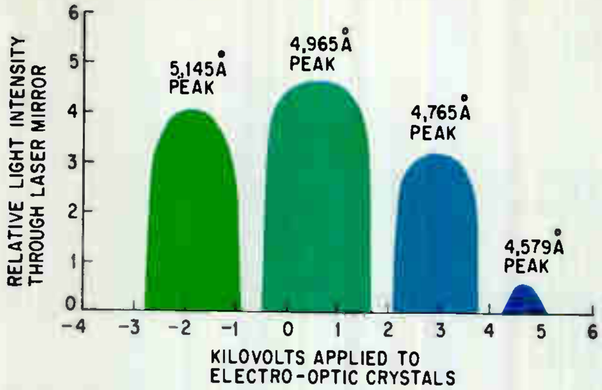
Selector and deflector are both required to establish the correct color and position of data stored in film.



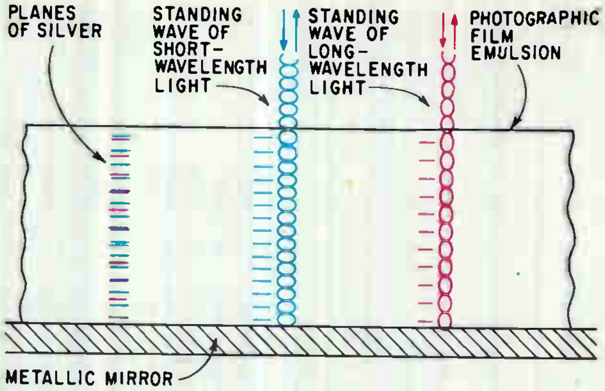
Lippmann memory is read by illuminating each storage area with all the colors used during writing, so a multicolor beam and a selector are used. The prism disperses reflected light into discrete wavelengths. Detecting the presence or absence of light tells whether a color stored a binary one or zero in a selected area.



Color and position of a displayed character are selected by switching beam wavelength and position.



Intensity of the laser output is plotted as a function of voltage applied to the KD*P crystals of the Q spoiler. The four emission wavelengths produce the colors seen in the four Q-spoiler photographs on page 89.



Lippmann process allows data to be stored as spaced layers, corresponding to colors, in the same film area. A laser beam's brightness and coherance keeps the antinodes and layer structure sharply defined.

information by reversing the photochromic reaction. The erase mechanism could be infrared heating or some other mechanism appropriate to the material. A gas laser which has a short wavelength and infrared emission could be used. A high-speed, laser-wavelength selector would be desirable to switch rapidly from writing to erasure.

Selecting the spots

A high-density optical memory may contain hundreds of millions of bits. The exposing light beam has to be directed rapidly and precisely to any spot in the memory to fill the memory in a reasonable time.

This is made possible with a digital light deflector.[15, 16] The deflector is capable of addressing any one of 65,000 different spots within a 3-to-5-centimeter-square film chip in about 10 microseconds. It was constructed at the Systems Development division of the International Business Machines Corp. under contract to the U.S. Army Electronics Command, Fort Monmouth, N.J.[17]

The different wavelengths can be selected with the laser wavelength selector, as in the setup for writing the information into the memory at the left, above; for reading, a multicolor beam is employed, and the colors separated by a prism, as shown at the left, center.

Multicolor displays

The extreme brightness of laser beams is an advantage in displays since the output images can be viewed in a normally lighted room. Color adds another dimension and further increases the information content and versatility of displays.

The elements of a multicolor display system are in the figure left, below. The symbols selector deflects the laser beam to the desired character on a character mask. The symbol positioner projects the character anywhere on the screen. The displayed character could appear in any of the colors corresponding to the discrete wavelengths of the laser's emission. The laser frequency selector rapidly switches from one color to another.

The pure color wavelengths of 6,328, 5,145 and 4,880 Å correspond to the dominant red, green and blue emissions of helium-neon and argon-ion lasers. Mixing various intensities of these three emissions will give almost any color in the visible spectrum plus white light. Ideally, the primary colors emitted by a single laser would be coupled with a wavelength selector and the intensity controlled with an electro-optic modulator. The correct intensities of the three colors would sequentially be directed to one spot. The eye looking at the spot would see the color corresponding to the mixture.

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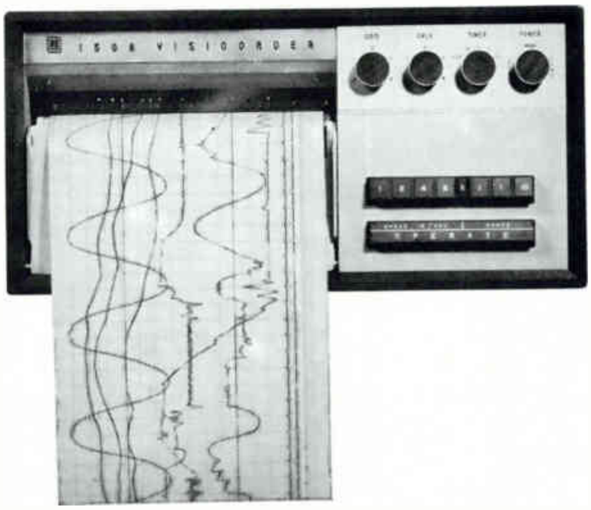
small wonder



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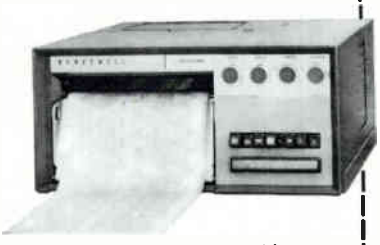

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Harmonic testing pinpoints passive component flaws

Measuring nonlinearities in linear passive components provides a way of finding hidden flaws that can cause serious problems in complex equipment

By Vilhelm Peterson and Per-Olof Harris
L.M. Ericsson Telephone Co., Stockholm

A fast, nondestructive testing method that saves both time and money can analyze a wide variety of nonlinearities in all types of passive electronic components.

Early detection is important because these minute flaws can indicate the presence of design or manufacturing weaknesses which later may lead to failures. These defects could not be discovered with conventional testing methods but were found by measuring the distortion they created.

The new test can uncover uneven film depositions, base material flaws, bad grindings and unreliable contacts in resistors; imperfect dielectrics and unreliable contacts in capacitors; and determine the hysteresis dissipation factor and hysteresis loss coefficient in magnetic components and materials.

The authors

Vilhelm Peterson is manager of L.M. Ericsson's Long Distance Division's component laboratory. Previously, he designed telephone carrier systems and had been leader for the filter calculation group.

Assistant manager of the division's component laboratory, Per-Olof Harris was previously engaged in the design and manufacture of electronic components at various component manufacturing companies.

When high reliability is desired this test can be made part of an over-all screening program.

The cause of nonlinear distortion

The simplest linear passive component is the resistor. The ideal resistor should conform to Ohm's law where the current through the device is directly proportional to the voltage across it. If the resistor contains a nonlinearity, Ohm's law is no longer valid.

When a pure sinusoidal current flows through such a component, the voltage across it is distorted by any nonlinearities present. The distorted voltage can be considered the sum of a fundamental frequency voltage and a number of voltages at harmonic frequencies. The magnitude of these harmonic voltages can serve as a measure of the nonlinearity present in the component. For convenience, the third harmonic is usually chosen since it has the largest amplitude and therefore is easiest to measure.

This measuring principle is not restricted to resistors, but is also valid for the other passive, linear components, the capacitor and inductor. The nonlinearities arise from various causes in different components, coming either from the active material—the resistance material in resistors, the dielectric in capacitors and the magnetic material in inductors—or from the imperfect contact at the connections.

Certain nonlinearities are always present in the active material of components and the magnitude that can be tolerated depends on the eventual application of the component. For example, components with large nonlinearities must be avoided in circuits where intermodulation products between different frequencies are intolerable.

Other nonlinearities, especially sporadic ones that show up at contact points, are good indications of impending component failures.

Designing a nonlinearity tester

Nonlinearities in components can be measured with a bridge circuit, as was demonstrated by both C.E. Mulders and G.H. Millard.[1,2] One of the advantages of this approach is that the measuring voltage does not have to be filtered very well since the harmonics are partly balanced in the bridge circuit. But this method is time-consuming since the bridge must be rebalanced at the fundamental frequency for every test specimen.

Therefore a direct method has been developed that employs filters to suppress the fundamental frequency.[3] The test circuit is shown on page 95. The direct method is very fast—the test specimen is connected to the circuit, the test voltage applied and the results are available in less than a second. One difficulty with this method is that those components in the low-pass and bandpass filters situated nearest the test specimen must be free from nonlinearities or else the results will not be valid. An oscillator supplies the fundamental frequency for the test circuit; a variable attenuator enables the operator to set the test voltage at a suitable value. A power amplifier with two different output impedances is included in the circuit so a broad range of component values can be tested without loading down the oscillator. Harmonics generated by the oscillator and amplifier are eliminated with a low-pass filter.

When the test specimen is connected and voltage applied a bandpass filter attenuates the fundamental frequency and higher harmonics. A voltmeter reads the third-harmonic voltage directly.

The input impedance of the bandpass filter is capacitive. This allows a tapped inductor to be inserted between the low-pass filter and the test specimen to provide a means of possibly increasing the test voltage across high-resistance and capacitive test specimens. With this arrangement, the test voltage may be increased up to about 300 volts.

When studying very low-resistance test specimens, such as contacts, it may be advantageous to modify the test circuit according to the diagram on page 95. The resonant circuit is tuned to the fundamental frequency and produces a large increase in the test current while reducing the influence of harmonics from the amplifier. It is possible to determine the impedance of the test

Harmonics in a homogeneous material

If a sinusoidal current, I, flows through a nonlinear element, the voltage that appears across the element will contain harmonics. Only one of the harmonics need be considered since they all are a measure of the nonlinearities present. The third harmonic, E_3, is usually chosen since its magnitude is the largest. If the current is increased resulting in a corresponding increase in the current density in the component, the third-harmonic voltage, E_3, will increase in proportion to the current density, J^n, where n, an exponent characteristic of the material, is often constant over a wide current range. In many cases, n has a value of approximately three.

If two equal, nonlinear elements are connected in parallel and each carries a current, I, a third-harmonic voltage, E_3, is generated in each. The voltages have the same phase relationship and the third-harmonic voltage for the parallel combination will be E_3. E_3 is determined by the stress in the material, characterized by the current density, $J = I/A$ where A is the cross-sectional area of the component.

If the same two elements are connected in series the same current density appears in each. Again third-harmonic voltages are generated in each of the components, but this time they add. The resulting third-harmonic voltage is proportional to the total length of the nonlinear element. It is therefore possible to develop a general expression for the third-harmonic voltage generated in a nonlinear element that has a constant cross section and is made of a homogeneous material. This expression is

$$E_3 = C_3\, l\, J^n \qquad (1)$$

where C_3 is a characteristic constant for the material
l = length of the element
J = current density ($= I/A$)
A = cross-sectional area of the element
n = constant characteristic of the material

Substituting $J = V/\rho l$, where ρ is the material's resistivity, into equation 1 yields

$$E_3/l = C_3/\rho^n\, (V/l)^n \qquad (2)$$

From this equation, it is apparent that the third-harmonic voltage generated per unit length is equal to a constant times the nth power of the applied voltage per unit length.

Properties of spiraled resistors. In the figure below, the resistor element has a diameter d and a thickness t. The length is l′. Before the spiral is made, the resistance is

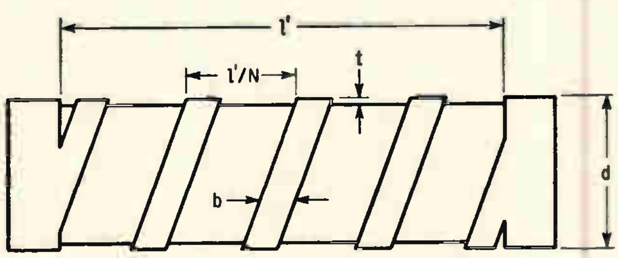
$$R = \rho l'/A_1 = \rho l'/\pi dt \qquad (3)$$

where ρ is the material's resistivity and A_1 is the cross-sectional area.

When the resistor is ground, the resistance element becomes a spiral with N turns. The resistance is now

$$R' = \rho\pi d\, N^2/kl't \qquad (4)$$

where
l'/N is the pitch between turns
$kl'/N = b$ is the true width of the film band
πdN is the length of the film band
$kl't/N$ is the area of the film band



specimen by reading the value of the fundamental voltage across it.

A switch turns off the voltage to the test specimen terminals during hook-up. This is necessary, especially when testing capacitive components or low-resistance specimens in the resonant circuit, since current transients could otherwise develop which might create high voltages causing premature component failure. The low-pass filter suppresses any current transients that may occur.

The original tester had two different fundamental frequencies, 10 and 50 kilohertz. However, this was reduced to one frequency—10 khz—in the later models.

In the test circuit described, the impedance of the specimen and the input impedance, Z_1, of the bandpass filter at the third-harmonic frequency, $3f_1$, form a voltage divider. In the test equipment developed, the filter's input impedance is resistive and equal to 300 ohms.

The general equation for the third-harmonic voltage, E_3, produced by component nonlinearities is

$$E_3 = V_3\,(1 + Z_x/R)$$

where V_3 is the third-harmonic voltage measured at the filter input terminals, Z_x is the impedance of the test specimen and R is the input impedance of the filter. For resistors, capacitors and inductors this equation becomes, respectively

$$E_{3R} = V_3\,(1 + R_x/R);$$

$$E_{3C} = V_3 \sqrt{1 + 1/(9\omega_1 C_x^2 R^2)};$$

$$E_{3L} = V_3 \sqrt{1 + \frac{9\omega_1 L_x^2}{R^2}}$$

where $\omega_1 = 2\pi$ times the fundamental frequency, f_1, and R_x, C_x and L_x are the values of the respective test specimens.

In some cases, it is convenient to express the nonlinearity logarithmically, as in the case of third-harmonic attenuation, which may be written

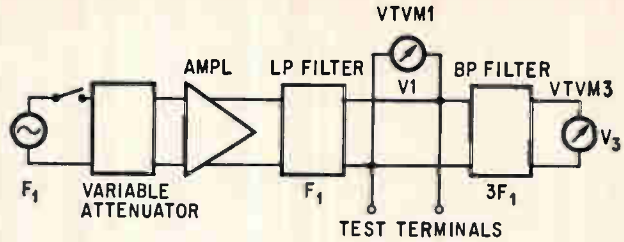
$$A_3 = 20 \log V_1/E_3 \text{ (in decibels)}$$

Third-harmonic attenuation up to 160 db can be measured in the test equipment developed when the test circuit and test specimen are matched.

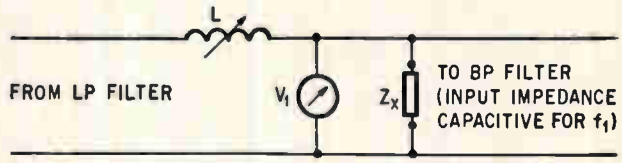
Interesting side effect

An interesting aspect of this method of testing components is the information obtained about spiraled resistors. Such a resistor is made by cutting a cylindrical film resistor into a spiral, increasing its effective length and consequently its resistance. When it is ground, the resistance element and current path become a spiral with N turns. It has been determined that, of two resistors made with identical resistive film, a spiraled resistor has a lower nonlinearity content than an unspiraled one. Also, there is a marked contrast in nonlinearity between spiraled resistors having a different number of turns. The table on page 96 compares some of these effects.

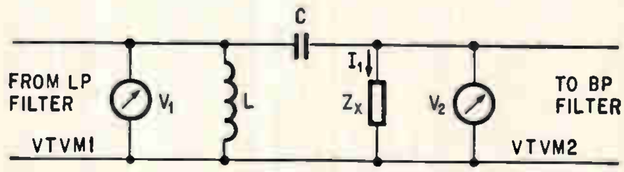
The table also shows that if the design param-



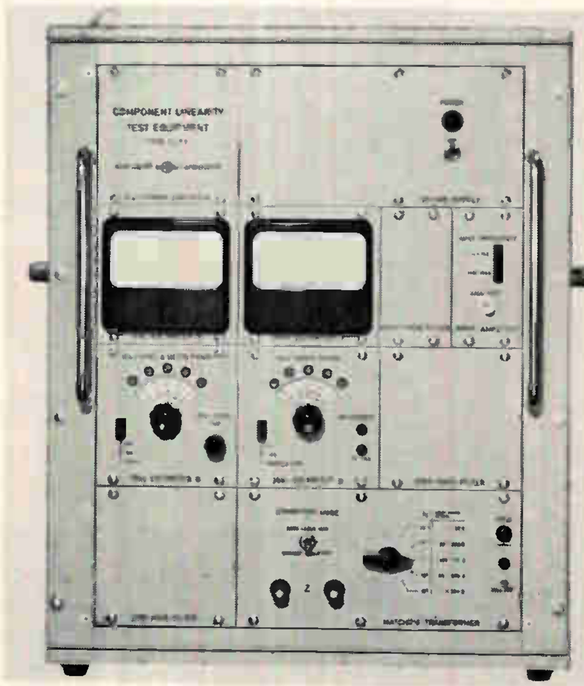
Nonlinearity measuring circuit measures the harmonic voltages generated by a component. Any harmonics generated by the drive amplifier are kept from reaching the component under test by the low-pass filter. The bandpass filter allows only the third-harmonic voltage to reach the voltmeter.



Test voltage control is increased by placing variable inductor in series with test specimens. This makes it easier to measure the nonlinearities in such specimens with the third-harmonic method.



Low-resistance specimens are easier to test if a resonant circuit is added to the test circuit. In this way, the current through these components is increased and the influence of any nonlinearities in the amplifier is reduced.



Nonlinearity tester, has a fundamental frequency of 10 kilohertz. Amplitude of the third-harmonic voltage is read directly from the meter on the instrument's front panel.

eters of the resistor are not known, it is impossible to accurately determine whether a single resistor is faulty or not from its nonlinearity level. It is even hazardous to draw a conclusion about a specific resistor type from the mean value of the nonlinearity for a batch of resistors. A high mean value of nonlinearity may only indicate a thin resistive film since thin films are more sensitive to oxidation and exhibit poor long-term stability. On the other hand, narrow film bands are more easily exposed to damage. Any small unevenness in the film may cause constrictions which lead to large nonlinearities and can result in local overheating.

Because of this, the distribution of nonlinearities has been found to be more valuable for judging the quality of a resistor type than for finding defects in individual resistors.

How the other methods fare

Two other methods for investigating deviations from ideal resistor behavior are the voltage coefficient and current noise techniques.

The voltage coefficient is

$$K_r = \frac{R_1 - R_{0.1}}{R_{0.1}} \times \frac{1}{V_1 - V_{0.1}} \times 100\%$$

where R_1 is the resistance at the rated voltage V_1 and $R_{0.1}$ is the resistance at 10% of the rated voltage, $V_{0.1}$.

This method is only suitable for resistors with high voltage coefficients since the temperature dependence of the resistor easily influences the results. Even so, Mulders and Millard have shown that it is possible to obtain the voltage coefficient by nonlinearity measurement. This measurement is simpler, more sensitive and more accurate than the direct resistance-voltage method.

The current noise technique is based on the fact that a noise voltage exists between the end terminals of a conductor or semiconductor due to thermal movement of the electrons. This thermal noise is independent of the absolute frequency within a given bandwidth.

If a direct current flows through a resistor made of a semiconducting material, the thermal noise increases. The root-mean-square value of the current noise can be written as

$$E_n = K_n F(f) V^a$$

where K_n = a constant for the resistor
V = the applied voltage
a = exponent between 0.7 and 1.1, often 1.0
$F(f) \approx (\log f_2/f_1)^{1/2}$

The current noise may also be given as the current noise index, N.I. = 20 log E_n/V where E_n is the rms value of the open circuit current noise in microvolts measured over the frequency decade ($f_2/f_1 = 10$), centered at 1,000 hertz; and V is the applied d-c voltage.

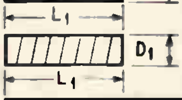
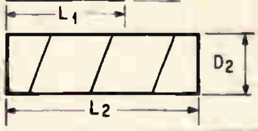
Theoretically, however, the same information that can be obtained from the current noise measurements can be gotten from measuring the third-harmonic voltage. But the third-harmonic measurements can be made much faster since a stabilizing time is required when making current noise measurements. In addition, the third-harmonic voltage increases when the applied current is increased, rapidly outdistancing system noise. With the current noise method, it is often necessary to correct the measured value for the influence of system noise.

Also, the nonlinearity measuring method is not sensitive to external fields and the reading is much more stable during measurement than the noise reading. This is important for production testing. When there is little mismatch between the test specimen and the test set, the sensitivity of the nonlinearity test method is as good as the current noise method for film resistors up to several hundred kilohms. But, unlike the current noise method, nonlinearity measurements can be made on resistances as low as one ohm.

Bad spirals

During the grinding of a film resistor to make the spiral, a flaw often develops which results in a conducting bridge of resistive material between turns. These bridges lead to high current densities that cause the resistor to show poor stability or even result in an open circuit. Measuring the third-harmonic voltage generated in a resistor can lead to the discovery of flaws of this type.

Consider the spiral resistor shown on page 97, which has a bridge between two adjacent turns. For simplicity, only a single bridge is considered and it is assumed that it has a constant area, A_2. The resistance of one turn of the spiral is $R_1 = R'/N$,

TYPE	DIMENSIONS	FILM THICKNESS	LENGTH	NUMBER OF TURNS	E_3 / E_{3A}
A		t_1	L_1	N_1	1
B		t_2	L_1	N_2	$(t_1/t_2)^{\frac{n-1}{2}} = (N_1/N_2)^{n-1}$
C		t_1	L_2	N_1	$(L_1/L_2)^{n-1}$

$$\text{RESISTANCE}_{\text{SPIRALLED}} = \frac{\rho \pi d N^2}{K l' t}$$

E_{3A} = THIRD-HARMONIC VOLTAGE OF TYPE A, ρ = RESISTIVITY
n = CHARACTERISTIC EXPONENT OF RESISTIVE MATERIAL, l' = SPIRALLED LENGTH
N = NUMBER OF SPIRAL TURNS, t = FILM THICKNESS, d = SPIRAL DIAMETER

where R′ is the total resistance of a spiraled resistor of N turns, defined by equation 4 in the panel on page 94.

The resistance of the bridge is

$$R_2 = \frac{\rho (1 - k) l'}{NA_2}$$

If $R_2/R_1 = x$, then the resistance of the turn bridged by R_2 can be expressed as

$$R'_1 = \left(\frac{x}{1 + x}\right) R_1$$

If the bridge is removed, the relative increase in the resistance that occurs is

$$\frac{\Delta R}{R} = 1/N\,(1 + x).$$

It is now possible to compare the increase in nonlinearity caused by the bridging with the nonlinearity present without bridging. The ratio between the third harmonic in a bridged resistor and that in a faultless resistor is approximately

$$\frac{E_{3tot}}{E_{03}} \approx 1 + \frac{x^n}{(1 + x)^{n+1}} \frac{N^{n-2}}{(1 - k)^{n-1}} \left(\frac{\pi d}{l'}\right)^{n-1}$$

An example of the effects of such a bridge is demonstrated quantitatively with a spiraled resistor having the following characteristics:

circumference / length	$\frac{\pi d}{l'} \approx 1$
number of turns	$N = 10$
part of pitch ground away	$(1 - k) = 0.3$
characteristic exponent	$n = 3$
bridge resistance	$R_2 = R_1 = R/N, \quad x = 1$

Under these conditions, the bridging introduces a resistance decrease of

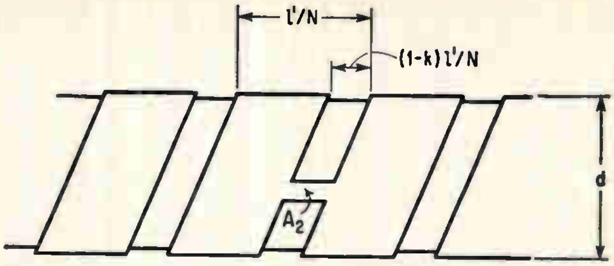
$$\frac{\Delta R}{R} = 1/10\,(1 + 1) = 0.05, \quad \text{or } 5\%$$

More significant, however, is the amount the bridging increases the third harmonic generated in the resistor. According to the equation above, this amounts to

$$\frac{E_{3\,tot}}{E_{03}} \approx 1 + (1/16)\,(10/0.3^2)\,(1) \approx 8 \text{ times}$$

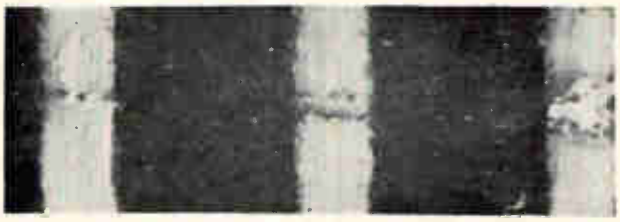
These calculations also serve to emphasize the degree of overheating that can result from bridging. In this example, the current density in the bridge between the turns is 16.7 times that in the normal resistance film.

Other sources of measurable nonlinearities in film resistors are the unreliable contacts between the end termination and the film or between the end cap and the connecting wire.[4] These problems occur mostly in low-valued resistors (less than 1,000 ohms) and often show up after soldering. An unreliable contact between the end cap and connecting wire is especially hazardous because it can result in an open circuit.



Spiral resistor with a conducting bridge between two of its adjacent turns. The area of the resistive bridge is assumed to be constant and equal to A_2. The pitch of the spiral is l'/N.

Example of carbon film resistor with conducting bridge detected by the nonlinearity method. Where the dark resistive film crosses the ground spiral gap of the resistor (light area) current flow causes the nonlinearity.



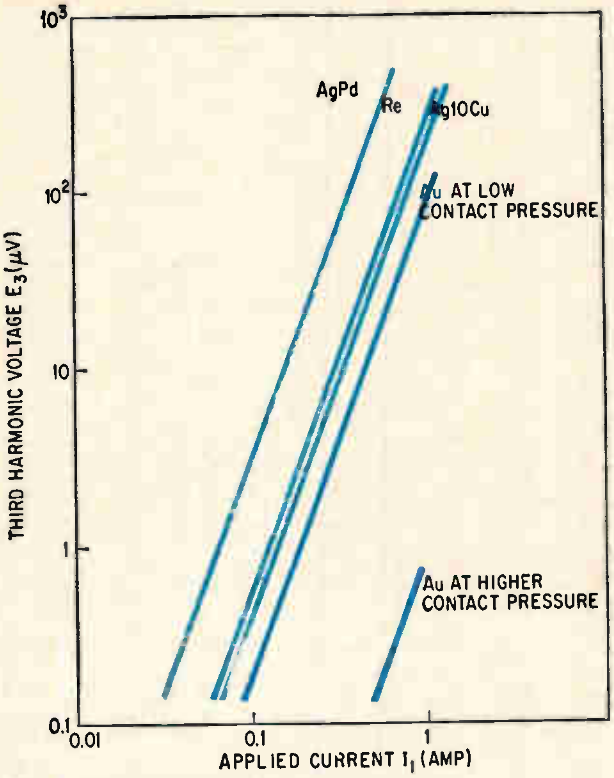
Cracks in the resistor body can also cause conductive bridges in spiral resistors. Although this type of bridge does not appear to be as clear as the previous example, chances for component failure are as great.

Nonlinearities in other resistive components

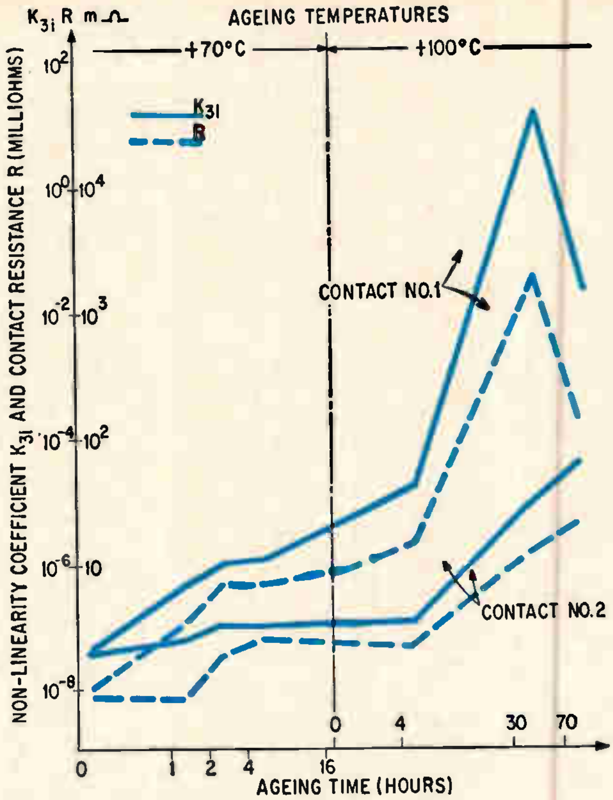
As a rule, composition resistors have much greater nonlinearities than carbon film resistors. The composition resistors also manifest more current noise. Even so, the nonlinearity test can be of use in those situations where the nonlinearity disturbs the function of equipment in which the resistors are to be used.

On the other hand, wirewound resistors made of a nonferromagnetic resistance material, with good contacts and adequate insulation between wire turns, are characterized by a very low third-harmonic voltage difficult to measure. It is possible though, for such wirewound resistors to have a measurable third-harmonic voltage if the connection wires are of magnetic material.

Thus one cannot conclude that resistors made with nonmagnetic materials are unreliable because they have a measurable harmonic voltage. For example, consider a resistor design in which the resistance wire is wound around the end of the connection wire and welded to it. Any spurious



Plot of third-harmonic voltage as a function of applied current demonstrates that even gold contacts can yield large nonlinearities. In this case, they result from low contact pressure.



Nonlinearity and contact resistance increase with age as shown by a plot of these two characteristics over a period of time.

contacts between the unconnected turns and the wire can generate third-harmonic voltages. The chances of an open circuit are slight, but a small resistance instability is possible.

Ferromagnetic resistance materials contain systematic nonlinearities. Resistors made with this material will produce a third-harmonic voltage that varies as the square of the applied voltage. The nonlinearities can be high in certain cases and will mask those caused by bad contacts or intermittent contacts between wire turns.

Potentiometer failures

Most of the previous remarks about wirewound resistors are also valid for potentiometers. However, potentiometers possess other failure mechanisms. A decrease in total resistance can occur if particles are worn off the winding to form a shunt between turns. Another problem is an increase in contact resistance between the winding and the slide wire due to oxidation. Both of these problems can be detected with normal resistance measurements; but with the nonlinearity technique it becomes possible to distinguish between galvanic resistance changes and changes caused by buildup of semiconducting films.

Some potentiometers are made with taps by connecting wire welded to resistance wire along the length of the winding. The quality of these welds varies considerably. Measurement of the third harmonic can easily detect bad welds.

Making contact

A good contact should be a purely metallic connection between two parts of a circuit. It should demonstrate a constant, low value of contact resistance, independent of current and time.

Chemical compounds build up on metal contact surfaces exposed to the atmosphere. These compounds, oxides and sulphides, for example, are semiconductive and tend to increase contact resistance. They have a nonlinear current-voltage characteristic that can be exploited to detect contamination by nonlinear measurements.

The circuit shown on page 95 measured the third-harmonic voltage generated by a number of relay contacts made of different materials. The results, shown above, indicate that contact even between electrodes of pure gold has measurable nonlinearity if the contact pressure is low. For each material, the third-harmonic voltage is proportional to the cube of the applied current:

$$E_3 = K_{3i} I_1^3$$

where the coefficient K_{3i} characterizes the nonlinearity of the contact.

A test was made with contacts between two copper wires. Measurements were made of the contact coefficient with newly polished surfaces after aging in dry heat for varying time periods. The graph above shows how both the contact resistance and the nonlinearity increased with aging.

A batch of cold-solder joints was made by joining together oxidized copper wires without the aid of flux. These joints were aged in the same way as the copper contacts and the results of the nonlinearity measurements were similar.

Nonlinearity measurement is, therefore, a method for investigating contacts in such components as resistors and capacitors where it is difficult, if not impossible, to make direct measurements of contact resistance.

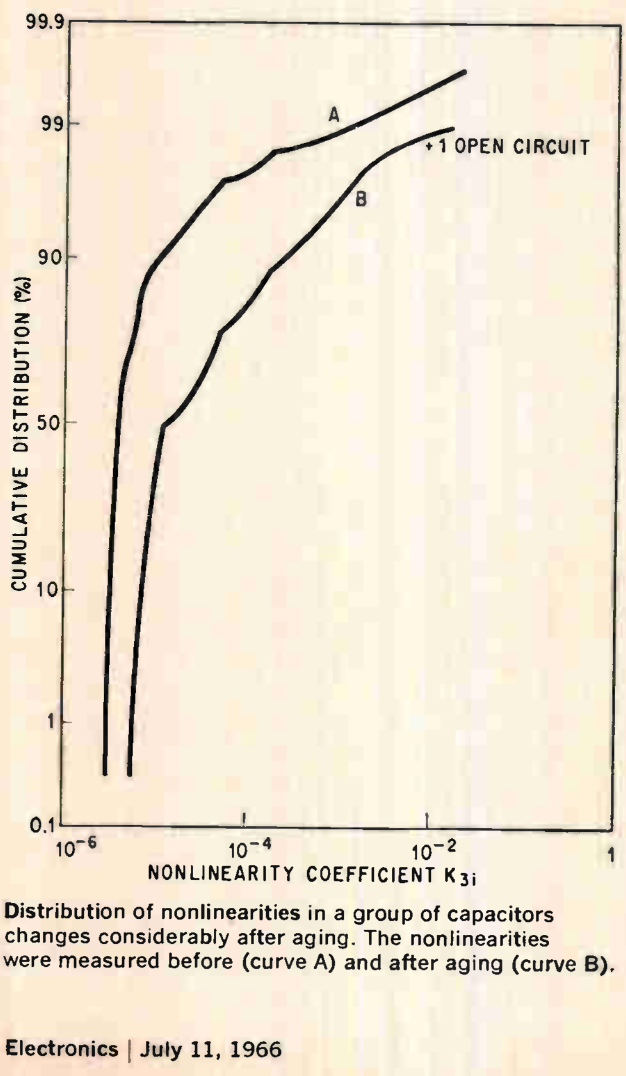
Finding capacitor flaws

Nonlinearities in capacitors can be separated into two groups—those that occur in the connections or electrodes and those in the dielectric.

Nonlinearities in connections and electrodes are caused by bad contacts from cold soldering, unreliable contacts due to low contact pressure or unsuitable materials, badly welded contacts and nonlinearities in the semiconducting materials.

Contact flaws have the greatest influence on the reliability of equipment in which capacitors are used. These faults are difficult to find before the capacitors are built into equipment where they can affect the operation of the device as the contact surfaces become oxidized with age.

Dielectric nonlinearities are caused by the use of materials with voltage-dependent dielectric constants, ferromagnetic particles in the dielectric, ionization of the dielectric by a high a-c voltage[5] or vibration of the electrodes.[6]



Distribution of nonlinearities in a group of capacitors changes considerably after aging. The nonlinearities were measured before (curve A) and after aging (curve B).

A variety of other methods exist for testing capacitor contacts, including one introduced in Germany about 15 years ago.[7] Unfortunately, with this method, one cannot obtain quantitative information about the increase in contact resistance. Other methods lack the sensitivity of the nonlinearity technique.

A batch of capacitors was measured for nonlinearity and the cumulative distribution plotted, as shown in curve A of the graph below. Some of the capacitators with large nonlinearities were dissected for further study. It was discovered that the connection to the positive terminal was made by a piece of copper wire pressed against the rivet by a rubber washer on the capacitor lid and the pressure exerted by this contact was inadequate. As the rubber ages, the contact pressure may be reduced still more and contact faults soon develop. As a test, the capacitors were stored at room temperature for six months and the nonlinearities measured again. The results, curve B of the graph, demonstrate that nonlinearities increased considerably; in fact, one open circuit was found. The first measurements were sufficient to reject this type of capacitor although the manufacturer claimed it had high reliability and long life.

Oxide film on contacts usually breaks down when capacitors are operated at high a-c voltages. As a result, capacitors with contact nonlinearities may function well for long periods. However, if the capacitors are operated at low a-c voltages, no breakdown occurs even if the capacitors are simultaneously subjected to high d-c voltages. The capacitors are charged to the d-c voltage level through the contact resistance and there is no d-c voltage drop across the contact. But the capacitor acts as an open circuit to weak superimposed a-c signals.

A test of a number of plastic-foil capacitors, encapsulated in metal cans, resulted in a fairly high percentage of nonlinearity. Dissecting the capacitor uncovered the design weakness—a cold-solder joint that resulted from joining to untinned leads.

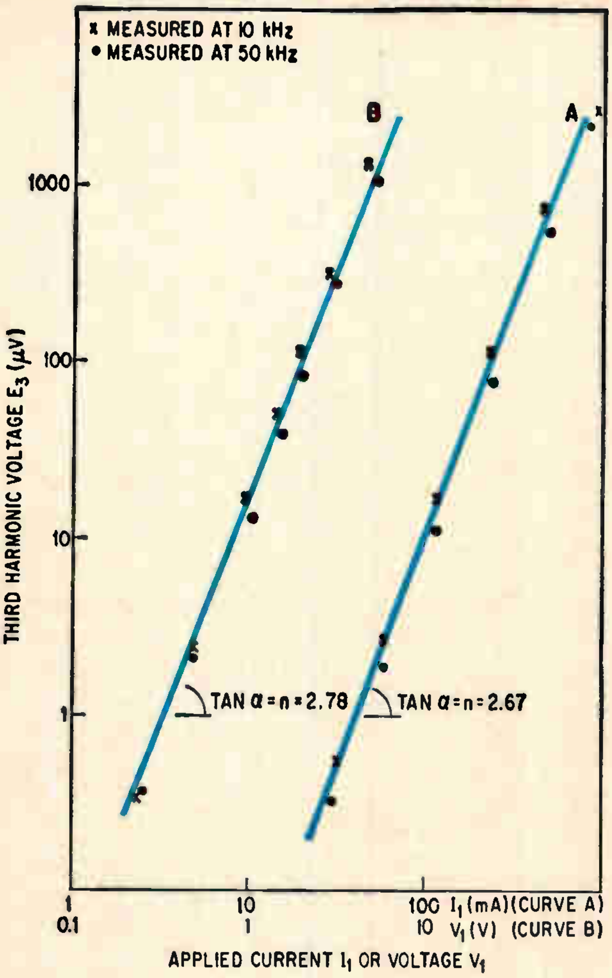
Another method of finding defective components is to subject them to a mechanical shock and test for variations in nonlinearity. If the component is connected to the test equipment and tapped, a varying measurement may indicate a faulty contact inside the component. In some cases, however, movements in the dielectric may give rise to small changes in nonlinearity.

Ceramic and dry tantalum oxide capacitors are examples of capacitors in which systematic nonlinearities are inherent. The third-harmonic voltage for each is shown in the graph on page 100. For a ceramic capacitor, the nonlinearity seems to be voltage-dependent according to the equation

$$E_3 = K_{3v} V^n.$$

Experimentally, n was found to be 2.78.

For the tantalum oxide capacitor, in which nonlinearities are believed to originate in the contact



Third-harmonic voltage is a function of current in a dry tantalum oxide capacitor (A) and a function of voltage in a ceramic capacitor (B).

material, nonlinearity appears to be current-dependent according to the relation

$$E_3 = K_{3i} V^n$$

where n is 2.67.

In both cases, the results were the same at both 10 and 50 khz. To keep the current constant, the voltage at 50 khz was one-fifth of that at 10 khz.

Testing magnetic materials

The inductance and equivalent loss resistance of an inductor with a magnetic core gains when alternating current through the winding is increased. In addition, odd harmonics are generated. These deviations from ideal behavior have importance in certain applications. In high voltage filters, for example, nonlinear distortion not only generates odd harmonics but also causes intermodulation products between different frequencies. In other applications, increases in the loss resistance or dissipation factor may be more important.

E. Peterson's work[8] led to the expression

$$E_3/V_1 = 0.6 \tan \delta_h$$

where E_3 = the generated third-harmonic voltage
V_1 = the applied voltage
$\tan \delta_h = R_h/\omega_1 L$, the hysteresis dissipation factor
$R_h = \Delta R$ = the increase in the loss resistance of the inductor due to hysteresis losses

Because of the direct relationship among changes in inductance, resistance and third-harmonic generation, measuring any one of these factors yields data on the other two.

Determining the hysteresis dissipation factor by the nonlinearity method gives results within 10% of those attained with conventional bridge circuits. Although both methods are suitable, the nonlinearity method provides more information on the generation of harmonics and intermodulation.

The nonlinearity method also furnishes a faster way to determine the hysteresis loss coefficient, eliminating the need to measure the dissipation factor at two different flux densities with an a-c bridge.

The nonlinearity method has an additional advantage of being insensitive to air gap variations.

The nonlinearity measurement principle has other uses besides studying nonlinearities in passive, linear components. N. I. Meyer and T. Guldbrandsen[9] employed the same principle to study distribution of impurities in semiconductor crystals.

The nonlinearity principle has also been used to detect unreliable contacts made to semiconductors.

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Ultrahigh-speed IC's require shorter, faster interconnections

As digital circuits become faster, the wiring delays must be reduced. Shorter wiring is only part of the solution—the transmission-line design must overcome the different forms of crosstalk that occur in high-speed systems

By Emory C. Garth and Ivor Catt

Motorola Semiconductor Products Division, Motorola, Inc., Phoenix, Ariz.

If digital systems are to benefit fully from the latest increases in integrated circuit speeds, the wiring delays between circuits must be reduced. Today's ultrahigh-speed IC's have switching times and propagation delays of less than 5 nanoseconds. This speed cannot be used effectively in a system if wiring delays between circuits are dominant.

To reduce wiring length, thus reducing wiring delays, requires structures with a high density of interconnections. However, even with such micro-interconnection structures, transmission-line considerations—output loading, signal reflections and signal cross-coupling—must be applied to the wiring design because the new circuits are so fast. Crosstalk must be considered more exhaustively; it takes less spurious energy to falsely switch the faster circuits and various forms of crosstalk may affect circuit operation.

Multilayer printed circuit boards are an economical form of high-density interconnection for packaged integrated circuits. In addition, methods of interconnecting numerous unpackaged IC's—either as chips or in monolithic arrays—with extremely short lengths of thin-film wiring are being developed. This represents the best foreseeable solution to the length-dependent delay and transmission-line problems. However, it also raises system-design problems [discussed in the article on p. 111].

Still another problem is that as interconnection density rises, thermal problems also rise. More heat must be removed from a smaller packaging volume because higher wiring density generally requires higher circuit density and because faster circuits generally dissipate more power in a given time than slower circuits. Eventually, it may become necessary to immerse the circuits in a refrigerating liquid.

The need for speed

Economic as well as technical reasons exist for reducing wiring delays. Manufacturers of large-scale digital computers have a strong incentive to develop higher-speed systems. It has been shown that information processing costs are, approximately, inversely proportional to the square root of the clock speed. That is, the cost of processing a given amount of data is about halved if the processing speed is quadrupled. Higher circuit speeds also make real-time computing possible in new applications and make practical the solving of problems previously considered too lengthy even for a computer.

In a fast system, short delays in the interconnec-

The authors

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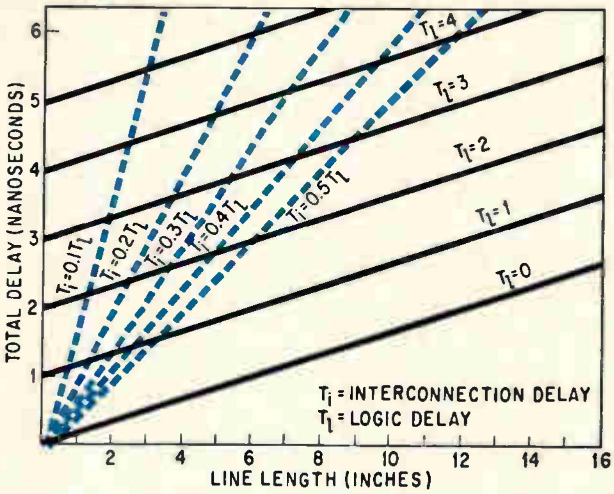


Wiring delay depends upon the length of the interconnection line and the dielectric constant of the propagating medium. This graph compares total signal delay and line length when the dielectric constant of the medium is 4.5—equivalent to epoxy glass—which gives a line speed of 6 inches per nanosecond. The curves in color can be used to determine line length needed to hold interconnection delay to a given fraction of logic delay.

tions are necessary, besides fast circuits. Line propagation time may exceed circuit propagation time in a clocked system, provided that the total propagation time is less than the allowed clock period.

Total signal delay versus line length is plotted in the graph shown above. Interconnection propagation speed is 6 inches per nanosecond, the speed when the dielectric constant is 4.5—about that of the epoxy-glass dielectric in multilayer boards. If line propagation delays are to be limited to less than 20% of circuit delays, line lengths must be less than 1.2 inches for 1-nanosecond circuits. If the dielectric constant could be reduced to near that of air, $\epsilon_r=1$, the line lengths could be increased to nearly 2.4 inches.

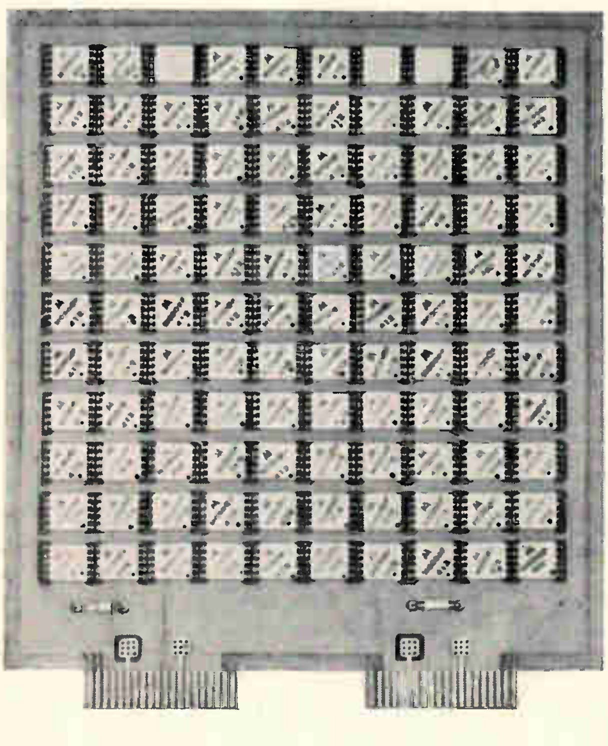
Multilayer circuit boards

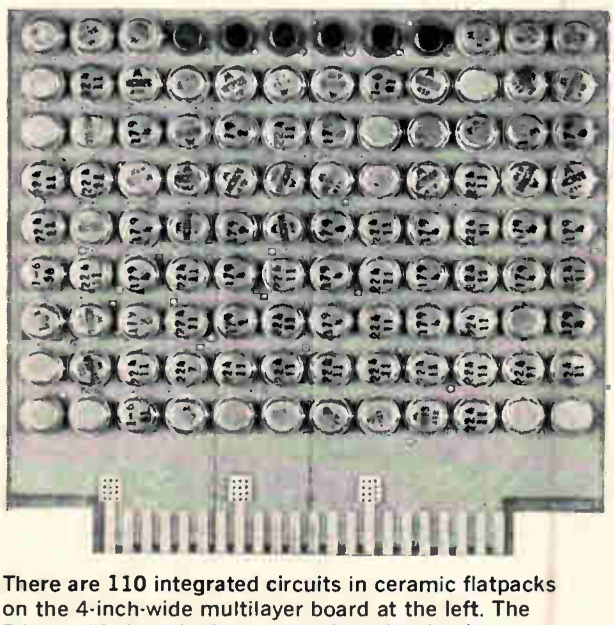
The layer-by-layer design of a multilayer board is shown at approximately half scale on the page at the right. The actual artwork used to make the board is shown, along with a section of the assembly, a data-input subsystem.

The signal paths within the assembly are short, generally 1 or 2 inches and in no case longer than 6 inches. This is close to the shortest possible lengths for interconnecting packaged IC's with circuit boards. The flatpacks are spaced apart slightly so that the IC leads can be lap-soldered to the pads on the boards. This makes it easier to replace the flatpacks (lap soldering is done by precoating the pads and IC leads with solder and reflowing the solder with a dual-probe resistance soldering machine with built-in control of joint temperature, heat rate and cooling rate).

The assemblies pictured in the photographs below, made with two major IC package styles, are closer to the maximum density for packaged IC's. Each of the transistor-like TO-5 packages occupies a board area of 0.165 square inch and an assembly volume of about 0.05 cubic inch. Each 10-lead ceramic flatpack takes approximately 0.12 square inch and 0.015 cubic inch (additional volume must be alloted if the assemblies are cooled by forced air). The density is higher because the packages are spaced as tightly as possible; the leads of the packages are soldered into plated-through holes in the multilayer boards.

Multilayer circuits are a preferred form of microinterconnection because they are economical and the fabrication techniques have been proved. Trans-





There are 110 integrated circuits in ceramic flatpacks on the 4-inch-wide multilayer board at the left. The 5-inch-wide board, above, contains 108 circuits in TO-5 packages. The assemblies are made by soldering the package leads into plated-through holes.

mission-line impedances and signal cross-coupling are predictable. Since line dimensions and dielectric thickness between layers can be controlled, reflection and crosstalk problems are minimal.[1]

Transmission lines

These assembly examples show there is a practical limit to the shortness of wiring lengths between packaged IC's when any appreciable number of circuits are needed in a system. So it is often necessary to design the interconnections as terminated transmission lines when ultrahigh-speed IC's are to be used.

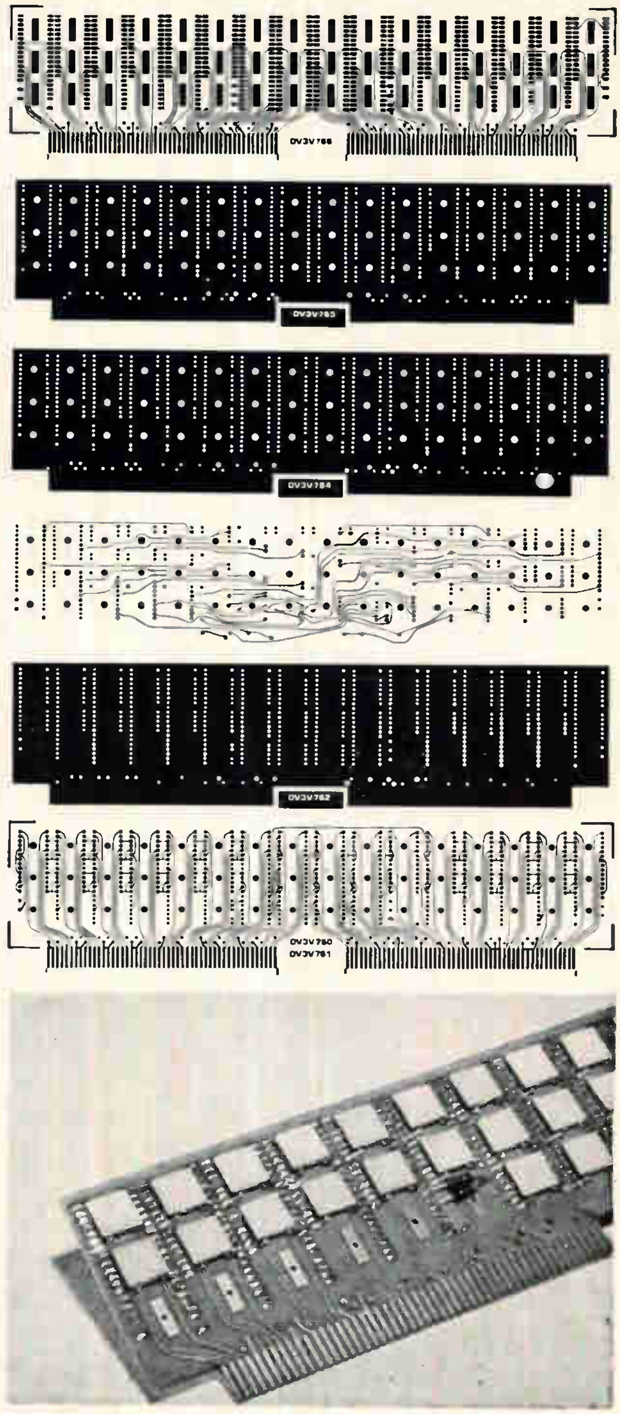
Interconnections will branch in a practical system. A branch seriously degrades performance, by introducing unwanted reflections, if the time it takes a signal to travel down the branch and back exceeds about one third of the signal rise time. As switching speeds increase, branches and interconnections as a whole must be shortened.

Interconnections which act as transmission lines present their characteristic impedance Z_o to the circuit as a load. If the circuit can't drive the load, it won't operate properly. To overcome this performance degradation requires higher-current circuit components and reflection-preventing terminations for each transmission line. Also, the input capacitance of driven circuits farther along the line should be kept low. Otherwise, unrealistically low values of characteristic impedance and propagation times may have to be assigned to the transmission line.

Further loading and termination problems arise when fan-out is accomplished with parallel transmission lines. If n is the number of parallel lines, the circuit must drive the heavy load, equal to Z_o/n, where Z_o is the characteristic impedance of each line.

Normally, a driver circuit can handle a single line with distributed loads, but the worst-case propagation delay becomes longer.

The distribution and effect of eight loads spaced along a 120-ohm line is given in the figure on page 106. The reflections due to the capacitive inputs raise the low logic-voltage level by about 100 millivolts, as the upper reproduction of the oscilloscope traces indicates. The capacitive inputs have lowered the characteristic impedance enough to require reducing the terminating resistances from 120 ohms to 100 ohms. When the change is made, the lower set of curves is produced, indicating that distributed loads may be compensated for by properly selecting the value of the terminating resistor.



Artwork for producing a 6-layer multilayer board is reproduced above at almost half size (actual width of the board is 6½ inches). The signal planes have thin lines and the voltage planes are mostly black. The photo above is the left half of an integrated-circuit, data-input module made with the board.

Modifying the impedance

The characteristic impedance Z_o is inversely proportional to the square root of line capacitance. Therefore, known values of input capacitance can be averaged per unit length to modify Z_o and:

$$Z = \frac{Z_o}{\sqrt{1 + C_d/C}}$$

where Z is the new characteristic impedance and C_d and C are input capacitance and original capacitance, respectively, per unit length.

The effect of distributed input capacitance on signal propagation time t_p is:

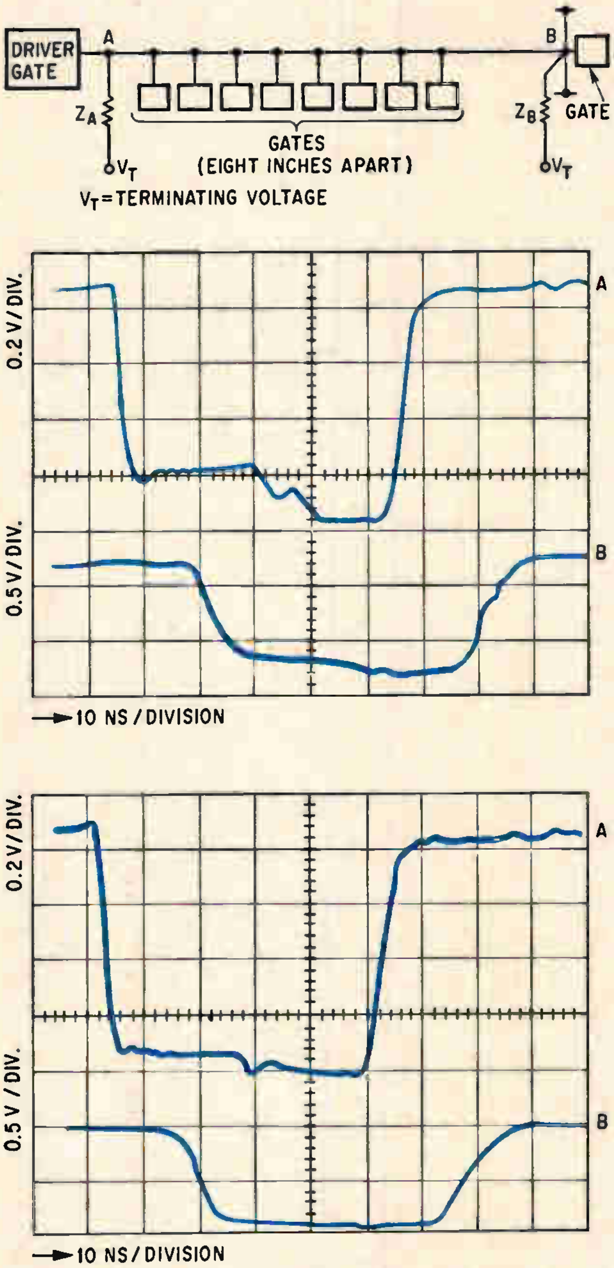
$$t_p = Z_o\,(C + C_d).$$

This relationship shows that distributed input capacitance always increases propagation time and decreases characteristic impedance, but that lines with a lower characteristic impedance are least affected due to their higher capacitance per unit length. The minimum practical impedance is, of course, determined by device limitations.

The variation of Z_0 with printed circuit transmission-line dimensions is plotted in the right-hand graphs on page 107. One gives values for lines in the vicinity of a single voltage plane, as indicated by the inset drawing, and the other for lines between two voltage planes. The values have been verified experimentally.

Approximate values for dielectric thicknesses other than the 0.008 inch given in these examples may be obtained by scaling the pertinent dimensions. The important ratio is that of line width W to dielectric thickness.

Board materials with a lower dielectric constant than epoxy glass become more desirable as circuit speeds increase. Multilayer boards have been made successfully with materials whose dielectric constant approaches 2. Propagation velocity is proportional to $1/\sqrt{\epsilon_r}$ and Z_0 is proportional to $\sqrt{\epsilon_r}$. Therefore, an improvement of 35% is possible. The most benefit would be in the buried signal planes where high characteristic impedances cannot be obtained, even with greater thicknesses of dielectric. Signal lines surrounded by epoxy glass have a Z_0 below 100 ohms if the dimensions are practical, as shown in the graph at the right, while lines exposed to air could have a Z_0 above 150 ohms.



Effect of distributed loads on transmission-line impedance is indicated, for the configuration shown at the top, by the two sets of oscilloscope traces. The upper set shows that the low logic-voltage level is raised 100 millivolts, which is compensated for by changing the terminating resistance, resulting in the lower set of curves.

The kinds of crosstalk

Crosstalk between an active line—one carrying a voltage and current step—and a supposedly passive line nearby places a spurious pulse on the passive line. If the spurious pulse is large enough, it could falsely switch circuits on the passive line.[2,3,4] Ultrahigh-speed circuits require careful consideration of this problem, since it takes less energy to switch a fast circuit than a slow one.

However, to avoid reflection due to mismatch, the designer was forced to make long interconnections as transmission lines of constant Z_0 (as in the graphs on page 107), correctly terminated at their destination. Therefore, the problem of designing for worst-case crosstalk deals only with the case in which two lines run parallel for a long distance.

This case, on page 108, has been studied exhaustively by the authors and they have developed a complete theory. The theory is demonstrated by the oscilloscope waveforms on page 108, taken at the indicated points along the active and passive lines. To simplify the explanation, the lines are very long and are placed closer together than would occur in practice. The lines are on the surface of a board, above a buried ground plane.

The lower trace in the first photograph shows a very narrow pulse introduced at the front end of the active line. If there were no parallel passive line nearby, this pulse would travel down the active line more or less unchanged, in a mode approximating the TE_{00} mode. However, as the other two traces show, the presence of the passive line caused the original narrow pulse to break into two similar pulses. These travel at different velocities and the smaller pulse is the faster one.[5,6]

The small crosstalk pulse at the front end of the passive line (seen in the lower trace of the second photograph) also breaks up into two pulses. The smaller, faster pulse is equal and opposite to the smaller, faster pulse on the active line. This pair of equal and opposite pulses is the odd-mode signal,[6] which travels in a differential mode down the active and passive lines.

The larger, slower pulse on the passive line is equal to the larger, slower pulse on the active line.

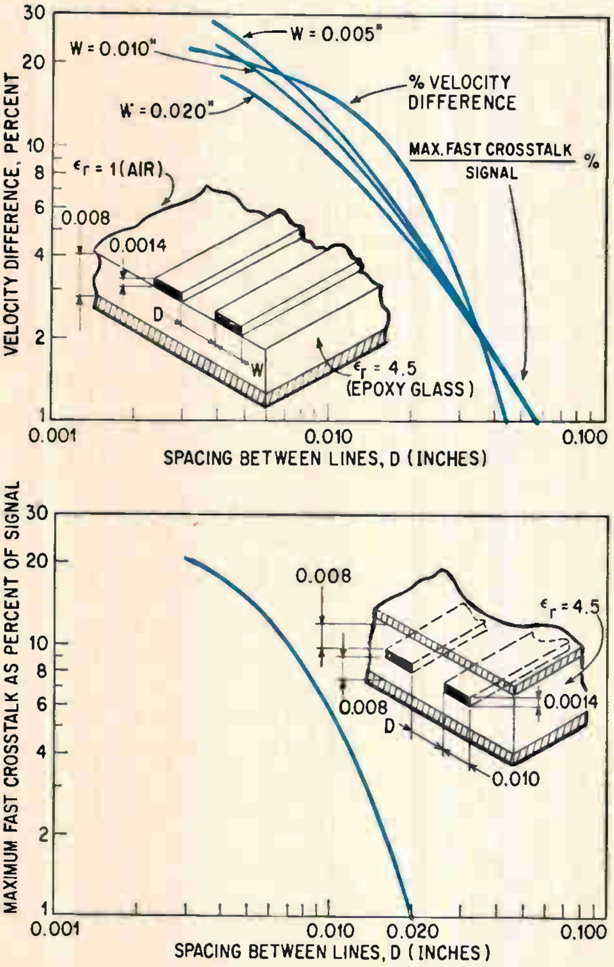
This pair of pulses is the even-mode signal, a common-mode signal down both lines with the ground plane as a return path.

Step, not pulse

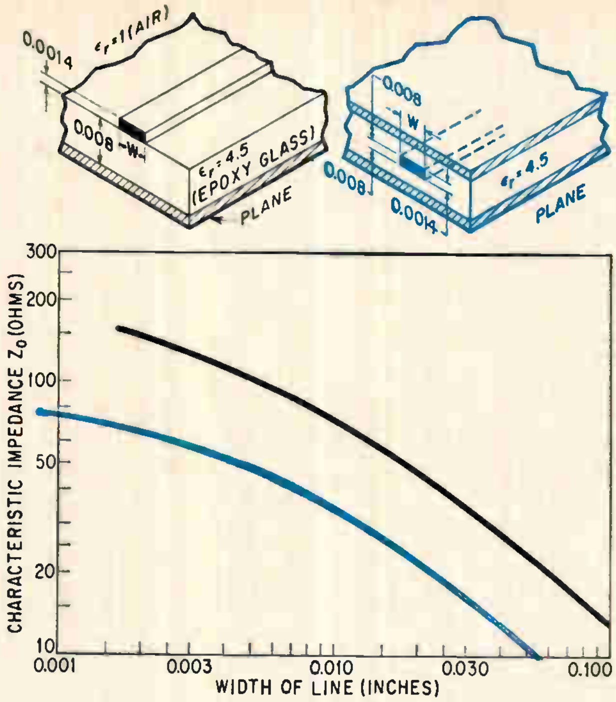
A narrow pulse is not usually introduced at the front end of an active line in a digital system. Usually, a step representing a transition from the false state to the true state is introduced. The equivalent waveforms for a step are illustrated in the next two oscilloscope photographs.

The initial negative-going spike seen in the second and third traces of the passive-line photograph is defined as differential crosstalk. It is so named because it results from a velocity differential that causes the odd-mode, or differential-mode, signal to appear on the passive line before the slower odd-mode, or common-mode, signal has arrived.

All three traces of the passive-line photograph show a positive level equal to the even-mode signal superimposed on the odd-mode signal. This is defined as fast crosstalk; it would appear on the



Fast crosstalk occurs when line propagation times approach or exceed signal rise times. The upper graph indicates the maximum fast crosstalk between surface conductors and the percentage difference in velocity between slow and fast propagation modes. When the medium is continuous, lower graph, there is no differential crosstalk. The lower graph gives the amplitude of the fast crosstalk signal as a function of line spacing.



Characteristic impedance varies with transmission-line dimensions and is lower when the conductor is surrounded by a medium with a high dielectric constant. The black curve gives values for a line near a single voltage plane, as indicated by the configuration in black, while the curve in color is for a comparable line in a continuous medium between two planes (color inset).

passive line even if the two signals traveled at the same velocity, as they do when conductors are buried between two voltage planes in a multilayer board.

If the lines were short, the full amplitude of fast crosstalk would not have time to appear. Instead of a flat-topped pulse on the passive line, there would be a spike of smaller amplitude. This is called slow crosstalk, because the signal rise times are too slow for fast crosstalk to appear.

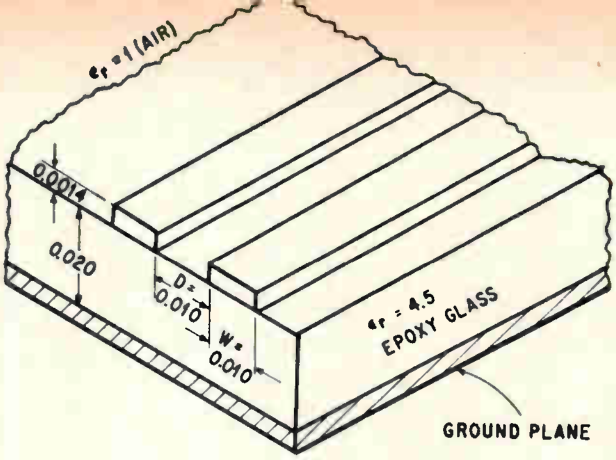
Crosstalk calculations

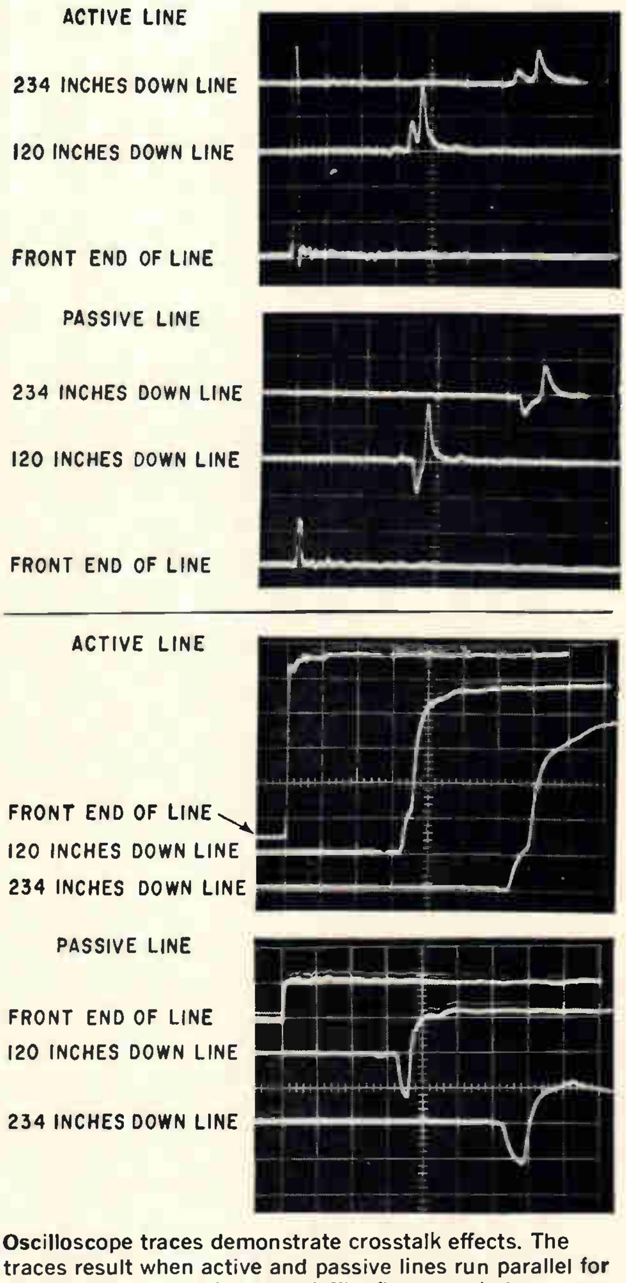
As initial design guidelines, the following may be used:

- If signal rise times are faster than 2 nanoseconds, the designer must consider both fast crosstalk and differential crosstalk.
- If signal rise times are between 2 and 5 nanoseconds, only fast crosstalk need be considered.
- If signal rise times are slower than 5 nanoseconds, slow crosstalk applies.

To calculate differential crosstalk, refer to the top graph at the left. It shows the percent of velocity difference between parallel surface conductors for the odd-mode signal and the even-mode signal, for 0.010-inch-wide lines.

The maximum amplitude of differential crosstalk equals about 50% of the signal amplitude on the active line. Of course, this amplitude would only be reached in very long lines, such as those used to prepare the oscilloscope photos on page 108. In shorter lines of practical length, differential





Oscilloscope traces demonstrate crosstalk effects. The traces result when active and passive lines run parallel for a long distance, as diagramed. The first two photos show what happens when a narrow pulse is introduced on the active line and the second set shows the result of a step pulse. The horizontal scale is 5 nanoseconds per centimeter and the vertical scale is (10 X) 20 millivolts per centimeter. The instruments used were an E-H pulse generator through a 10-decibel attenuator and a 500-ohm (10 X) passive probe through a 10-db attenuator into the 4S2 plug-in unit of a Tektronix 661 oscilloscope.

crosstalk can be calculated from the following equation:

$$\text{Differential crosstalk} = \frac{V_{ag} \dfrac{\Delta c}{C_{avg}} L_p}{2C_{avg}\, t_r}$$

where V_{ag} is the signal amplitude on the active line; $\Delta c/C_{avg}$ is the percentage of velocity difference between the differential-mode signal and the common-mode signal; C_{avg} is the average propagation velocity for the two signal modes; L_p is the length of the passive line; and t_r is the rise time of the signal introduced into the active line.

No calculation of fast crosstalk is needed. The two graphs at the left on page 107 give the fast crosstalk for lines of various dimensions.

Slow crosstalk can be determined from the fast-crosstalk graphs. Take the fast-crosstalk value and reduce that value with the following formula:

$$\text{Slow crosstalk} = \frac{[\text{fast crosstalk}] \times 2L_p}{c\, t_r}$$

where c is signal-propagation velocity, equal here to c_{avg}, the average propagation velocity.

If lines terminate in their characteristic impedance, the amplitude of all types of reflected crosstalk is less than the values for initial crosstalk calculated above, and the designer need not concern himself with reflected crosstalk.

The ratio in amplitude of the odd-mode signal to the even-mode signal changes if a resistor is added between ground and the front end of the passive line. The amplitude of slow and fast crosstalk is reduced and the amplitude of differential crosstalk is slightly increased. The changes are not impressive. The designer can keep to the calculations outlined above when the front end of the passive line is open circuit, which gives worst-case (maximum) results. Specific examples of what happens are:

- If the front end of the passive line is shorted to ground, the first two traces in the upper set of oscilloscope photos at the left will show spikes of equal amplitude. A slightly increased negative spike of differential crosstalk will result in the second and third traces of the passive line. In the same figure, the amplitude of fast crosstalk will drop to zero. However, no real reduction of fast crosstalk is achieved, because there will still be reflected fast crosstalk to contend with.
- If the front end of the passive line is terminated with its characteristic impedance, fast crosstalk will be reduced by about 50%.

Thin-film multilayers

Line lengths have been reduced below those possible in conventional multilayer boards by several film techniques. These techniques make it unnecessary to design the interconnections as transmission lines, since the wiring delays are negligible, compared to signal rise times.

Monolithic integrated circuit chips (dice) can be mounted to thin-film wiring on glass or ceramic, with the die-to-film bonds made by ultrasonic bonding or aluminum-germanium eutectic solder. Since ultrasonic bonding does not require high temperature, the substrates don't have to be glass or ceramic. The thin-film memory shown below was made by bonding chips facedown to thin-film wiring on glass. The entire memory is only a few inches long. Most of the interconnections between chips are fractions of an inch long. It was made by the Univac division of the Sperry Rand Corp. under an Air Force contract; most of the bonded devices were provided by Motorola, Inc. The production methods were previously reported.[7]

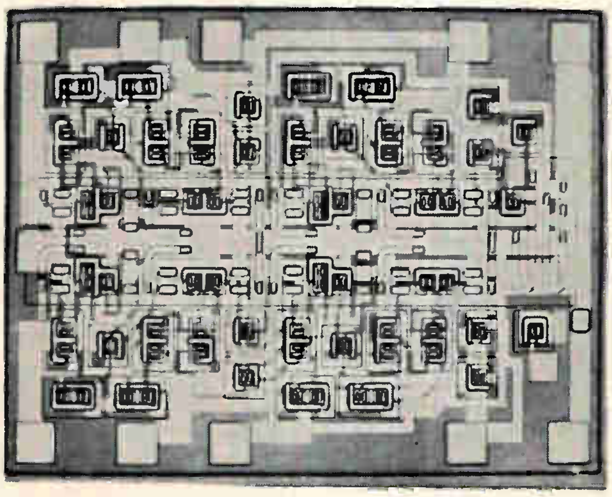
Multiple-level interconnections can be made on ceramic substrates by applying and glazing insulating layers over the conductor layers. Each layer of glaze serves as a substrate for the next conductor layer and has openings for layer-to-layer interconnection.

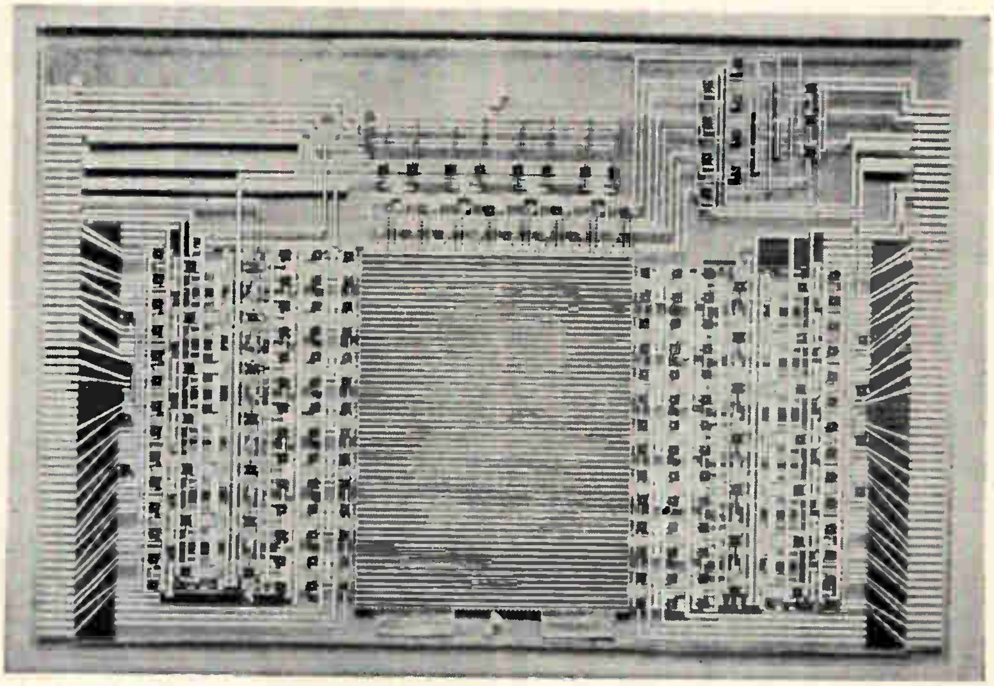
The ultimate in microinterconnection is circuit interconnection on the face of the silicon die, resulting in arrays such as that below, right. Arrays of even greater complexity will be produced as processes and material yields improve. Arrays allow integration of complex digital functions on a chip, but require multilevel metallizations to accommodate the crossovers required for high-density wiring patterns. Other interconnection methods more complex than have usually been found in IC production may also be needed.[8]

Unfortunately, logic and systems designers generally disagree about the practicality of large functional blocks. Although arrays promise faster circuitry some designers contend that wiring patterns will vary so widely that interconnections will have to be custom made. Others feel that completely functional blocks are possible. A compromise and perhaps the best solution may be techniques that allow rapid changes in the wiring of a matrix of circuits on one die. This would require computer control over the wiring layout. When a computer is being used to wire the arrays, it could also be used to design the wiring between arrays. In any case, a design and fabrication technique that allows wiring changes to be made rapidly is necessary, since wiring errors and changes will be inevitable.

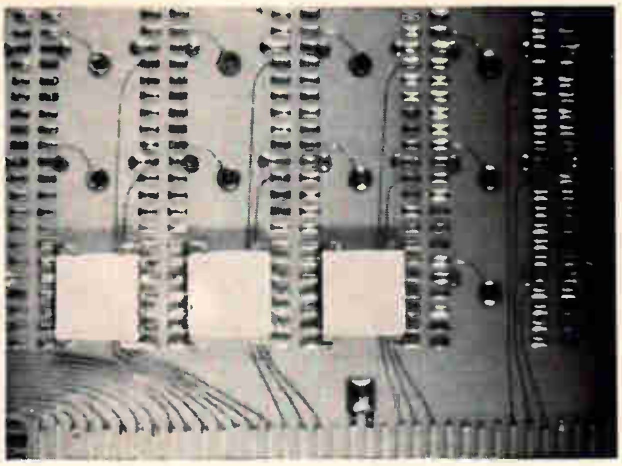
Temperature control

Another inevitability is that greater speed and packaging density produce more heat. To protect the circuits, heat must be transferred from the assembly to a heat sink at lower temperature by one of the natural means: conduction, convection and radiation. In the past, this transfer was accomplished by forced air, materials with high heat conductivity, refrigerated cold plates and similar techniques. These methods are still effective for packaged IC's. However, specifications for the device package's thermal resistance, the sink tempera-





Thin-film wiring cuts line lengths to fractions of an inch. At the right is a memory, a few inches long, made by bonding integrated-circuit chips to interconnections deposited on a glass plate. Above is a memory array of four gated storage elements intraconnected with two layers of thin-film woring; it measures 0.046 by 0.060 inch and contains 101 circuit components.



Thermal resistance of mounting techniques

190°C/watt	not inverted, not sinked
167°C/watt	inverted, not sinked
131°C/watt	thermal compound sink
88°C/watt	soldered sink

Best way of heat-sinking ceramic flatpacks is to solder the metallized package base to the heat conductor. The soldered-sink value given in the table above was obtained with the mounting method in the photo: soldering the base to a plated-through hole leading to a copper plate. The wiring pattern isolates diodes in the IC's to allow monitoring of junction temperature.

ture, or other parameters, generally place added restraints on the remaining parameters.

An ideal device package would present little or no thermal resistance, but it is about 30°C to 50°C per watt for TO-5 packages, measured at the mounting flange, and about 30°C to 40°C per watt for a ceramic flatpack, measured at the surface beneath the IC chip. The bond between the chip and the package base, a gold-germanium eutectic solder, contributes about 20°C per watt for a 50-mil chip.

The device package material is also of significance. Ceramics containing beryllia have heat-transfer coefficients nearly as high as aluminum. However, if the thermal paths of materials such as alumina are kept physically short, the over-all thermal drops will be correspondingly less and special materials might be avoided. An important system thermal drop—and possibly the one most often ignored—is the package-ambient drop.

First choice: cool air

Convection cooling with natural or forced air is always considered first, because it has proved so successful. The rate of convective heat transfer is proportional to a surface-transfer coefficient, the heat-transfer area and the temperature difference between the surface and the air at a relatively far distance. The surface-transfer coefficient increases with increased air velocity to a point governed by the air flow mode (that is, its turbulence and the subsequent effects on boundary layers) and changes in heat capacity and thermal conductivity of the air.

Heat-transfer area, the remaining parameter, must not be raised by a method that materially increases the over-all volume since that would increase interconnection lengths. A low thermal conduction path must be provided to a larger area. One technique employs strips of copper beneath rows of IC flatpacks. The strips conduct heat to a lower-temperature sink at the edge of the printed circuit board. A thermal joint compound or adhesive may be used between the package and the copper to reduce thermal resistance. However, the one-way heat flow causes thermal drops along the strip.

Superior cooling results from a plated-copper hole beneath each package to conduct heat through the board to a continuous copper sheet. The sheet can be exposed to forced-air convection, or it can conduct heat in two directions to the board's edges, or it can do both. A low thermal path from the package to the through-plated hole may be achieved with thermal adhesives or by suitably metallizing the package bottom and soldering the package to the plated hole. Results of alternate mounting methods are given in the table, left. The measurements were made by monitoring the forward voltage drops of isolated diodes within each IC, to obtain junction temperatures. The tests were performed with an experimental system: 48 ceramic flatpacks with 14 pins were mounted on each multilayer board, the boards were spaced 0.2 inch apart and air flowed across the board at a pressure of 0.2 inch of water.

Liquid cooling

As packaging density increases, air cooling and metallic heat-sinking will become inadequate. The next step seems to be immersing assemblies of packaged circuits—or even unpackaged circuits—in a liquid with low conductivity and low dielectric constant. The cooling mechanism can be natural or forced convection, as in air cooling. However, it would be better to have a liquid that boils at a safe operating temperature so that the relatively large heat of vaporization can be employed to clamp the circuit temperature at a fixed value. The vapor must then condense out on a cold plate and return to a reservoir so it can flow continuously through the cooling system.

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Complex integrated circuit arrays: the promise and the problems

Theoretical and practical obstacles to the development of high-density computer circuits that can switch at subnanosecond speeds may be overcome by compromise

By Michael J. Flynn
Systems Engineering Department, University of Illinois, Chicago

Microelectronics offers the promise of circuit modules with both high density and high speed. As many as 1,000 logic circuits may go on a single monolithic integrated circuit chip and switch at subnanosecond speeds. But this great promise gives rise to many problems that can be solved only by compromise. These compromises arise from the theoretical limitations on technology, from the practical limitations on design and manufacturing and from the implications of these limitations on computer systems of the future, which will probably be built of monolithic IC's interconnected in large arrays.

The theoretical limitations are those of reflected energy along unterminated transmission lines, power dissipation from terminated transmission lines and the behavior of semiconductor materials at high frequencies and high temperatures.

The practical limitations are the cost spread between the first and subsequent IC chips of a given design and the fact that traditional guideposts—for example, a minimum number of components—no longer are applicable.

These limitations will have a significant effect on all areas of computer system design and on computer engineering.

The author

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Switching at top speed

Computers will be built in the not too distant future with decision times (logic block delays) of 1 nanosecond. Such a speed places formidable constraints on the system designer.

In the past, switching speeds of circuits usually stayed comfortably ahead of machine speeds. Switching speed was fast enough so that sampling and other logical techniques could always compensate for the possibility of occasional false signals—at a cost of just a little more time than was required for uncompensated logic.

Now, switching speeds of circuits are approaching an upper limit. The signal propagation delay is becoming significant relative to the signal timing. This means that input conditions cease to exist before the input is properly energized, the logical compensating techniques fail, and the result sometimes is a false output.

To prevent these false outputs where unterminated transmission lines are used, an extraordinarily short distance—about an inch—must be maintained between switching circuits operating at high speeds. When a signal from A with a rise time of 1 nanosecond must switch two circuits B and C, (diagram, top of p. 112), some energy will be reflected from one of the circuits to the other. False outputs will occur if the reflected energy takes too long to travel from B to C.

The conditions for avoiding false outputs may be calculated. Assume unterminated transmission lines between the circuits, a distance, d, between B and C equal to the distance from A to B, and a signal propagation delay of 0.2 nsec per inch. (The absolute minimum delay is 0.09 nsec per inch—the speed of light—degraded to 0.2 by dielectric limitations.) If a signal reflected from B is not to cause a false output from C, then it must arrive at C no later than the time that C reaches its threshold —about half the rise time t_r. The rise time and the propagation delay place an upper limit on the distance, 2d, that the signal must travel. Thus,

$$2d < \frac{\frac{1}{2} t_r}{0.2}$$

or, equivalently, d must be less than 1¼ inches.

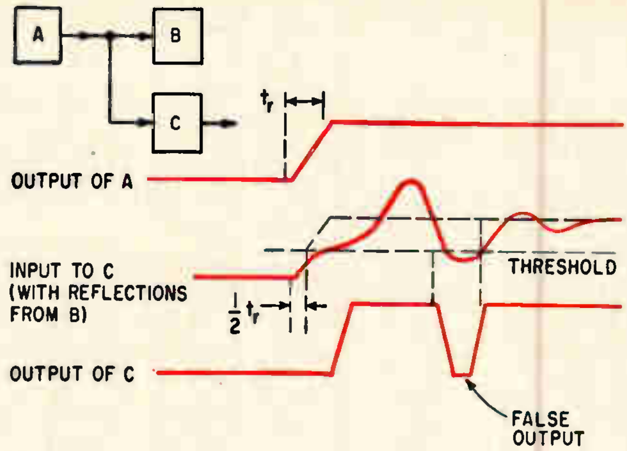
External terminations

Connections between the circuits contained on a monolithic IC chip probably will not require terminations, because chips are limited to sizes no more than a few hundred mils on each side, and the maximum line length of 1¼ inches is never exceeded. (Larger chips would present difficult registration problems in manufacturing.) But most external connections from IC to IC within the computing systems will exceed the maximum length; therefore, to avoid reflections, they will almost always require terminations. The terminating resistor and the power capability of the driver are represented by large areas on the chip—areas perhaps 100 times larger than those occupied by unterminated circuits on the chip. The area required for a bonded connection is also about 10 times greater than that of a single circuit.

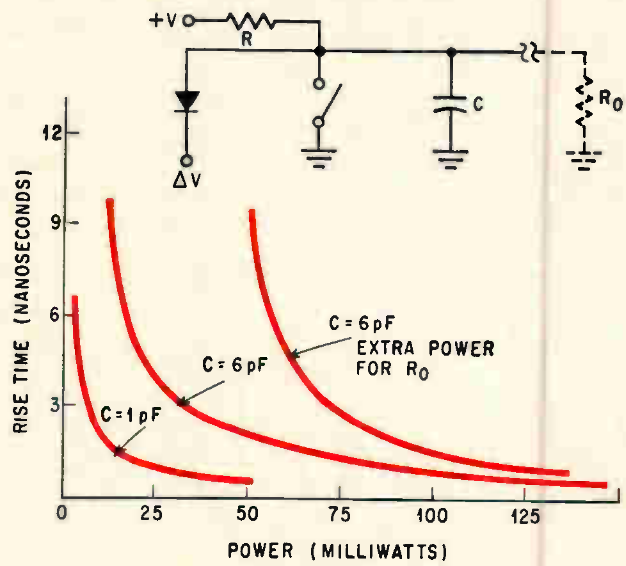
Therefore, for every external connection not made perhaps 100 or more internal circuits can be added to the monolithic array—neglecting such considerations as the topology of interconnections on a single chip.

The power dissipated by externally connected circuits is another significant factor in their design. With a 1-volt signal on a transmission line terminated with a 50-ohm resistor, the power dissipated at the termination is 20 milliwatts. The circuit supplying this power will itself dissipate two or three times that much, and a reduction in the circuit's dissipation to less than 10 mw is unlikely for reasons related to the basic physics of semiconductors. A further reduction in dissipation would be possible by increasing the value of the terminating resistor, but only at the cost of reflections on the line.

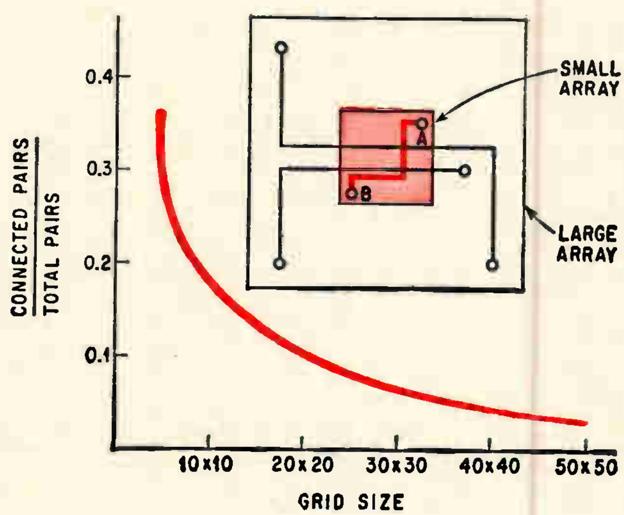
These considerations of speed and power are depicted in the curves at the right, center, which plot the rise time versus power for the same



False outputs can be generated if logic blocks operating at nanosecond speed are connected by an unterminated transmission line more than 1¼ inches long. The signal is reflected from one of the driven circuits and can cause a "spike" to appear at the output of the other circuit.



Rise time versus power is plotted for an idealized circuit operating in three different environments. The curves show, left to right, the time-power relationship when all driven circuits are on the same chip, when external circuits are driven and when there are external circuits plus a transmission line termination. In the idealized circuit, the switch represents the transistor.



Grid size affects a computer's ability to interconnect random points in an array. The ordinate of the curve is the ratio of the number of pairs of points connected, to the total number of unique pairs. As the curve shows, the bigger the array, the sooner (proportionately) the computer designing the connections runs into trouble. The inset diagram shows how interconnections in a large array help block those in a smaller array. If the longer connections shown are made first, they take up some of the space that would otherwise be available for the direct path between points A and B.

idealized circuit operating in three different environments. The lowest curve refers to circuits connected on a single chip. The driving circuit must provide only enough energy to switch the driven circuit; total load capacitance is taken as 1 picofarad.

The second curve shows what happens when external loads must be driven, with an additional 5 picofarads appearing in the transmission line.

If the line is longer than 1¼ inches, then a terminating resistor must be placed at the end of the line; the third curve relates to power in this case.

The idealized circuit is shown in the inset with the curves. The switch represents a transistor; the fan-out is 5 and the load is assumed to be a pure capacitance (plus the terminating resistance, where used). Such a circuit is closely approximated by any high-speed device driven by a constant current; the current is equal to the capacitance multiplied by the rate of change of voltage, or

$$I = C\frac{\Delta v}{\Delta t}$$

The total capacitance is the sum of C_i, the input capacitance of the driven circuit; plus C_s, the capacitance of the connection to the transmission line; times the fan-out—the number, n, of loads driven. Then

$$\Delta t = t_r = \frac{n\,(C_i + C_s)\,\Delta v}{I}$$

But the available current is also equal to the voltage divided by the total power from the supply, so that

$$t_r = \frac{[n\,(C_i + C_s)\,\Delta V]\,V_s}{P_s}$$

In this equation, the numerator is a constant and the denominator is the independent variable; therefore the curves are hyperbolas.

The power shown in the curves is peak power for the capacitive load. If the circuit is considered to have a duty cycle, then the power requirement might be reduced. However, high-speed circuits are usually current-switching circuits, which switch current among various paths rather than on and off. The current is always on somewhere in the circuit; therefore the duty cycle is 100% and no such power reduction would be correct.

Circuit designs have been predicted with a 1 nanosecond rise time, adequate fan-out and power dissipation as little as 1 microwatt,[1-4] but these predictions are all based on the use of unterminated transmission lines. Therefore the circuits can be used only within individual chips, where the 1¼-inch maximum length is not exceeded.

Liberal discounts for quantity

Compromises arising from practical limitations are based primarily on the cost of producing the chips in quantity. The total cost of the first IC chip of a given design may be as much as 1,000 times greater than that of subsequent chips of the same design. Automatic production facilities do not reduce this cost spread—indeed, they could make it greater.

Efforts are being made, however, to reduce the spread by designing arrays of identical circuits on a chip, with the interconnections generated by a computer program. The program takes into account the function to be performed by the chip and the number of defective circuits on the chip, and routes the wiring accordingly [Electronics, March 21, 1966, p. 144]. Each chip is effectively custom-wired, and no two chips are necessarily alike even in a production run of many hundreds of functionally identical chips.

However, this approach has large disadvantages. For one thing, the bypassing of defective circuits when the chip is wired is not a guarantee of chip reliability, because chip failures are caused as much by wiring defects as by circuit defects.[5]

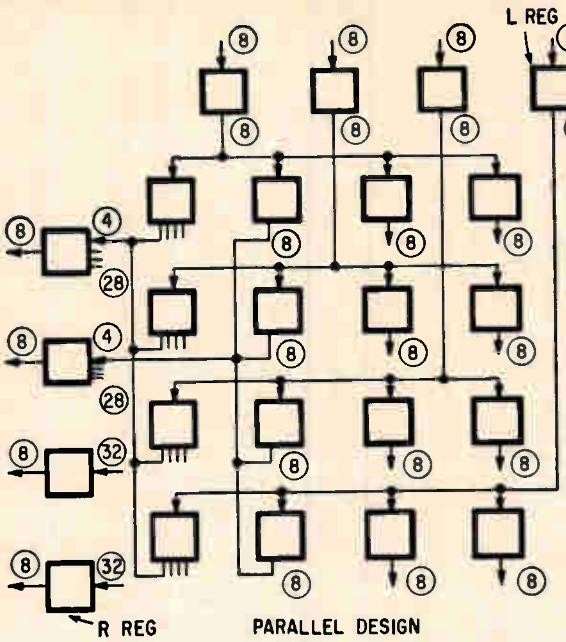
For another, the computer time required to generate the interconnections is long and increases rapidly as the wiring becomes more complex. And the larger the array, the more likely is the computer's inability to connect some of the points, as in the bottom graph on the opposite page. The curve was generated by a computer program that simulated the connecting of random points on a series of very simple grids on two planes—horizontal connections on one and vertical connections on the other, with jumpers between planes as needed. In the simulation, only one line could pass through a channel defined by two adjacent rows of points. The shape of the curve is explained, at least in part, by the fact that a large array of points is actually several small arrays both interconnected and intraconnected. Connections between small arrays (interconnections) are in addition to those within arrays (intraconnection), complicating the task of linking any two given points in a small, monolithic array of circuits.

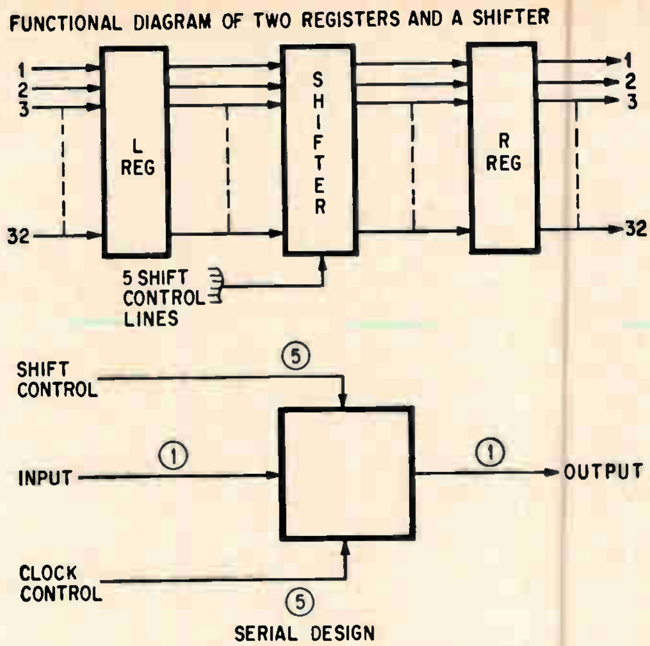
The difficulty of generating interconnections on large arrays by computer is borne out by experience. For instance, the back-panel wiring for International Business Machines Corp.'s System 360 computers, which is mostly printed wiring on a two-sided board, takes about a half-hour to lay out using a large-scale computer. The boards are 8⅜ by 12½ inches and contain 300 to 400 circuits connected among a grid of 65 by 72 points.

Technological implications

The problems inherent in external connections, power dissipation and the cost of making replicas imply that, in the future, logic design will be in terms of functional units on a chip. The principal characteristics of these functional chips will be size and cost, and will have a profound effect on computer systems and engineering.

The size will be determined by the number of external connections. Logic minimization, number of circuits and other considerations that have been





Lots of chips may be required to package a relatively simple design, such as the register-to-register shift shown here, unless traditional design techniques are carefully reviewed. In this example, it would be unwise to assume that the shifter should operate in parallel. A simple high-speed serial shift arrangement can be packaged on only one chip. The circled numbers show the number of lines in each group.

important previously will not be significant.

The cost will be established by the number of different kinds of chips rather than by the number of circuits on a chip or even by the number of chips. This is certain to have a profound effect on computer organization.

Systems implications

A computer is essentially an array of data paths, hardware for executing arithmetic and other algorithms, instruction decoders and controls and memory. (Input-output equipment is not considered here because it is basically electromechanical.)

Data paths are intrinsically regular and repetitious. The problem in future designs will be to divide the path into segments that will contain a maximum number of circuits with a minimum number of external connections, the ideal situation for using large IC arrays.

For instance, a machine may contain two registers L and R, each 32 bits long, as shown in the diagram above. One of the machine's instructions shifts the contents of L into R, as shown at the top of the diagram, under control of 5 lines that determine how much the data is displaced in R relative to L. The chips from which the machine is built are of two types—a 12-pin chip with 1,000 circuits and a 24-pin chip with 100 circuits. This corresponds approximately to the previously mentioned trade-off of 100 circuits for a pin.

The ideal design would be a single chip with 69 pins—32 input, 32 output and 5 control. But no 69-pin chip is available. If parallel operation is assumed, then each register must be divided up into several pieces. If each piece of register L is pin-limited, then it contains 12 register positions and 24 pins. Four positions on the third chip are not used. If complete utilization of the chip is desired, then only 8 register positions and 16 pins per chip can be used. Either way there should be plenty of room left on each chip, unless the register is built with some unusual circuits.

The shifter itself can be built from 16 chips each with 8 inputs from register L, 8 outputs to register R and 5 inputs for the control lines. But this presents a problem in designing register R, which must now accommodate 4 inputs per bit from the shifter. Therefore all the available pins are used, however the chips contain only 4 register positions —that is, the chips are pin-limited. And a chip with only 4 register positions has hardly any circuits at all on it. The discussion above has assumed that the registers and the shifter operate completely in parallel, which has been the normal approach.

But if the data could enter L and leave R serially, one bit at a time, with the requirement that the assembly operate at 32 times the data rate of the system of which it is a part; then the entire set of two registers, shifter, and control logic could be accommodated on a single chip with 12 pins and several hundred circuits, as shown at the bottom of the diagram. Therefore the serial approach is more efficient in terms of microcircuits, but is easily overlooked when only traditional design techniques are applied.

The large number of circuits and the higher speed of the serial approach—32 times the main computer system speed—will require more power than the parallel design. On the other hand, the fact that the entire subassembly fits on one chip, avoiding a great many external connections, could produce an over-all power saving.

An example of execution hardware similar to that of the shifter could be presented. The problem would be the same—one of slicing. But the real challenge in design is in terms of restating the algorithms so that microelectronic circuitry can be used with maximum efficiency. The challenge requires a logic designer to acquire the skills of a systems designer.

Flanking a tough problem

Instruction decoders and controls present a much more difficult problem, because conventional designs contain no repetitive patterns like those in data paths and arithmetic units and have many external connections. The secret of design is in the application of a control memory, as diagramed at the right. The control memory may be a read-only memory, and will contain a long list—hundreds or thousands—of microinstructions. Each program macroinstruction from the main memory addresses a sequence of microinstructions in the control memory. Each microinstruction in the sequence describes the state of the entire machine during its next cycle, and prescribes the next microinstruction to be used, perhaps contingent upon certain conditions that may arise during the machine cycle. The last microinstruction in the sequence returns control to the instruction-fetching mechanism for the next instruction from the main memory.

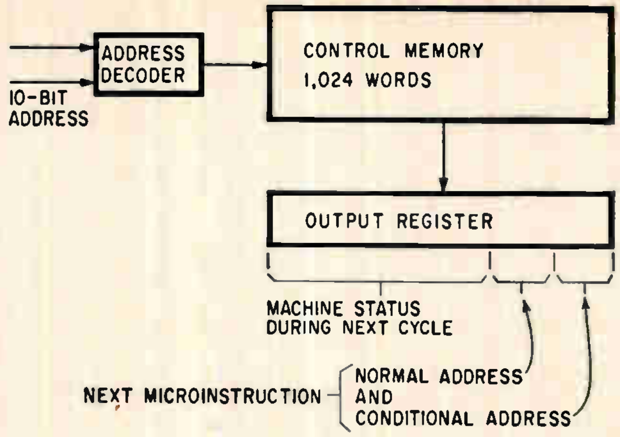
The control memory divides easily into segments because its only external connections are the word-address inputs and the bit outputs. There is little or no interaction between bits in the control memory.

The same considerations apply both to the main memory and the control memory, insofar as implementation in microelectronics is concerned. The principal consideration is the economic advantage of various data storage technologies—such as ferrite cores, or thin films.

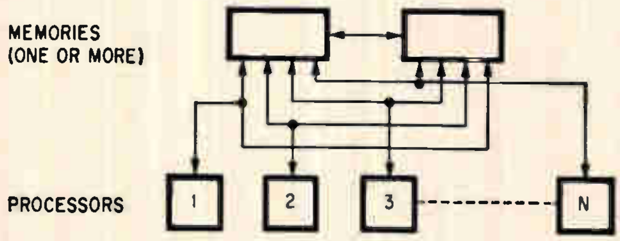
On the other hand, associative or content-addressed memories may become available as major features of future computers through the application of integrated circuits. An associative memory, as in the block diagram on page 116, is interrogated with a known word or portion of a word; any and all words stored in the memory that match the interrogating word are retrieved. Data is not retrieved by its address, and therefore data need not be sorted before storing. Logical ability in each memory cell, as well as storage ability, is characteristic of associative memories.

Relatively small associative memories have been built with various technologies, such as multi-aperture ferrite cores, cryotrons, and various thin-film techniques. The logical flexibility of microelectronics makes large associative memories practical.

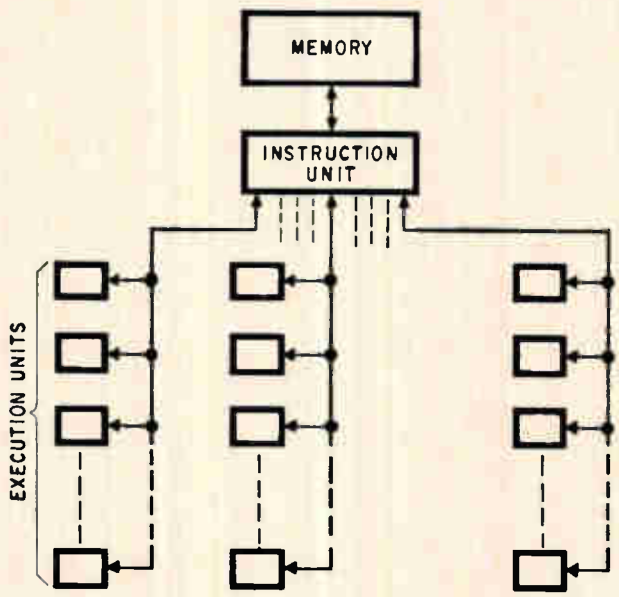
Among other things, dividing an associative memory into sections that can be built with IC's is easier than dividing a conventional memory, because there are no address inputs.



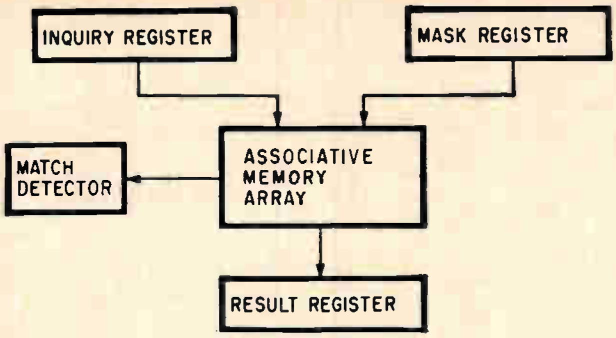
Control memory simplifies the task of laying out instruction decoders and controls in microelectronic circuitry. Each macroinstruction from the computer program causes the execution of a sequence of microinstructions from the control memory; each microinstruction sets up the entire computer for the next machine cycle of a few hundred nanoseconds.



Multiprocessing system, which contains many computers all connected to a common memory, can solve complex problems at a speed inconceivable with single systems. The individual processors, built with microelectronics, can be substantially slower than large single machines, reducing the design problems encountered with speed.



Solomon computer, another advanced multiprocessing system. Each individual execution unit works on a small part of a large problem; all of the execution units and all of the problem parts are identical, so that all can operate simultaneously under control of the single instruction unit. The computer resembles an advanced system being designed at the University of Illinois; the same man directed both projects.



Associative memory, from which information may be obtained by content instead of by location, can be built easier with microelectronics than with any other technology, because of the logical flexibility of microelectronics.

Most operations in future machines will be checked for errors with an almost insignificant amount of additional hardware. The checking would be possible without extensive external connections, and a record of faults could be stored on each chip.

Cheaper multiprocessing

The same economic considerations that apply to multiple chips also apply on a different scale to multiple machines. If the first chip costs $1,000 and subsequent chips cost $1, machine organization will be affected. In the same way, if the first machine costs $1 million and subsequent machines cost $1,000, system organization will be affected. Part of the effect may be in degrees of multiprocessing hardly dreamed of today—the connection of many machines to a common memory to participate in the solution of a common problem as in the bottom two diagrams on page 115.

If an entire data processor could be built on a single chip, a thousand machines could easily be put to work on a single problem.[6] Each individual machine might be radically slower than present full-size machines, but mounted in such an array, the performance of the system would be dramatic. The problems of line termination and power dissipation may or may not exist in these machines. Fast machines require fast circuits, but slow machines do not necessarily require slow circuits, where the termination and dissipation problems are most pronounced. Thus, a slow machine might profitably be built of fast circuits that remained idle much of the time; if the circuits made economical design and operation possible.

A few such systems already have been built or are being designed. Examples are the Solomon computer of Westinghouse Electric Co.,[7] and the Illiac IV, now being designed at the University of Illinois Digital Computer Laboratory [Electronics, April 4, 1966, p. 36].

Computer designing computers

The effect of microelectronics on computer engineering will be as impressive as the effect on systems. Obviously if subsequent chips are a thousand times cheaper than the initial chip, the first chip will have to be right; and words like "debugging" and "engineering change" will have to be stricken from the vocabulary. Two tools to help make this possible are being developed: automation of design and simulation of design.

Automation of design has made rapid progress in the past 10 years and more can be expected. In the future, once a design has been specified, computers will entirely control the record-keeping, optimization and parts procurement. They will take over the tasks of making the topological layouts of a chip and the interconnections between chips, and the output data will include everything needed to control production equipment. Because there will be no room for error, no human interference will be tolerated; but all data will be checked extensively prior to production. Before all this can happen, however, there must be substantial improvements in the current technology of each of the computer's tasks. Now, for example, a man can still lay out a chip better than a machine can.

Simulation of design on a computer will be the final step in checking a design before committing it to production. The simulation must examine all timing and logic problems, all interactions between chips, and finally the operation of the entire machine. The simulation will include many hours of processing on existing machines—at a substantially lower cost than the redesign of even two or three chips after production is under way.

Eventually, automation of design and production could lead to the ultimate in machine maintenance —replacement. When a machine failed, it would simply be thrown away and replaced. The penultimate is the replacement of major portions of the machine when failures occur. In either case, the part with the failure must give a positive indication of the failure so it can be recognized properly.

When hardware no longer is a major cost item, it seems reasonable to assume that all pluggable modules in a machine can be made to show this positive indication—even of an intermittent failure. This could eventually lead to a machine repair by the customer, without calling a serviceman.

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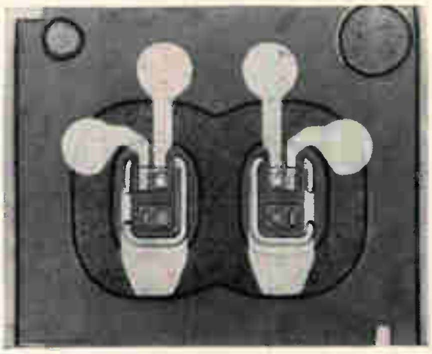

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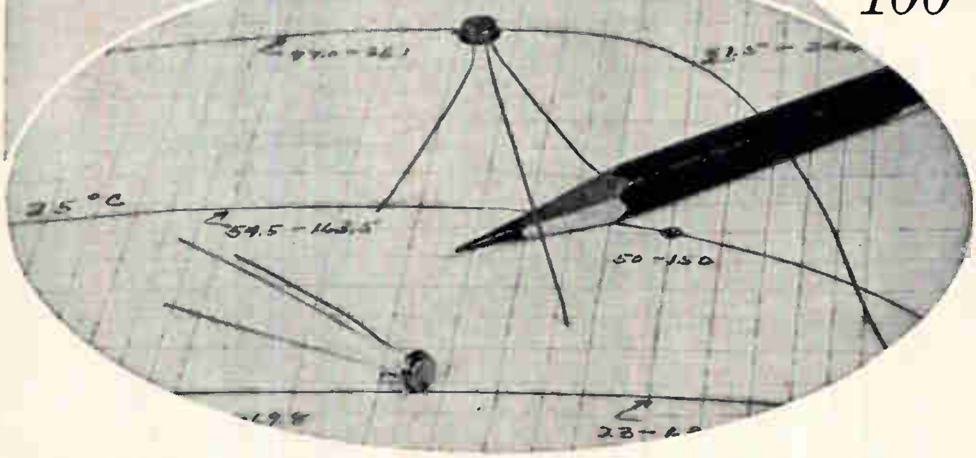

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		°C	°C/W	@100°C Case	Volts	Volts	Volts	@I_C = 0.5A V_{CB} = 2V		@I_C = 0.5A I_B = .05A	@I_C = 0.5A I_B = .05A	V_{CB} = 30V	V_{CB} = 60V	mc
		Max.	Max.	Max.	Min.	Min.	Min.	Min.	Max.	Max.	Max.	Max.	Max.	Min.
MHT5001	TO-46	200	25	4	60	40	8	50	150	1.2	0.35	0.1		50
MHT5002	TO-46	200	25	4	80	60	8	50	150	1.2	0.35	0.1		50
MHT5003	TO-46	200	25	4	100	80	8	50	150	1.2	0.35		0.1	50
MHT5004	TO-46	200	25	4	140	100	8	50	150	1.2	0.35		0.1	50
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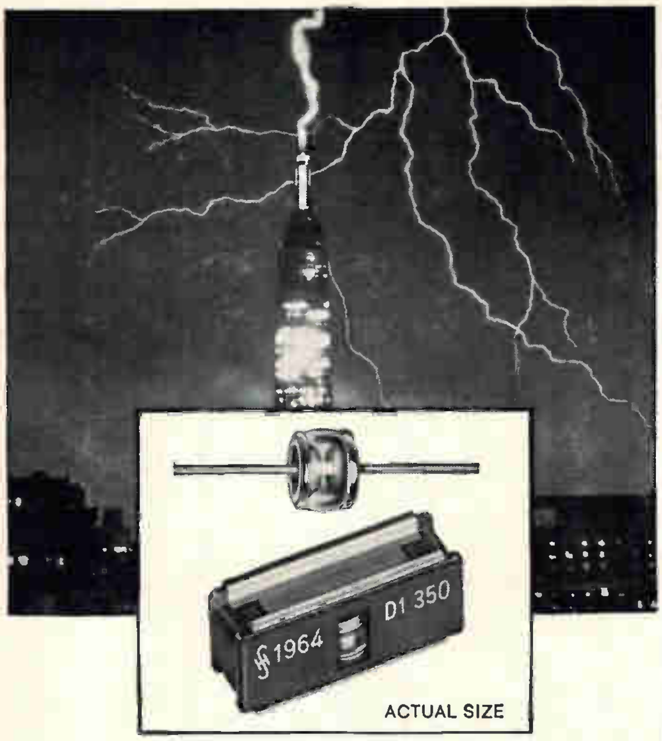

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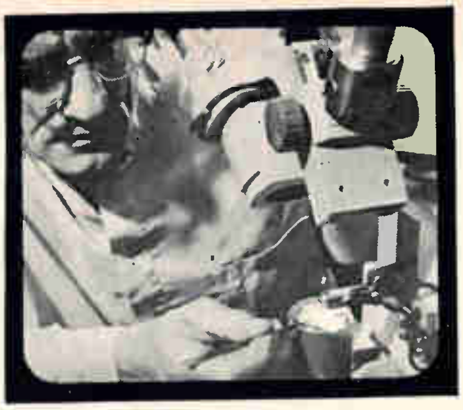

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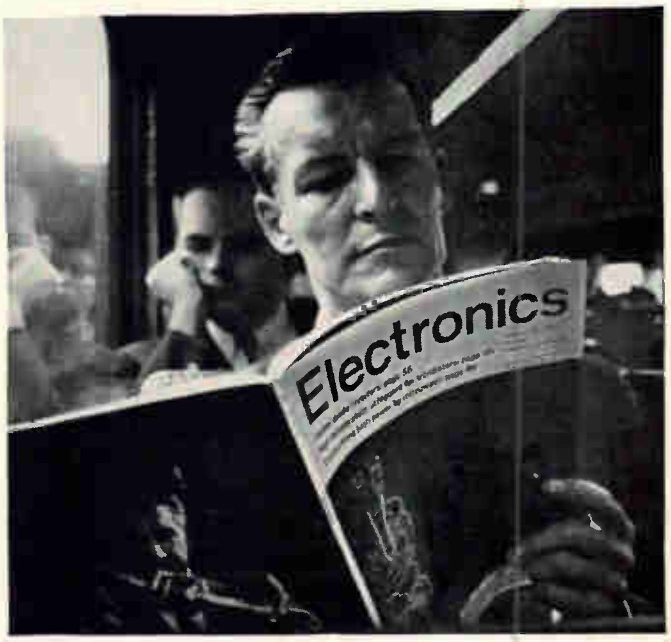

Great editorial is something he takes to work

(What a climate for selling!)

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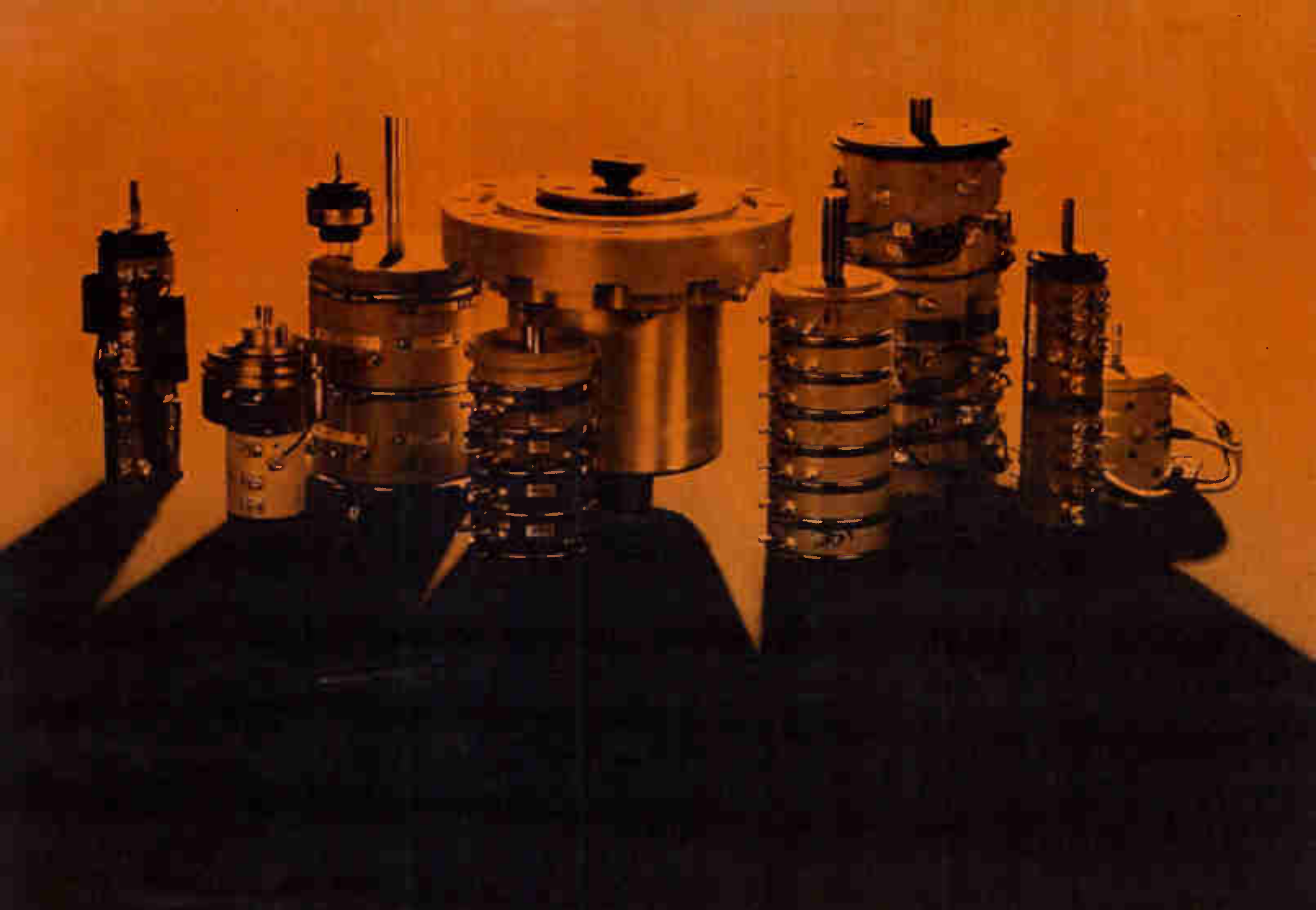

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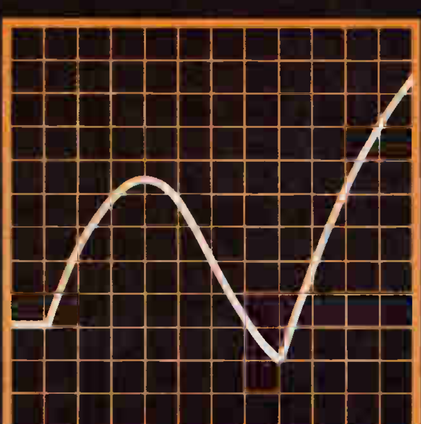

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P.S. Lou remains all heart. He left more clues to help you find him. How many do you see in the picture? Check Lou's first set of clues in the June 13 issue of this magazine if there aren't enough for you here.

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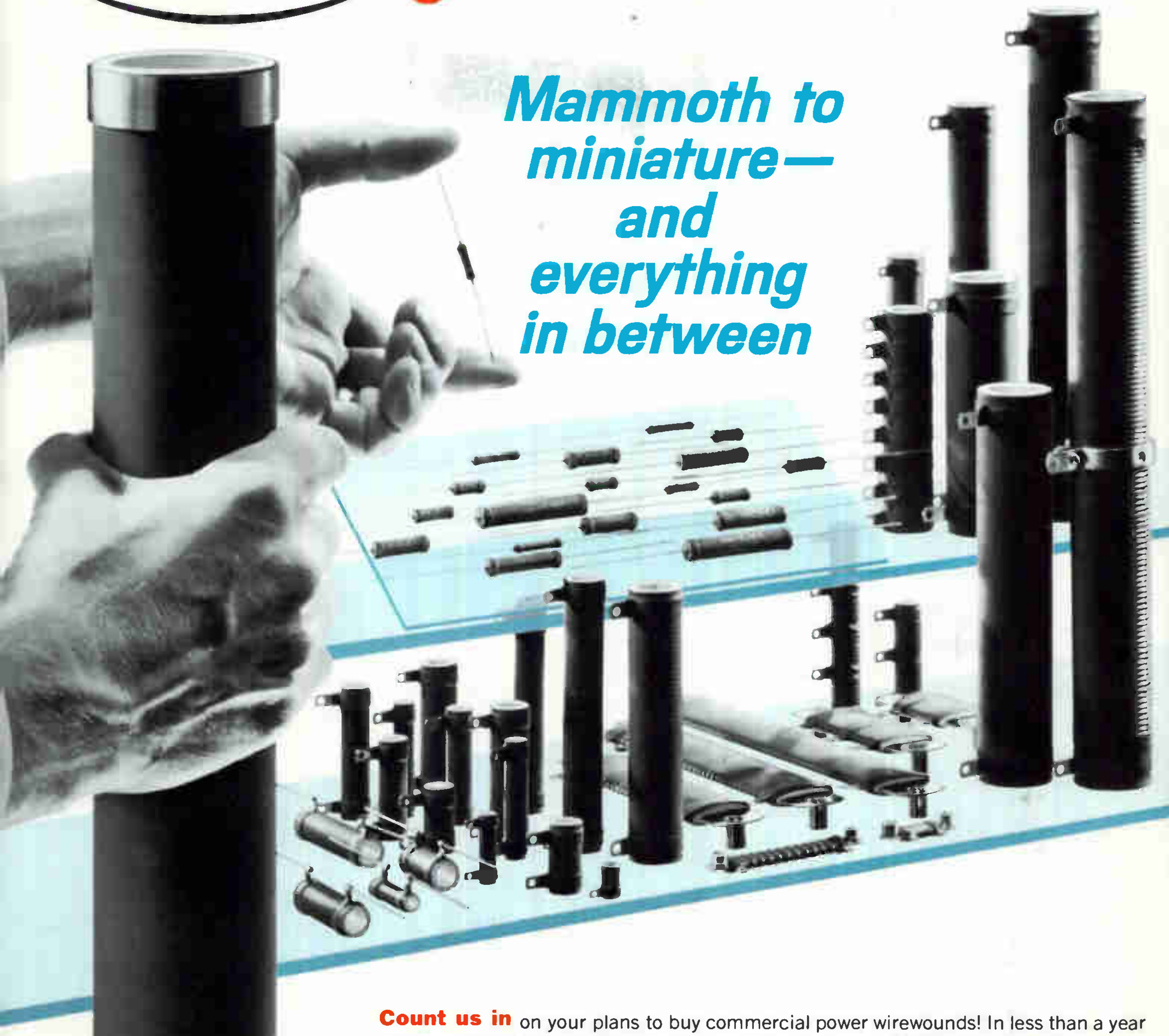

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DALE ELECTRONICS, INC. DALE
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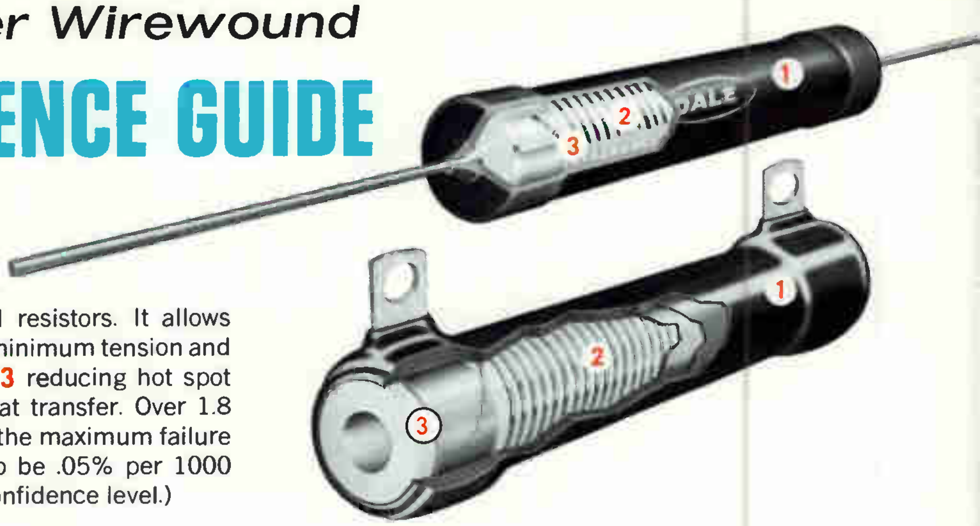
QUICK REFERENCE GUIDE



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 **CW** Axial Lead	Axial leads. For applications requiring high performance at low cost	MIL-R-26 RW-57, 58, 59	4.25-13 watts	.1 ohm to 273K ohms	Body Dia. .188 to .375″ Body Length .500 to 1.781″ Leads 1.5 to 2″	Leads	Terminals	±5%
 **HL** Tubular	Silicone-coated general purpose wirewound resistor. A direct replacement in both cost and performance for vitreous enamel types.	MIL-R-26 RW-29, 30, 31, 32, 33, 35, 36, 37, 38, 47	5-225 watts	.1 ohm to 1.3 Megohms	O.D. 1/4 to 1-1/8″ Length 1-10½″	Lugs	Push-in bracket or thru-bolt	±5% (10% below 1 ohm)
 **NHL** Non-Inductive	High frequency circuits and applications requiring low inductive effect and minimum distributed capacity	None	5-225 watts	1 ohm to 90K ohms	O.D. 1/4 to 1-1/8″ Length 1-10½″	Lugs or Leads	Push-in bracket or thru bolt	±5%
 **HL** Flat	For limited space requiring high power-to-size ratio. Vertical or horizontal stacking.	MIL-R-26 RW-20 thru RW-24	24-95 watts	.1 ohm to 150K ohms	Length 1¼ to 6″	Lugs	Spring push-in	±5% (10% below 1 ohm)
 **HLM** Miniature Flat	For limited space, high power-to-size requirements particularly in high vibration areas.	None	10-20 watts	.1 ohm to 51K ohms	Length ¾ to 2-1/16″	Lugs	Thru mount with eccentric spacers	±5% (10% below 1 ohm)
 **HLA** Adjustable	For resistance or voltage adjustment	MIL-R-19365C RX 29, 32, 33, 35, 36, 37, 38, 47	12-225 watts	1 ohm to 100K ohms	O.D. 5/16 to 1-1/8″ Length 1½ to 10½″	Lugs	Push-in bracket or thru bolt	±5% (10% below 1 ohm)
 **HLT** Tapped	For voltage divider networks	None	11-225 watts	.1 ohm to 1.1 Megohms	O.D. 5/16 to 1-1/8″ Length 1½ to 10½″	Lugs	Push-in bracket or thru bolt	±10% each section (±10% total)
 **HLW** Tubular	General application where terminal wires are required for direct electrical connection	None	5-20 watts	.1 ohm to 80K ohms	O.D. 1/4 to 7/16″ Length 1 to 2″	Lugs with terminal wires	Terminals, thru bolt or push-in bracket	±5% (10% below 1 ohm)

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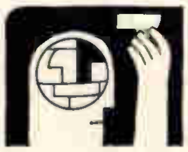

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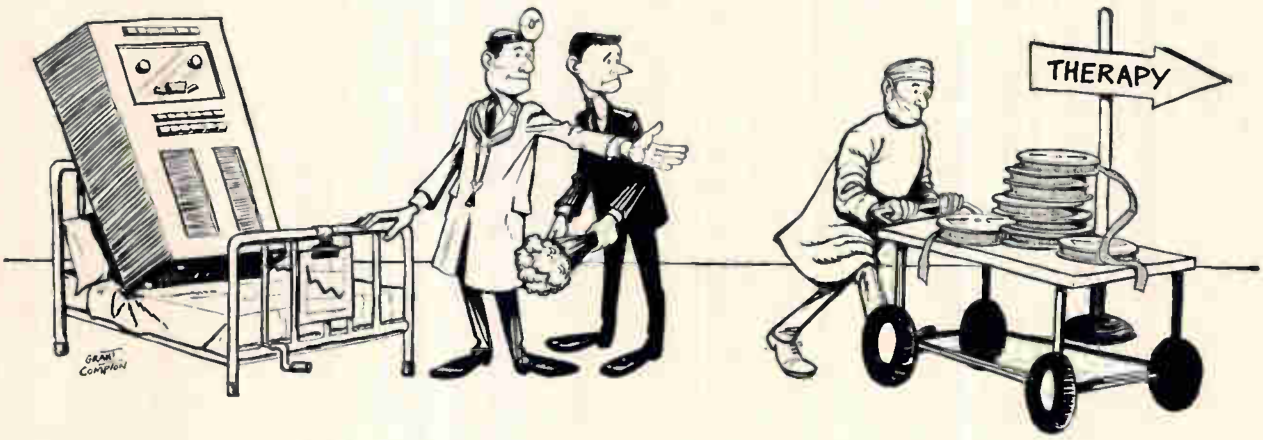
Computers



Third generation computers in trouble as complaints mount on software

Data processing industry is facing a revolt by irate customers unhappy about the hardware and software for the new computers; IBM's troubles with its 360 series is typical

By Walter Barney
San Francisco Regional Editor

All is not well in the world of third generation computers and the data processing industry is beginning to feel the heat as customers' complaints pour in. For the most part, disappointed customers have been discretely quiet, but the city of Los Angeles griped in an open meeting last month about its new International Business Machines system 360 computer.

The complaint against the giant of the industry highlights the problems being encountered with the software, and to a lesser extent with the hardware, of the new computers. But the findings of an extensive study by Los Angeles shows that the problems being experienced by the city appear to be general in business and industry. The report says, "current reports in industry indicate that other manufacturers of third generation computers are also having hardware/software problems."

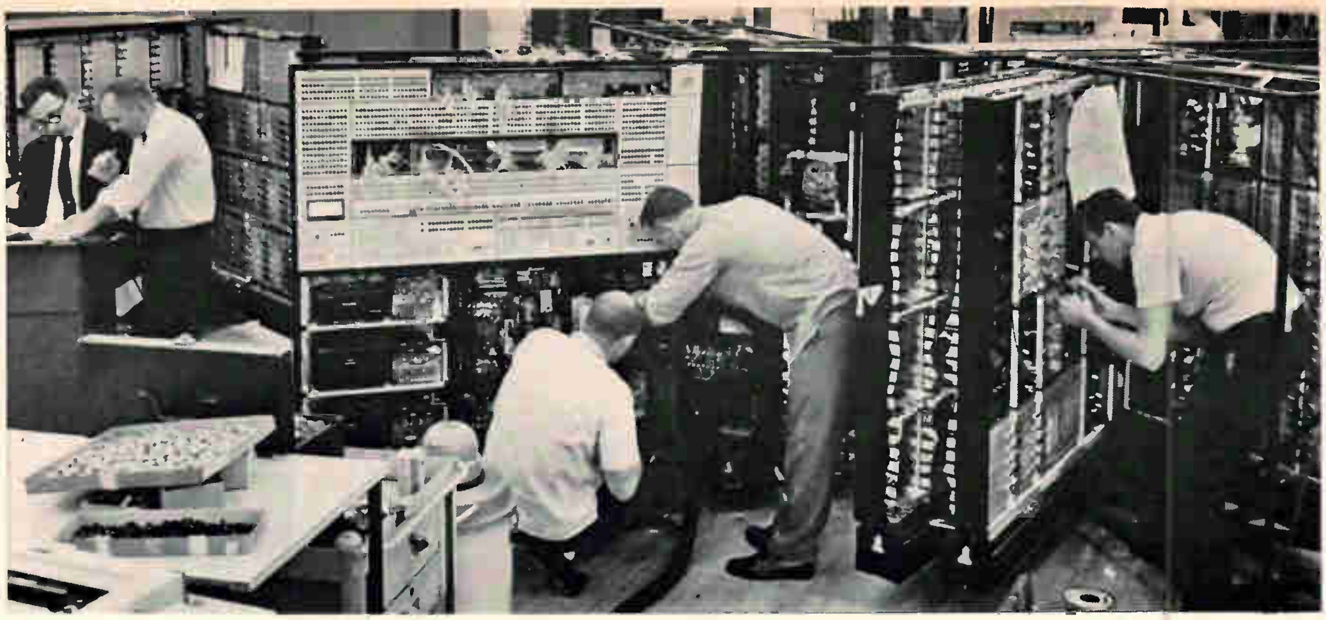
IBM installed the 360 model 30 computer in Los Angeles last Dec. 15 and the basic software on Jan. 27. It declared the computer operational on Jan. 28, but the city charges that the computer was not operating effectively on that date nor has it operated well since. Los Angeles therefore rescinded its acceptance of the machine, stopped its $14,600 monthly rental payments and demanded credit for two monthly payments it had made.

T. Tamaru, general manager of the city's Data Service Bureau, says the difficulties with the computer lie in the Cobol compiler, which translates business-oriented programing language into computer language, and in the diagnostic program to uncover bugs. Both are supplied with the computer.

Not big enough. According to an IBM spokesman, the Cobol compiler in the 360 system in Los Angeles is too small for the computer and the jobs it's called on to do. The E level compiler, as it's called, is the smallest Cobol planned for any computer in the 360 series and the only one built so far. It is designed to use only a limited amount of core storage and as a result, says IBM, it has not been entirely satisfactory for systems with large core capacities.

IBM says it will have larger and faster compilers within six months to a year as well as multiprograming and communications support. The firm says the larger compiler also will solve the diagnostic problems, and indicates that until then, the Los Angeles system probably will not be improved.

One of Tamaru's recommenda-



Software problems aren't affecting sales of third generation computers. Manufacturers are hard put to meet orders.

tions, adopted by the board, was that the Data Service Bureau continue its tests until Aug. 1 before making a final decision. "Definite progress is being made by IBM in respect to the current hardware/software problem," said his report to the bureau.

System downtime since Jan. 28 has been much greater than normally expected of a new computer, but the improvement in May and June over April indicates that definite progress is being made. In February and March alone, IBM made more than 100 engineering changes in the computer itself, and supplied two new versions of the software modules—the Cobol compiler, the linkage editor and the input-output sort and merge device.

Costly delays. The city, however, has declared that if IBM cannot make the system work by Aug. 1, Los Angeles will "take the necessary actions to secure all remedies available." Under an amendment to the basic contract for the computer, IBM has been paying $100 liquidated damages per day since Dec. 16, because it has not yet delivered the entire software package.

Los Angeles does not want to abandon the 360 if it can help it. "If IBM clears up the software problem in a couple of months, it will still be ahead of the other computer makers," Tamaru told the Board of Administration. He said, "If we switch now, any other computer we get might have the same problems, and we would have to start all over again."

IBM has not been so lucky with other customers. The Aerospace Corp. recently canceled its order for three models of the 360 in favor of a Control Data Corp. 6600, but refuses to discuss the action.

I. Cobol is the culprit

The Cobol problem was discovered by the city's library registration project to automate all technical library services, such as maintenance, overdue books, library cards, cataloging, book orders, and circulation among branch libraries. When the 360 failed to do the job, the public library hired an outside consultant who, after meticulous reprograming, got the system to operate, after a fashion.

It was this experience that led the data processing bureau to suspect that part of the difficulty lay with Cobol. The library found that when its program was fractured into eight or nine partial programs, it could be run on the 360. The entire program, however, would not work, and it was suspected that the trouble was in the size of the memory core.

"The amount of magnetic core storage required for Cobol programs far exceeds original predictions," says the bureau's report. The library wants to buy time on a 360 model 40 or 50 to see whether a bigger machine will accept its program.

Shouldn't happen. In addition, Cobol is not fast enough. Any 1401 program emulated on a 360 will run faster than it will on a 1401. But when, for purposes of comparison, the library matched the 1401 emulation performance against Cobol performance, the emulator still proved to be up to twice as fast. This report flabbergasted the IBM representative at the Board of Administration meeting. "It just shouldn't happen," he said. "The 360 should be four times as fast as the 1401 emulation."

One of the board members replied, "'should' is the characteristic word of this whole program."

But his harshness was only momentary. The Board of Administration appears sympathetic to IBM's problems, and even though the city believes that it has legal grounds for action against the company, it does not want to take it. "We aren't out to pin anybody against a wall," Tamaru said. "Nailing IBM for damages won't make the computer work."

Who's fault? The Board of Administration is not familiar with computer technology, and takes a gingerly approach to the 360 problem. C. Erwin Piper, the administrative officer, insisted that the Data Service Bureau double check its own programing efforts to make sure that it was not mere unfamiliarity with the system that was causing the problem.

Tamaru assured the board that these checks were being made, but he said later that the inability to get clear results from the diagnostic program has led to further confusion. "When a problem comes up, we can't tell if it originated in the hardware, the software, or the specific program," he said.

II. An old tradition

At least one computer user took the software difficulty in stride. "Manufacturers are traditionally late with software," said Jerry Hanna, assistant to the manager of the Computer Center Department at the Systems Development Corp. of Santa Monica, Calif.

SDC, which is in the business of writing computer programs, got a system 360 model 50 last October—minus the software. "Fortunately," Hanna says, "we were always skeptical of the software and we didn't depend on it. We're in the software business and could write our own, though it's a hell of a bother."

It was IBM's hardware slippage that surprised Hanna. Last fall, it slipped two to four months on delivery of the original systems, and this spring there was about three months slippage on delivery of the model 92, the biggest of the family. SDC has ordered a model 65 to replace the 50; it was supposed to be delivered in April, but has slipped three months. Still, the company has put in an order for a 360 model 67 to be delivered in January.

Sales pitch. With the giant computer producer so tangled up, other computer manufacturers are naturally scrambling to take advantage of it. Control Data Corp. reportedly will deliver a computer to the Boeing Co. that CDC was using itself just to get a toehold in the aircraft company. Boeing had been waiting for several 360 models from IBM and says it has not canceled these IBM orders.

Availability of a 6600 reportedly was a factor in Aerospace's decision to cancel its 360 orders. Industry sources say that CDC had sold a 6600 to a French nuclear research company, but could not get an export license for it under United States policy which forbids the sending abroad of computers large enough to be of use in developing a hydrogen bomb. CDC had a computer just standing on the platform, so to speak, and Aerospace grabbed it.

These instances may be isolated, but they could also indicate that IBM, which had the West Coast aerospace industry all sewed up, is in for some strong competition.

Big money in Omega

Electronics firms expect millions of dollars in orders when Navy's Omega navigation system begins guiding planes and ships

By Seth Payne

Washington News Bureau

The electronics industry is anticipating a $100-million to $200-million market for the Navy's very-low-frequency Omega navigation system that will blanket the world with only eight stations. Loran A, transmitting at 2 megahertz (high frequency) requires 80 stations to cover 15% of the world. Besides the gain in range caused by going to vlf, Omega is also more accurate than loran A—it will have errors of one-half nautical mile; loran A's best is four or five.

The Navy estimates that it will spend about $125 million to put Omega into operation with $65 million for stations and another $60 million for receivers for all ships and submarines and most planes. In the last two years about $14 million has been paid out with the big spending to start with a jump to $40 million to $50 million in 1968. But the Navy isn't the only market.

Big market. The United States commercial market and the foreign commercial and defense markets could far surpass the domestic defense market. The Federal Aviation Agency has worked closely with the Navy throughout the program to ensure that commercial craft can navigate with it. The British, French and Norwegians already are cooperating with the Navy, and Japan and New Zealand recently expressed an interest in the system.

The demand for electronic receivers is expected to remain high for several years after the system goes into operation as more and more countries adopt it for both commercial and military service. The predicted cost of receivers ranges from about $1,000 to $100,000 each, depending on how automatic the equipment is. The accuracy is the same for low-cost or deluxe receiver units.

The system. The range of Omega's eight stations will be so great that signals from at least three stations can be received at any one place on earth. The intersection of the lines of position derived from these three stations provides a geographical fix. The lines of position are determined by receivers in the craft that measure the time each signal takes to travel from each station to the craft. Precise atomic clocks with cesium beams, developed by the Naval Electronics Laboratory, measure the time span to within a few microseconds.

The Navy began experimental operations of Omega stations this spring in Hawaii, Trinidad, Norway and Forestport, N.Y. The New York station is to be moved to Michigan for the final operational system. During the tests, the stations transmit at 3 kilowatts, but this will be stepped up to 10 kw for the operational system.

The Navy currently has 35 Omega receivers in operation aboard ships, submarines and shore facilities to test the transmission stations. Tests are scheduled this month with four aircraft, including a helicopter, that are being fitted with receiver units from the International Telephone and Telegraph Corp. ITT is developing 10 common receiver units—for use aboard ships or aircraft—under an approximate $2-million contract. Submarines will be able to receive Omega signals while submerged to depths of about 30 feet.

Test planes. Flight testing of two prototypes of computer navigational sets built by Lear Siegler, Inc., will begin this fall. One will be installed in a Navy aircraft and the FAA is putting the other in one of its planes. Initially, the system will be tested at subsonic flight, then at supersonic speeds up to mach 2.

The equipment includes a receiver built by ITT and its own computer and coordinate converter. This will provide automatic readout of the aircraft's latitude and longitude and will tell the pilot the course and distance of his destination. The information can be fed directly into an automatic pilot, and a map display may be added to show the pilot visually where he is all the time.

Years of plans. Work on perfecting Omega began with a proposal by J. A. Pierce of Harvard University about 1950. In addition to the receiving units built by ITT, the Northrop Corp.'s Nortronics division has built 10 shipboard receivers under a contract for about $1 million.

A number of agencies are working on Omega: the Naval Electronics Laboratory is working on the transmitting stations and performing propagation studies; the Naval Research Laboratory is conducting aircraft reception studies and additional propagation studies; the Navy Oceanographic Office is preparing navigators' charts and tables; the FAA is working out aircraft antenna configuration. The Coast Guard eventually will operate the stations.

The eight transmitting stations will be located in Trinidad, Norway, Hawaii, Minnesota, and in the areas of the Philippines, Mauritius (off southeast Africa), Australia and the southern part of South America.

Other systems. Omega will replace the loran A system but it won't be the only system in operation after 1972. The Navy also plans to keep loran C's 29 stations. Loran C is even more accurate than Omega and can spot a position to within 60 feet. The Navy also has a navigation satellite system, formerly called Transit, which is even more precise although details are classified.

Both loran C and the satellite system are used extensively by the Polaris missile submarines for the precise fixes they require for launching their missiles.

Memories are made of these

Growing single-crystal ferrites around gold wires and etching toroids from permalloy foil produce new forms of magnetic memories

By Thomas Maguire
Boston Regional Editor

Engineers want to build shoe box-size computers for space and airborne systems but, to do that, they've got to pack more storage bits into smaller computer memories.

For the past year or so, techniques for producing smaller memories have been contending like horses in a race. One grabs the lead, falls back, and then pushes forward again.

Because they are cheap, magnetic cores have dominated computer memories despite their bulk and the lengthy, manual procedure required to build them. But lately, magnetic films, plated wires, integrated circuits, cryogenic structures and silicon on sapphire which can be batch fabricated quickly and in quantity, have been threatening core memories.

Now the threat is lessening. Ways are being found to batch fabricate core-type magnetic memories by chemical processes. At least two companies are working to fabricate such memories for less than a penny a bit, in the very small sizes that mean low power and high density.

In California, the Autonetics division of North American Aviation, Inc., is experimenting with chemical vapor deposition of single-crystal ferrites over thin-film gold wires. The research could lead to batch fabrication of memories with micron-sized cores. The technique might eventually permit production of thin-film inductors in sizes compatible with integrated circuits. For want of suitably small inductors, integrated circuits are still unsuited to many linear applications. Improved microwave components are a third possibility—single-crystal ferrites now have to be grown, then machined, to produce microwave devices.

In Boston, LFE Electronics, a division of Laboratory for Electronics, Inc., is nearing pilot production of memories made entirely by printed-circuit techniques. The cores are etched from thin foils of magnetic alloy sandwiched between printed wiring. An entire memory plane—hundreds of cores—can be produced as a unit.

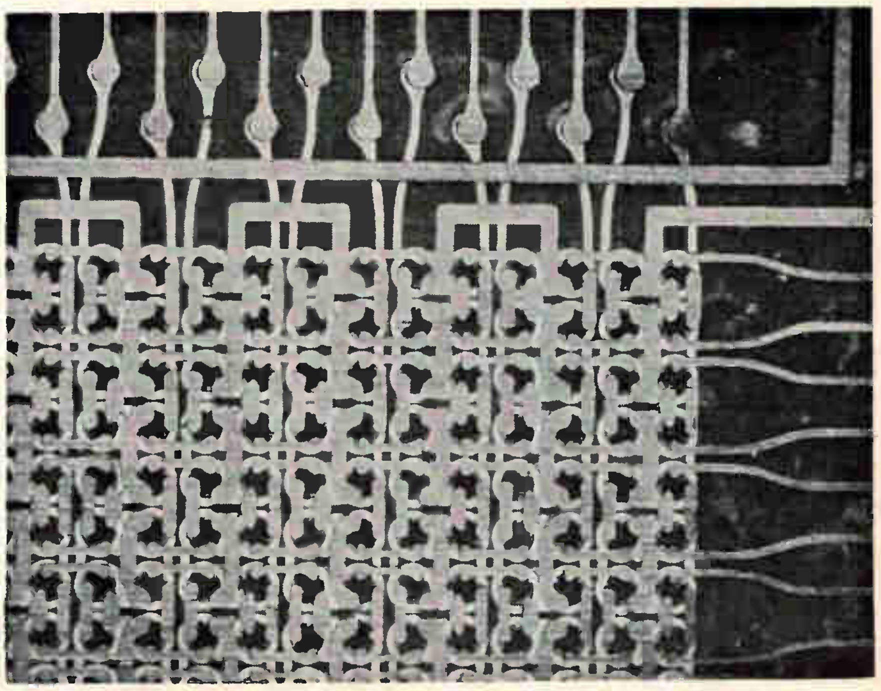
This basic process, in development for several years, is now being extended to experimental fabrication of cores with adjustable magnetic weights. LFE hopes this process will lead to the production of extremely large but economical adaptive memories — needed for self-learning computers the Air Force wants for signal and pattern-recognition applications.

I. Deposited ferrites

"It is a new form of magnetic material for memories," says John L. Archer, research engineer at Autonetics, of the single-crystal ferrites. The project is believed to be the only approach today employing the single-crystal characteristics of ferrites to shrink the size and improve the performance of memories.

Archer and his colleagues hope to produce nondestructive readout (NDRO) memories composed of high-density planes requiring voltages as low as 3 to 5 millivolts and drive currents of only 50 to 100 milliamps. This would permit production of associated integrated circuitry as batch-fabricated arrays [Electronics, March 21, p. 144].

"Our development goal," says



Section of an etched-permalloy memory plane. The toroids are the small, round structures partially hidden by the copper wiring.

Archer, "is 10,000 bits per square inch"—a density comparable to that of the diode arrays made of silicon on sapphire already developed by Autonetics [Electronics, May 30, p. 152A]. "All the bits can be produced in one operation," Archer adds, so the technique obviously lends itself to batch fabrication.

Reversible domains. One advantage of depositing the ferrite as a single crystal enclosing the memory wiring is that conductor paths align with the ferrite's magnetic-vector direction. The magnetic domain walls are completely reversible, so readout from the memory can be nondestructive.

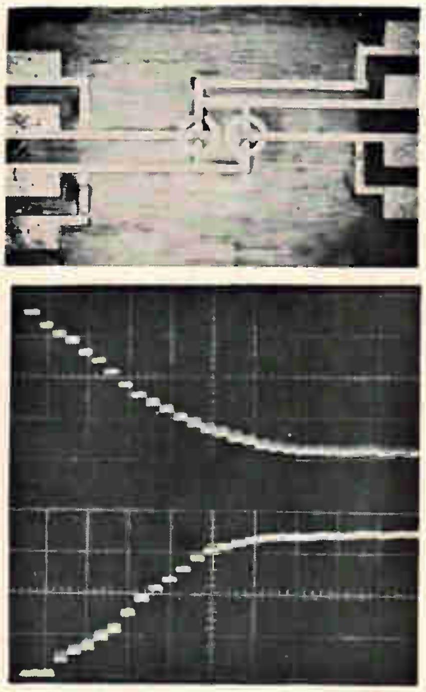
For readout, a pulse of current in one wire discloses the state of flux closure. When this interrogation current is shut off, the domain walls return to their original state. To change the state irreversibly, the combined current from two coincident wires alters the flux closure. The first operating mode could be used to read data stored in the crystal and the second to store new data.

Chemical vapor deposition. Ferrite crystals are grown up to 100 microns thick around gold wires up to 50 microns thick. First, about 50 microns of manganese-iron ferrite are formed on a substrate of single-crystal magnesium oxide. The gold is vacuum deposited and another 50 microns of ferrite are added to encapsulate the gold wires.

The ferrite is deposited in a T-shaped reactor made of quartz tubes. Metal halides react with water to reduce the halides to ferrite. Besides manganese iron, nickel and cobalt ferrites have been fashioned on magnesium-oxide seed crystals. The reactor is equipped for the introduction of different halides at specific temperatures, plus oxygen and inert carrier gases.

One of the experimental structures made by Autonetics is the 4×4 array of memory elements shown in the photograph at the right.

When he reported the process at the First International Conference on Crystal Growth in Boston last month, Archer explained that the process had not yet been perfected. Cleavage of the manganese oxide presents some problems and care must be taken that the thermal coefficients of the MgO substrate and the ferrites nearly match. If too much oxygen is used in the reduction process, free bromine and hydrobromic acid byproducts will etch the conductors. Deposition rates vary between 10 and 25 microns an hour.



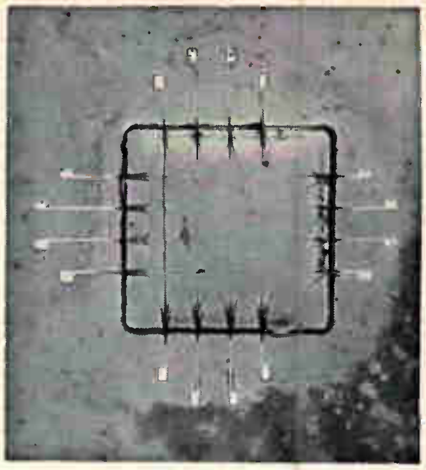
Magnetic adaptive component for computers that learn is a pair of etched toroids (top). Lower photo shows its positive and negative adaptation.

II. Etched cores

Three batch - fabrication techniques—etching, plating and evaporation—make LFE Electronics' etched-permalloy memory planes. One wiring layer is etched from copper foil, toroids are etched from permalloy foil, the interconnection mesas are built up by plating and another wiring layer is evaporated and plated, resulting in the structures such as the segment of a plane shown on page 135. LFE's Harrison W. Fuller has directed technique development for several years.

LFE leans heavily upon lithographic techniques originally devised for printing. For example, the registration methods which keep the layers of the planes aligned are mechanical, not optical, because mechanical registration is faster and less expensive.

Two models. Three Air Force agencies sponsor the development programs. This month, the Avionics Laboratory at Wright-Patterson Air Force Base in Ohio will get the first model of a low-power memory designed for airborne and missile systems. It has a capacity of 1,000 words of 30 bits each. In September, Rome Air Development Center in N.Y. will receive another demonstration model containing 8,000 16-bit words.



Experimental model of ferrite memory plane that Autonetics made by chemically growing ferrite crystal around gold wires.

The larger model will have a read-write cycle time of 2 microseconds, consume less than 10 watts of power, weigh 5 pounds and cost less than 10 cents a bit to produce, complete with associated circuitry.

The first major goal of the program is a memory containing 100 million bits. Improvement in techniques to permit construction of such a memory is being sponsored by the Manufacturing Technology division at Wright-Patterson.

Split-frequency selection. Cost—on a production basis two years from now—would be 0.2 to 0.3 cent per bit. This mass memory would weigh about 400 pounds, consume 200 watts, occupy less than 5 cubic feet and read or write in 20 microseconds.

"Our fundamental limitation is speed," says Thomas L. McCormack, manager of development at LFE's solid state laboratory. Ferrite cores can operate in 0.5 microsecond in a linear-select organization, while the permalloy takes about 1 microsecond. But, McCormack adds, the permalloy offers a 10-to-1 advantage in power consumption and its operating current is only 50 to 80 milliamperes compared with 500 ma for ferrite.

"This makes it easier to make permalloy memories compatible with integrated circuits," he says.

LFE plans to use conventional coincident-current writing in its random-access mass memories, but a novel two-frequency technique handles the reading. Two frequencies—one for columns, the other for rows—produce a combined field at the selected bit. Detecting the phase of the signal on the sense line reveals the state of the bit.

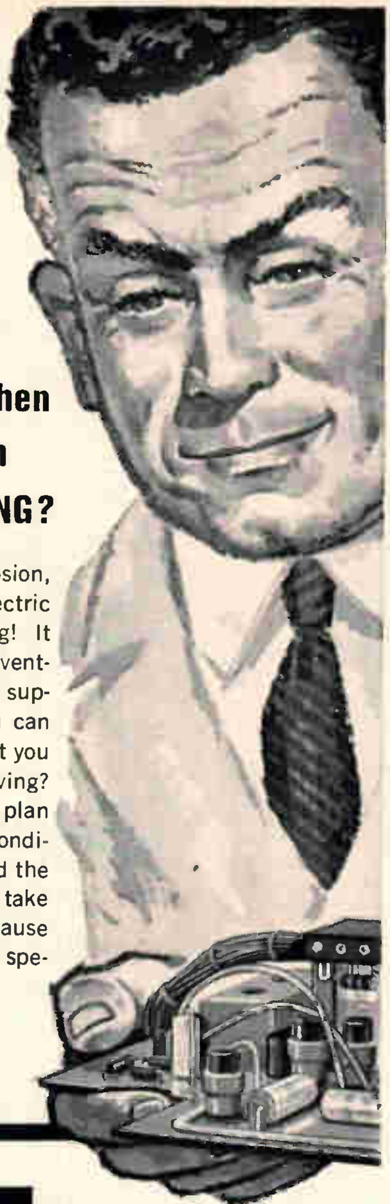
More speed, more power. This method allows LFE to put 256×256 bits on a single plane, compared with the usual 64×64 for ferrite cores, and makes readout nondestructive. Also, writing does not interfere with reading.

Etched memories could be made to operate in less than a microsecond, LFE believes, with linear organization and toroids made of a material with higher coercive force than permalloy. However, the cost in circuitry and dollars would be higher. Keeping the power low enables the memory to work with relatively cheap IC's. Stretching cycle time from 2 microseconds to 12 microseconds in the 8,000-word model slashes power consumption from 10 watts to 1.7 watts.

Adaptive memories. A lack of an inexpensive analog memory element constitutes one of the major barriers to development of self-learning computers. They have to be mass produced, because the computers require vast arrays of memory elements.

The Avionics Laboratory is sponsoring LFE's attempts to produce adaptive classifiers made up of pairs of etched toroids. Each of these adaptive elements would have many possible states—30 to 50 resolvable levels. These would be assigned weights depending upon what the computer learns in its efforts to classify signal patterns. Shown on page 136 is such an element and its learning curve.

LFE's work updates research in learning systems carried out for several years at Stanford Research Institute [Electronics, Sept. 15, 1961, p. 20 and June 8, 1962, p. 20]. Stanford tried to do it with tape-wound toroids and electrochemical cells, which are relatively slow and costly.



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$200-million Mark-2 plum to Autonetics

Most significant avionics buy of year will keep engineers and production lines busy for next seven years at giant California electronics complex

By Robert Henkel and William Hickman

Electronics Washington Bureau

To employees at Autonetics, it was even better than if their California Angels were to win the World Series. From project engineers to the president, everyone at the North American Aviation division in Anaheim, Calif., was wearing a broad smile after the Air Force declared Autonetics the winner in the Mark-2 avionics system competition.

The happy faces were more than justified. The hard-won victory gave the company a program that ultimately will amount to more than $200 million and will keep engineers and production lines busy until at least 1973 on what is called the most significant avionics buy this year.

Winning also erased deepening frowns at the sprawling California facility, which is sometimes billed as the largest single electronics complex in the world. Autonetics, which had seen its employment skyrocket to some 35,000 employees in early 1964 because of such programs as Minuteman, the Hound Dog missile guidance system and the radar for the F-104 aircraft, has been dropping people steadily for the past two years as these programs were completed. Employment had dipped to about the 20,000 level when the good news came in late last month.

Losers in the final Mark-2 competition were the Sperry Gyroscope Co., a division of Sperry Rand Corp., Great Neck, N.Y., which recently signed the contract for the Navy's Integrated Light Attack Avionics System (Ilaas) and the Hughes Aircraft Co., Culver City, Calif., which currently is developing the trouble-plagued Phoenix missile system for the Navy's F-111B.

Mark-2 avionics will go into late production models of F111A.

The Mark-2 system, which will go into the Air Force version of the F-111, will combine the aircraft's various radars, computers, displays, and inertial navigation into one integrated electronics system. This approach stems back to a May, 1963, directive from Eugene G. Fubini, then Deputy Director of Defense Research and Engineering. He ordered the military services to develop modular, integrated electronic systems and to quit putting together "collections of black boxes." Out of this has come the Navy's Integrated Helicopter Avionics Systems (IHAS) and Ilaas and the Mark 2.

Now rolling off the assembly line at General Dynamics Corp.'s Fort Worth, Tex., plant, the F-111A is being equipped with the Mark-1 avionics system, actually a collection of black boxes assembled in the traditional way. The Mark 2 will be phased into later production F-111A fighters.

I. Total package

Autonetics will soon get its first chunk of money, some $39.8 million, to cover research, development, test and evaluation, and production of long lead time items. The contract—fixed-fee for both development and production—is described as a type of "total package" contract, wrapping development, production and provision of spare parts into a single contract. The contract also carries a harsh "liquidated damages for late delivery" clause, calling for heavy penalty payments by the contractor if delivery dates are not met.

The Air Force is insisting on having an operational Mark-2 system ready by the summer of 1969, says Major Thomas A. Anderson, Mark-2 project officer in the Pentagon—not a prototype system but a production version of the entire system, he emphasizes.

On-schedule delivery of the avionics is crucial because the F-111A fighter-bomber is already flying and the FB-111, the strategic bomber version, is slated for its first flight next year. The FB-111 will carry the SRAM, a short range attack missile now under development at the Martin Co., Orlando, Fla.

Big orders. Current Pentagon planning calls for about 500 F-111A Air Force fighter-bombers, some RF-111 reconnaissance models—probably 25 to 45, and not more than 300 FB-111 strategic bombers. Great Britain also has said it will buy about 50 F-111's. It is believed that General Dynamics, which is building the Air Force models, and the Grumann Aircraft Engineering Corp., Bethpage, N.Y., which is producing the Navy version, have orders, firm and tentative, for about 1,400 aircraft, including prototypes and spare parts for them.

The Mark-2 go-ahead by the Air Force will bring joy also to other manufacturers who will build major subsystems. None has been selected as yet, but Autonetics is expected to subcontract between 50% to 70% of the Mark-2 dollars. Autonetics has authority to select suppliers, but the Air Force says it will be up to General Dynamics, as prime contractor on the F-111A, to make sure that Autonetics builds the Mark 2 "in the best and most economical way."

II. Subsystem awards

The competition for the major subsystems currently shapes up this way:

- Inertial navigation set, including platform and its computer: Autonetics is said to have no serious competition.
- Doppler radar: In the running are the Canadian Marconi Co., Montreal, and the GPL division of General Precision, Inc., Pleasantville, N.Y.
- Central computer complex containing two identical general-purpose digital computers, one for navigation and the other for weapons delivery, either air-to-air in the Mark 2 or air-to-ground in the Mark 2B—used with the bomber version's SRAM. The computers will have 16,000-word memories, expandable to 32,000. The International Business Machines Corp., Armonk, N.Y., and the Univac division of Sperry Rand are competing for the computers, with Univac said to have the edge.
- Attack radar: Competing are Autonetics and the General Electric Co., Utica, N.Y. Autonetics is said to be a sure bet because the Air Force wants the Autonetics microelectronics radar. GE supplied the radar for the Mark-1 system and is expected to get a piece of the Mark-2 pie in the form of an upgraded version of its radar for backup.
- Signal converter: Autonetics and the Kearfott division of General Precision in Little Falls, N.J., are bidding for this.
- Heads up display: Competing for this equipment are the Norden division of United Aircraft Corp., Norwalk, Conn., and Elliott Brothers, Ltd., of London.
- Vertical situation display: Sanders Associates, Inc., Nashua, N.H., and Norden are after this one.
- Horizontal situation display: In the running are Computing Devices of Canada, Ltd., Ottawa, an affiliate of the Bendix Corp., and ITT Gilfillan Inc., a subsidiary of the International Telephone and Telegraph Corp., Los Angeles.
- Multisensor display: Being bid on by Sanders and Norden.
- Storage management system: Competing for this subsystem are Lear Siegler, Inc.'s Instrument division in Grand Rapids, Mich., and Technical Measurements Corp., North Haven, Conn. This digital inventory unit tells the pilot how many missiles he has remaining.

III. Mark 2's future

The pacing item on the Mark 2 is the Autonetics attack radar, according to the Air Force. The microelectronic, multimode radar, which is in the XR45 family of lightweight airborne radars at Autonetics, requires still more research, an Air Force spokesman said. The first radar in the family, the XR45, has 231 monolithic and 691 hybrid microcircuits. In initial tests recently [Electronics, May 30, p. 26], the XR45 recorded only three failures in 256 operating hours, including 64 flights totaling 79 hours. Autonetics is also proposing one of its XR45 family, the R57, for the Ilaas system.

Calling the Mark-2 design "conservative state of the art," Major Anderson optimistically predicts that the system could be used in the 1980's without major changes. The principal differences between the Mark-2 and the initial Mark-1 avionics package are changes in the central computer complex, including a shift from an analog to a digital system, improved navigation and attack radar and an upgraded display complex.

The Mark 2 will weigh about 1,000 pounds and will have a volume of some 40 cubic feet.

Interface. Not a part of the Mark-2 system is the terrain-following and avoidance radar now being produced for the F-111A by Texas Instruments, Inc., Dallas. TI has been awarded a relatively small contract to upgrade the system for use with the Mark 2.

The Mark 2 also does not include the communications gear for the aircraft nor the electronic countermeasures equipment (ECM). Part of Autonetics' job will be to make sure of a good interface with this equipment, including the ECM, with the navigation radar.

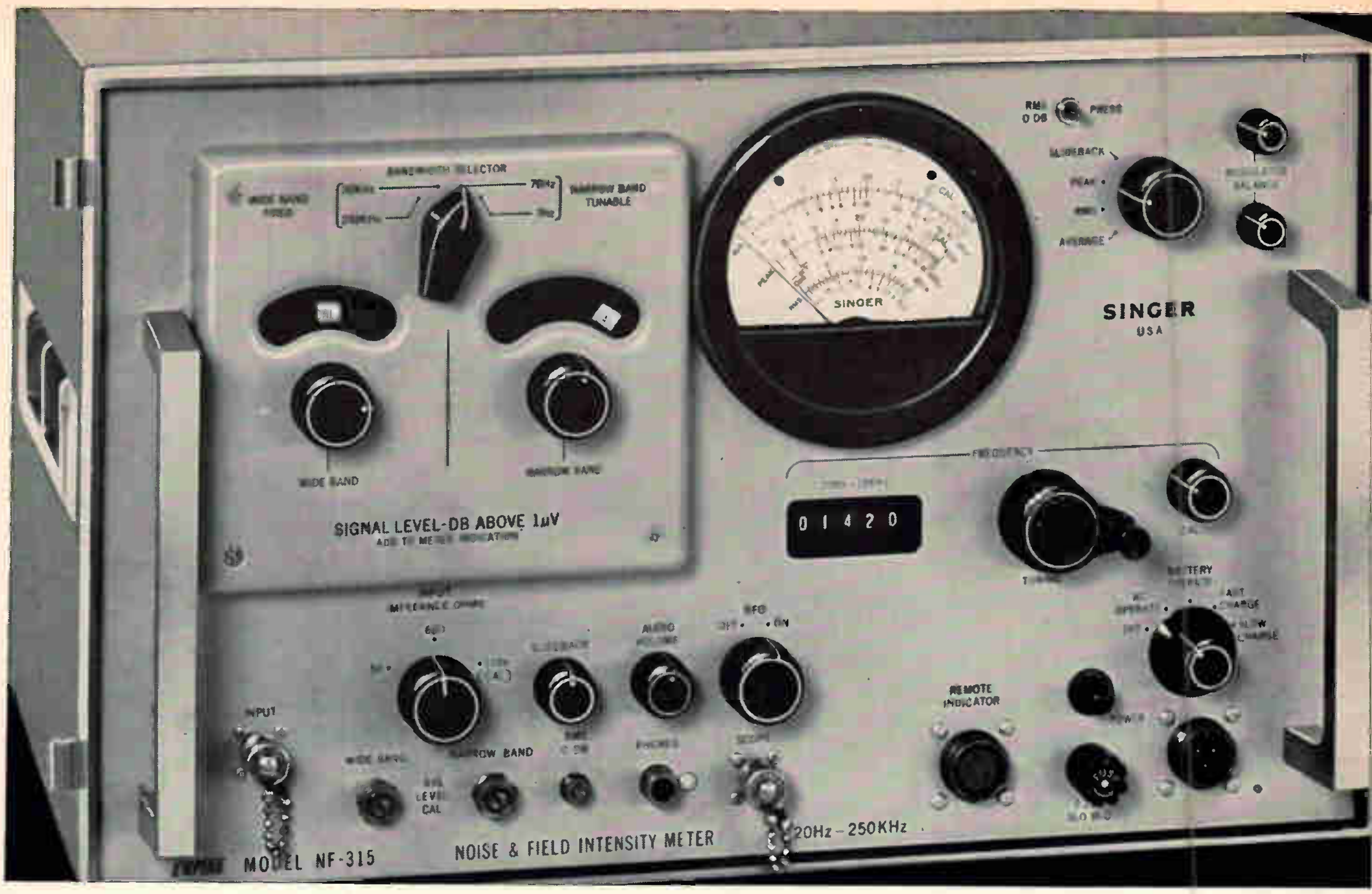
The doppler navigation radar set will be used as a backup to both the inertial system and the weapons delivery system.

Finding faults. One of the main requirements in the design of the Mark 2, spelled out by the Air Force, was to reduce the ratio of maintenance-man-hours to flight hours. The Mark 2 will incorporate automatic fault-finding techniques good enough to detect and isolate failures in 95% of all cases with self-testing techniques. This approach and the modular Mark-2 design will permit the use of relatively unskilled repair personnel that may be found at small air fields not equipped with large amounts of test gear.

The system will also display subsystem or component failures in the cockpit to the two-man F-111 crew. In case of a failure, the pilot can switch to a different mode of operation for his avionics and continue the mission.

For example, the navigation and weapons delivery computers both have excess capability not normally used. This excess capability could be switched to handle the job of a faulty system and keep the mission going.

The extra storage capacity in both digital computers also is used in automatic fault-finding. The reliability of the system is not based on strict equipment redundancy, but instead on the "federated systems approach," which allows for "graceful degradation." Modularization will go down to very small throwaway modules in many cases.



Great editorial is something he takes on a business trip

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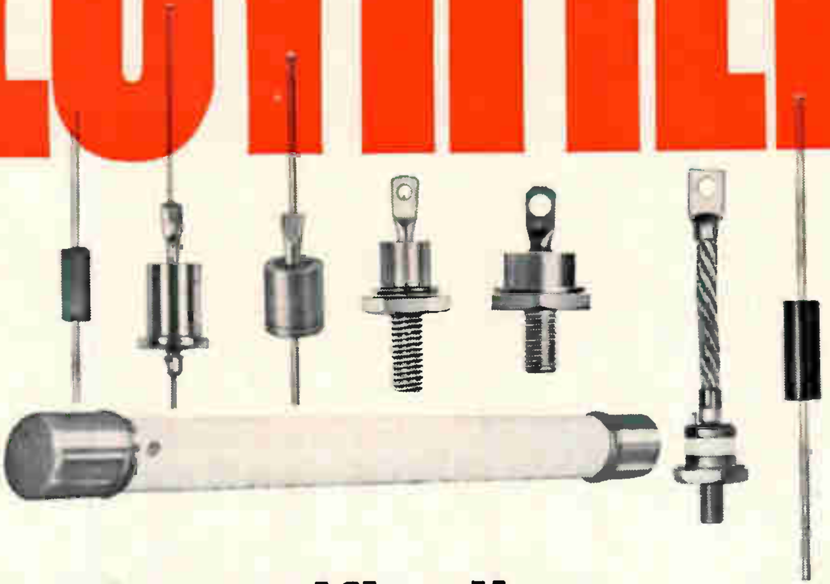

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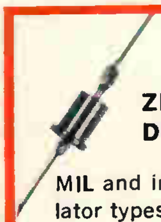

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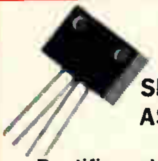

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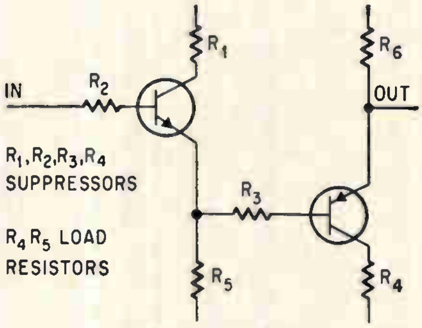
By switching to solid state components for its new variable bandpass filter, the Krohn-Hite Corp. has extended the frequency passband to 1 megahertz—at least five times the range of comparable instruments on the market, according to the manufacturer. Reduced loading effects of parasitic capacitances at high frequencies achieved by converting from vacuum tubes to transistors are responsible for the increased passband of the Model 3100. Both upper and lower cutoff frequencies can be continuously tuned over the complete range, making the filter useful for audio, ultrasonic and radio-frequency measurements.

The low-pass section of the filter consists of four cascaded resistor-filter elements coupled by transistor buffer stages. For most frequencies within the filter's passband, these RC elements operate as sequential voltage dividers with each stage contributing 6 decibels of attenuation; thus, the total attenuation is 24 db, since the low-pass section has four stages which simultaneously tune the high cutoff frequency. The ganged switches S_{2a}, S_{2b}, S_{2c}, and S_{2d} establish this cutoff in decades, while the ganged potentiometers provide continuous tuning within each decade. Feedback introduced around the pair reduces attenuation at the cutoff frequency from 12 db to 3 db.

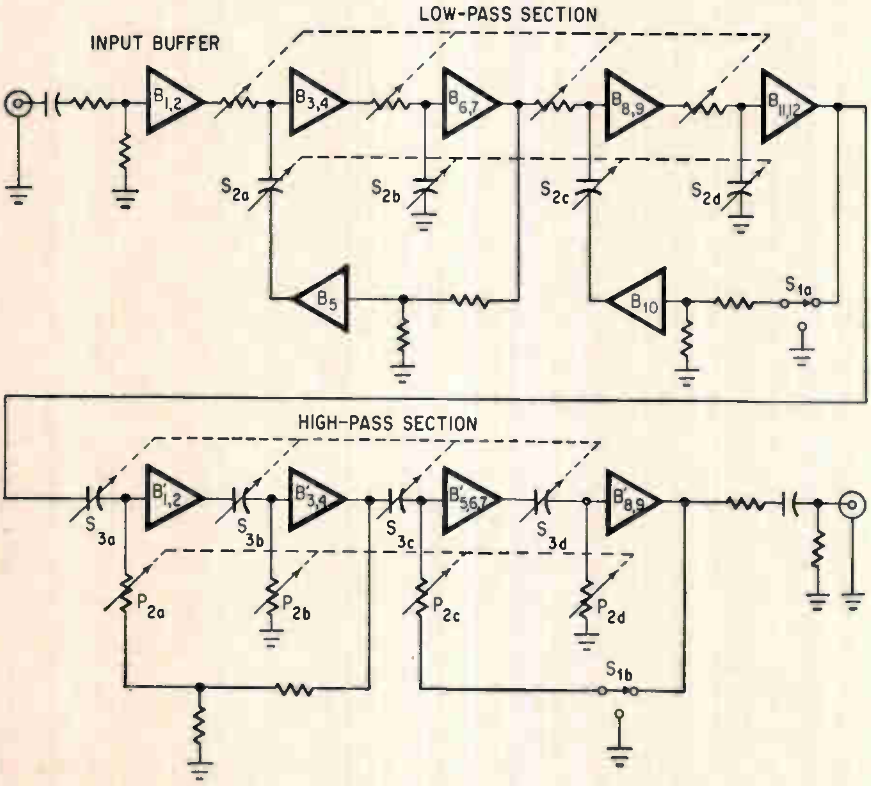
The buffer amplifier, shown above, is used throughout the circuit to isolate stages by presenting a high impedance to the driving source while providing a very low impedance drive to succeeding circuits. The buffer is a dual emitter-follower used as an impedance transformer with unity gain. In the dual arrangement, the second emitter-follower is inverted with respect to the first; this effectively cancels the bias voltage of the first transistor and provides significant thermal drift cancellation as well. Resistors R_1, R_2, R_3 and R_4 suppress high-frequency parasitic oscillations in addition to biasing and coupling.



STANDARD BUFFER AMPLIFIER

Four cascaded capacitor-resistor elements make up the high-pass section of the filter. These operate to give 24 db of attenuation at the high cutoff frequency in the same manner as the RC stages in the low-pass section, except that impedance transforming amplifiers B_5 and B_{10} are not required since both feedback paths in the high-pass section consist entirely of resistive elements.

Switch $S_{1a,b}$ is provided to open two of the four feedback loops; this improves the transient response by eliminating overshoot when pulsed inputs are used.



Specifications

Frequency range	10 hz to 1 Mhz
Frequency accuracy at cutoff	±10% (±5% on special order)
Insertion loss	zero ±0.5 db
Input amplitude	3 rms (maximum)
Output voltage	3 rms (maximum)
Output current	10 ma maximum rms
Price	$525

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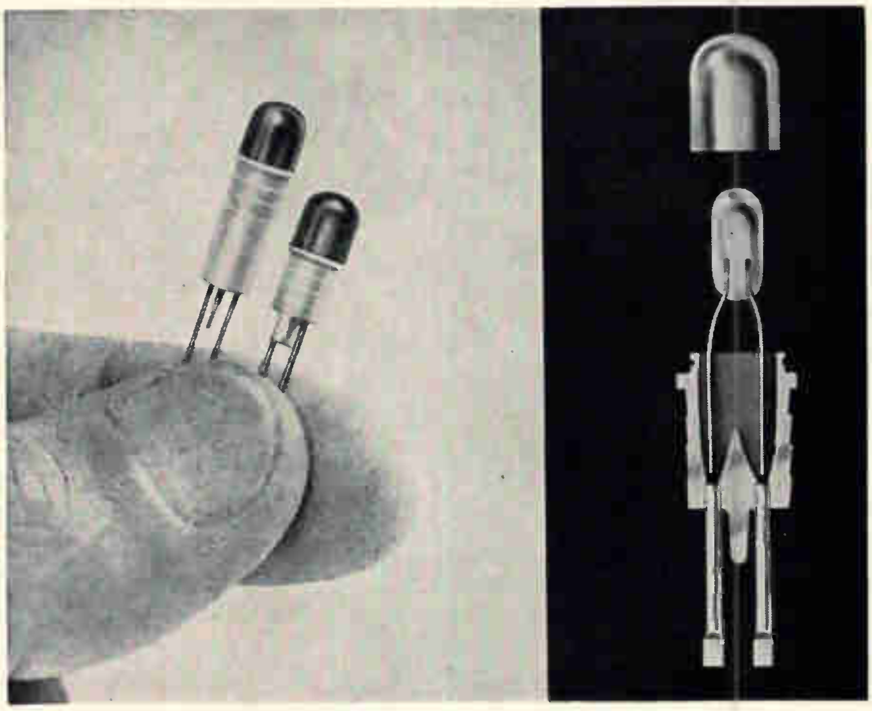
Circle 350 on reader service card

Changing bulbs, the easy way



"This little light of mine, I'm gonna let it shine," says Ben George, inventor of the Bright-Eye, a microminiature indicator lamp whose bulbs can be changed from the front of the panel. The new lamps are so small they can be mounted less than ¼ inch apart, yet are so bright they can be seen in direct sunlight. Made of a new heat-resistant plastic, they weigh less than an aspirin tablet.

Both the cap and bottom housing of the lamp are made with Lexan, the General Electric Co.'s trademarked heat-resistant polycarbonate plastic that can be injection-molded to close tolerances.

George first started manufacturing the Bright-Eyes two years ago, after spending seven years with the Chicago Miniature Lamp Co. He says they gained immediate success because of their small size and brightness and more than 200,000 were bought by some 400 customers. "But," says George, "I had 400 customers who didn't like the way the little lights relamped."

Most microminiature lamps have to be unbolted or unsoldered from the back of the panel to change bulbs. Sometimes the bulb is cemented to the base and, as a practical matter, many burned-out lamps are abandoned. The caps on the early Bright-Eyes could be snapped off to change bulbs from the front, but threading the fine wire leads of the bulbs into tiny sockets in the bottom housing was a difficult task.

George says he knew he needed two funnel-shaped holes inside the bottom housing to guide the bulb leads into the terminal tubes, as shown in the photo. It took him two years to find a Japanese molder who could produce the tiny core pins required to form an injection-molded bottom housing of Lexan.

"Now," claims George, "bulb changing is so easy you can do it with your eyes closed." He offers a relamping test kit with a blindfold (called "no-peeky, no-looky test glasses") to prove his point. The military was so impressed with the new Bright-Eye's replacement characteristics that George got military approval for his product in 30 days.

A Bright-Eye is the size of a vitamin capsule, but glows as brightly as larger lamps, which means display panels can be designed with less lamp space. The complete assembly weighs only 0.3 grams and according to George, this makes it appealing in aerospace applications. The entire assembly fits into a 0.191-inch mounting hole without fasteners, saving costly assembly time.

The Bright-Eye is available in a wide range of colors and cap styles with life ratings ranging from 1,000 to 60,000 hours. Since it will accept any baseless T-1 bulb, it can be operated with a wide variety of voltages and currents. To give additional flexibility, a transistorized Bright-Eye which operates at currents as low as 1 milliampere is also available, George adds.

Specifications

Voltage rating	1.5 to 28 v
Bulb type	T-1 or MS 24367
Mounting hole diameter	0.191 inch
Center-to-center spacing	0.225 inch
Colors	
Transparent	Clear, red, green, amber, blue
Translucent	Red, green, white, yellow, blue and amber
Terminal types	Straight for panels; right-angled for circuit boards
Cap styles	Standard round ball, square, and lens-end (embossed caps are available)
Military	MS 90308
Price	$1.14 to $2.65

Shelly Associates, Inc., 111 Eucalyptus Drive, El Segundo, Calif. 90246. **[351]**

Molded tube sockets for p-c-board use

A line of molded printed circuit board sockets has been developed for use with conventional tv receiver tubes, Novar tubes and multipurpose Compactrons that are Electronics Industries Association approved and designed for automatic assembly and soldering

Circle 147 on reader service card

into color and black-and-white tv receivers.

Both 7-pin and 9-pin p-c board sockets are made with self-retaining snap-in terminations for 0.093-in. diameter equally spaced mounting holes. General-purpose phenolic, low-loss mica-filled and alkyd insulator plastics are used. The 7-pin series (520) and the 9-pin series (540) employ brass contacts throughout to provide good mechanical and electrical connections in dip-soldering applications. Both series are available with full telescopic tube shields or half shields, with integral grounding. Tube shield terminals can be attached for external grounding as well.

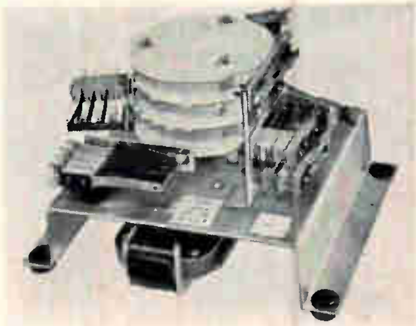
Access holes and area reliefs, lances and contact tails can also be made for special requirements, according to the manufacturer.

Three series of 9-pin Novar sockets designed for p-c mounting and conventional wiring are manufactured in the three basic insulator materials available.

A 12-pin series of molded Compactron tube sockets for snap-in p-c boards (series 470) and stand-off mounting (series 475) with center shield are also available. GP black mica-filled low loss and alkyd compounds are used as insulator.

Delivery time on production quantities is from 4 to 6 weeks after receipt of order. Prices are dependent upon customer's requirements. Methode Manufacturing Corp., 1700 Hicks Road, Rolling Meadows, Ill. [352]

Cam switch provides timing sequence



Series 205-2500 is an 30-circuit motor-driven sequence cam switch de-as larger lamps, which means display panels can be designed with less lamp space. The complete assembly weighs only 0.3 grams and according to George, this makes it appealing in aerospace applications. The entire assembly fits into a 0.191-inch mounting hole without fasteners, saving costly assembly time.

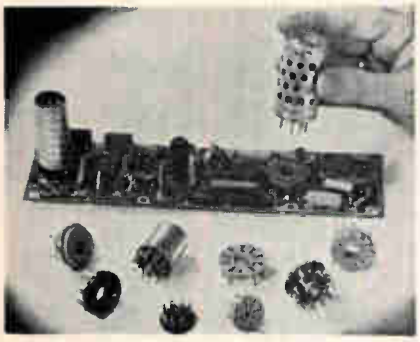
The Bright-Eye is available in a wide range of colors and cap styles with life ratings ranging from 1,000 to 60,000 hours. Since it will accept any baseless T-1 bulb, it can be operated with a wide variety of voltages and currents. To give additional flexibility, a transistorized Bright-Eye which operates at currents as low as 1 milliampere is also available, George adds.

Specifications

Voltage rating	1.5 to 28 v
Bulb type	T-1 or MS 24367
Mounting hole diameter	0.191 inch
Center-to-center spacing	0.225 inch
Colors	
Transparent	Clear, red, green, amber, blue
Translucent	Red, green, white, yellow, blue and amber
Terminal types	Straight for panels; right-angled for circuit boards
Cap styles	Standard round ball, square, and lens-end (embossed caps are available)
Military	MS 90308
Price	$1.14 to $2.65

Shelly Associates, Inc., 111 Eucalyptus Drive, El Segundo, Calif. 90246. **[351]**

Molded tube sockets for p-c-board use



A line of molded printed circuit board sockets has been developed for use with conventional tv receiver tubes, Novar tubes and multipurpose Compactrons that are Electronics Industries Association approved and designed for automatic assembly and soldering into color and black-and-white tv receivers.

Both 7-pin and 9-pin p-c board sockets are made with self-retaining snap-in terminations for 0.093-in. diameter equally spaced mounting holes. General-purpose phenolic, low-loss mica-filled and alkyd insulator plastics are used. The 7-pin series (520) and the 9-pin series (540) employ brass contacts throughout to provide good mechanical and electrical connections in dip-soldering applications. Both series are available with full telescopic tube shields or half shields, with integral grounding. Tube shield terminals can be attached for external grounding as well.

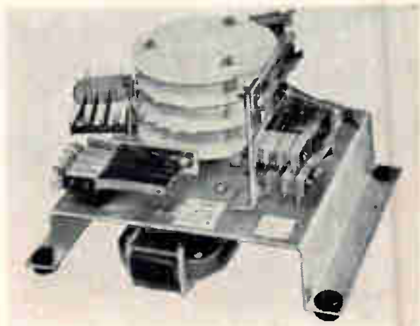
Access holes and area reliefs, lances and contact tails can also be made for special requirements, according to the manufacturer.

Three series of 9-pin Novar sockets designed for p-c mounting and conventional wiring are manufactured in the three basic insulator materials available.

A 12-pin series of molded Compactron tube sockets for snap-in p-c boards (series 470) and stand-off mounting (series 475) with center shield are also available. GP black mica-filled low loss and alkyd compounds are used as insulator.

Delivery time on production quantities is from 4 to 6 weeks after receipt of order. Prices are dependent upon customer's requirements. Methode Manufacturing Corp., 1700 Hicks Road, Rolling Meadows, Ill. [352]

Cam switch provides timing sequence

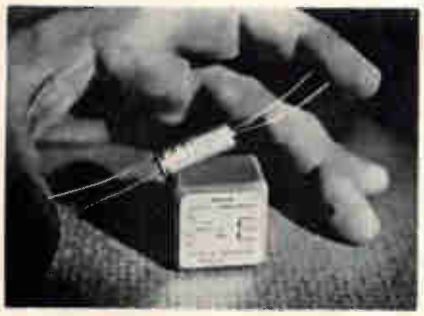


Series 205-2500 is an 80-circuit motor-driven sequence cam switch designed for repeat cycle control. Its life of over 1 million cycles and low cost make it suitable for high reliability commercial applications.

Any timing sequence desired is obtained by building the necessary contact arrangement and cams. Up to 80 spdt contacts can be operated at speeds of 1 through 35 cycles per minute, with a maximum of 20 notches on each cam. Switching sequence is determined by number and position of notches. Four cams are maximum for the standard unit. Cams are supplied notched or unnotched as specified. Price is $9 to $12 depending on quantity; delivery 30 to 60 days.

Chicago Dynamic Industries, Inc., Precision Products division, 1725 Diversey Blvd., Chicago, Ill. 60614. **[353]**

Solid state, choppers have low voltage effect



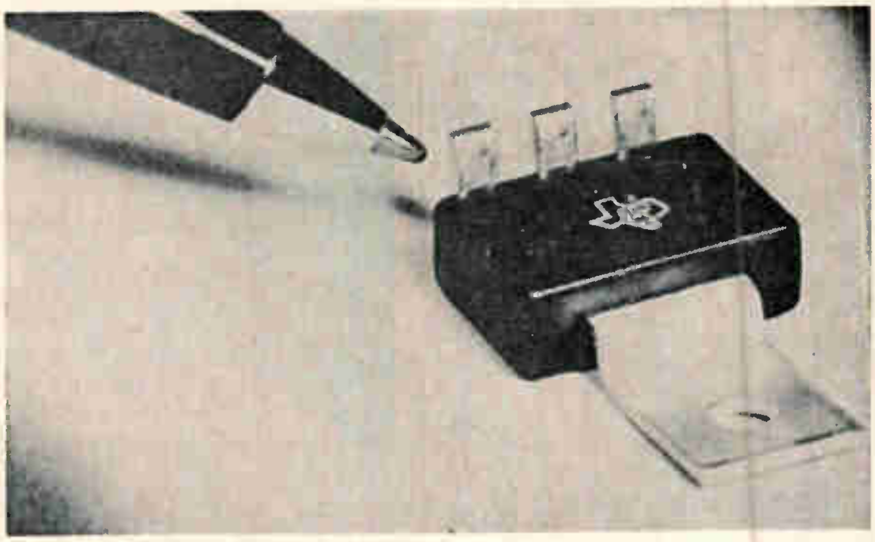
A line of low-level choppers—354256 (spst) and 354258 (spdt)—are now available for measurement and control circuitry. The solid state devices feature low d-c voltage offset (less than 1 μv); long life (25,000 to 50,000 hours); plus a wide design flexibility.

The company claims that careful selection of materials, proper physical arrangement of parts and closely controlled production techniques assure low thermal and low noise characteristics. The photocell is fully shielded from the lamp by a transparent electrostatic shield.

The choppers can be mounted either vertically or horizontally and are designed to operate with good efficiency with a wide range of circuit impedances in various circuits. Both the 354256 (spst tubular design) and the 354258 (flatpackage, plug-in design) can be used for 60-hz applications.

Leeds & Northrup Co., Components division, North Wales, Pa., 19454. **[354]**

Plastic-packaged devices bow

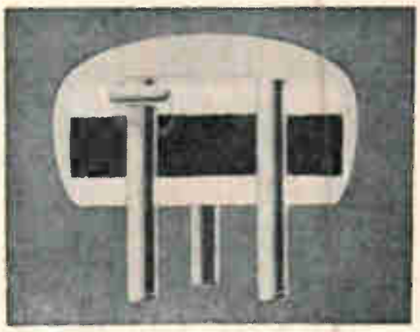


To the growing list of economy-class semiconductor devices especially designed for consumer products, add two plastic encapsulated transistors from Texas Instruments Incorporated. The two, a silicon power type and a germanium field effect transistor, are aimed primarily at a-m/f-m radios, television sets and high-fidelity equipment. Both offer excellent characteristics for such service and cost less than 75 cents in quantity.

The silicon power transistor is a planar epitaxial device designated TIP24. It is intended for use in class B audio amplifiers, especially loudspeaker drivers in high-fidelity components. The device is characterized by beta linearity over a wide range of operating current levels. Pairs of transistors with beta characteristics matched to within 20% are available for stereo amplifier applications and constitute an industry first, according to the manufacturer. The transistor has a saturation voltage of 0.3 volts (typical) at 1.5 amperes, which assures maximum circuit efficiency with minimized internal heating and power losses. The unit also has a high power capability dissipating 10 watts at 70 volts when the case temperature is 75° centigrade; this dating is twice the usual maximum power required in class B amplifiers.

The silicon device is priced at 55 cents in production quantities and is encapsulated in an epoxy-type plastic; a special mounting tab allows the unit to be mounted to a chassis in several positions using a single sheet-metal screw.

The germanium field-effect transistor is a planar epitaxial junction p-channel unit, the TIXM12. It was designed principally for use in mixers and amplifiers operating in the very high frequency band. Its most outstanding characteristic is its excellent frequency response, made possible by the high majority-carrier mobility of the germanium material. Its transconductance is typically 6.5 millimhos with a feedback capacitance of 3 picofarads. Like all FET's, it features low cross-modulation distortion and low noise, typically 2 db at 100 Mhz.



Germanium field-effect transistor

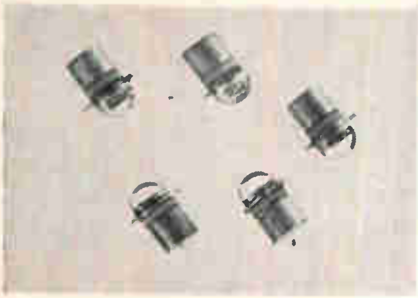
The FET is sealed with a ceramic/glass header. Like the power transistor it is encapsulated in plastic and fitted with a convenient mounting tab.

Specifications

TIP 24:	
Type	Germanium planar junction type p-channel unit
Noise level	2 db (at 100 Mhz)
Transconductance	6.5 mmhos (typical)
Feedback capacitance	3 pf (typical)
Small signal common source input conductance	1.0 mmho
Gate to source breakdown voltage	20 v (minimum)
Gate to source cutoff voltage	1 to 3.5 v
Zero gate voltage drain current	5 to 25 ma
Package	Ceramic glass sandwich header encapsulated in epoxy-type plastic
Price	$0.71 (in quantities over 100)
TIXM12:	
Type	Silicon planar epitaxial
Maximum current	2 amp
Saturation voltage	0.3 v (typical) at 1.5 amp
Beta linearity	50 (typical) at 50 ma and at 1.5 amp; 66 peak at 300 ma
Beta matching	All pairs are beta-matched within 20% at 1.5 amp
Power dissipation	10 watts (at 70 v and 75°C (Case temperature)
Package	Epoxy-type plastic encapsulation
Price	$0.55 (in production quantities)

Texas Instruments Incorporated, 13500 N. Central Expressway, Dallas, Texas 75222. **[361]**

Electroluminescent diode for small areas



The 4107 gallium-arsenide electroluminescent diode is a high intensity, solid state infrared light source, especially designed to meet the requirements of card and tape readers, optical encoders and other equipment where available space is critical.

The diode emits light with a wavelength of 9,000 angstroms (0.9 micron) which can be efficiently detected by a silicon photodetector. It is contained in a miniature ceramic-Kovar package fitted with a glass lens which concentrates the beam into a 20° cone with particularly high intensity along the axis (typical radiant power output is 75 μw for an input of 50 ma at

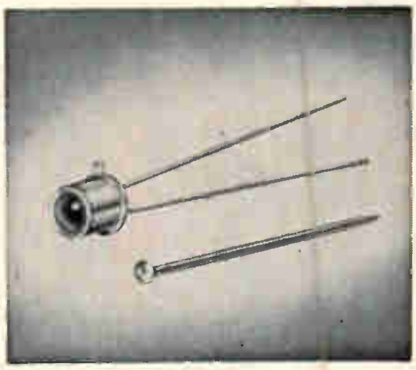
1.25 v). The package is 0.062 in. in diameter allowing a high packing density when using arrays of these diodes.

The 4107 is said to be an extremely rugged device that can survive vibrational environments where tungsten filament lamps would fail.

A silicon p-i-n photodetector (the 4205) is also available in the same package, and the two devices are well suited for application as photon coupled pairs.

These diodes are available from stock. Price is $28 in quantities of 1 to 9, and $23.80 from 10 to 99.
HP Associates, an affiliate of the Hewlett-Packard Co., 620 Page Mill Road, Palo Alto, Calif., 94304. [362]

Silicon photodiode in a TO-18 package

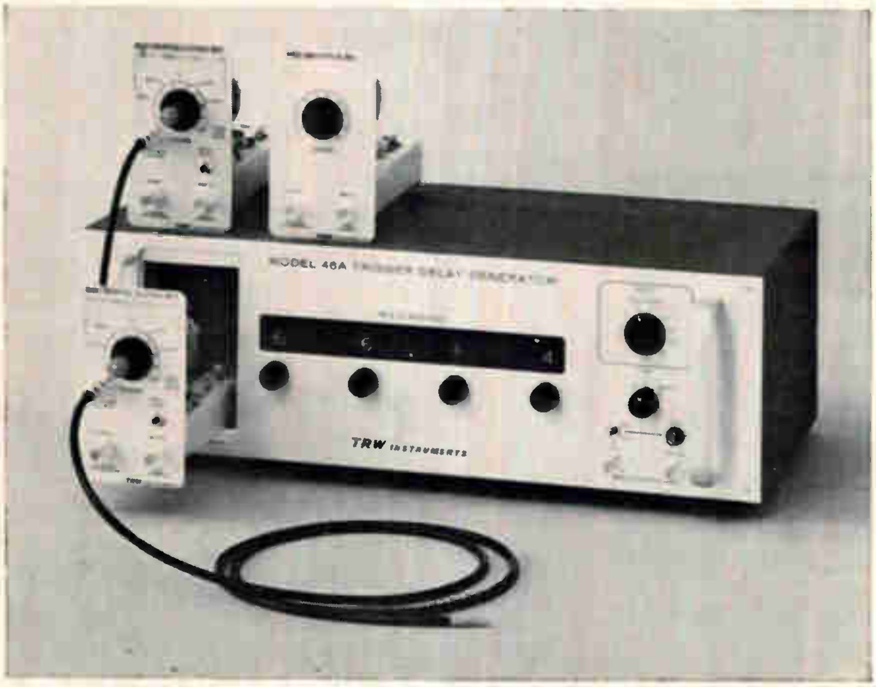


Type NSL-710P, a silicon photodiode in a TO-18 package, has been especially designed to operate with bias conditions required by low-cost silicon transistors.

Typical reverse current with −1.0 v and at 55°C is only 0.4 μa; typical short-circuit current output at 500 footcandles, 180 μa; spectral response peak, 0.85 micron; speed of response, 1 μsec; temperature range, −60°C to +125°C.

The device is an economical approach to the design of punched-card readers, encoders, optical sound track heads and many other photoelectric applications. Price in lots of 100 is $2.25 each. Samples are available.
National Semiconductors Ltd., 2150 Ward St., Montreal 9, Canada. [363]

Powerful trigger has high accuracy



High power output with nanosecond accuracy is featured in a new trigger delay generator, Model 46A, introduced by TRW Instruments. It is ideal for generating timing markers, measuring delay line time constants and calibrating oscilloscopes.

The generator may be triggered either electrically or optically by choosing an appropriate auxiliary plug-in trigger unit. The output trigger pulse height is variable between 50 and 500 volts in 50-volt steps, and has a fast 10-nanosecond risetime. Pulse delay is variable up to 99.99 microseconds in 0.01, 0.1, 1.0 and 10 microsecond steps. The pulse is virtually jitterless (less than a nanosecond) and repeatability is good (±1 nanosecond). Maximum pulse repetition rate is 50 pps.

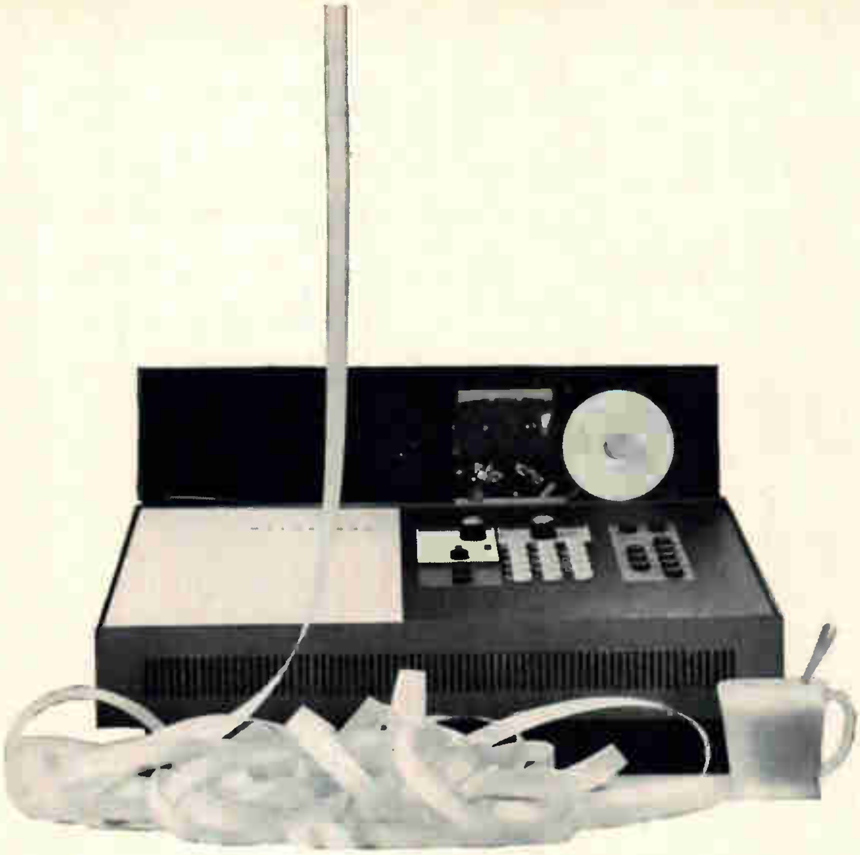
Delays are generated using LC resonant circuits. Charge storage transistors trigger output thyratrons. Use of thyratrons, notes the manufacturer, provides high signal-to-noise ratio, as well as fast-rise-time and high-voltage pulses. The generator has a peak pulse power output of 5 kilowatts.

A switch on the front panel selects a single or repetitive trigger and a panel light indicates the choice. The time delay in microseconds is displayed digitally.

Three plug-in trigger units are available. One is electrical only, the others are usable with either optical or electrical inputs. The two optical/electrical units differ in spectral range. Both can be internally triggered by a manual push-

Specifications

46A generator	
Pulse amplitude	50-500 v, in 50-v steps
Pulse delay	00-99.99 μsec in steps of .01, 0.1, 1.0, and 10μ sec
Rise time	10 nsec
Maximum repetition rate	50 pps
Jitter	less than 1 nsec
Repeatibility	0.01% or ±1 nsec
Calibration accuracy	adjustable within 0.01%
Weight	25 lb.
Price	$1783
Plug-in units	
Model 47A, 49A	
Triggering	
External	optical and electrical
Internal	2 pps or 30 pps or manual
Spectral response	
Model 47A	4000 to 6500 angstroms
Model 49A	400 to 11,000 angstroms
Optical attenuation factors	10 steps; 1 to 1,000
Price	47A, $642; 49A, $763
Model 48A	
Input	Electrical only
Minimum sensitivity	+1 v
Trigger level	1 to 300 v in 10 steps
Price	$209
Delivery	2 weeks, all units



button, or set for automatic triggering at a rep rate of 2 or 30 hertz.

The optical trigger units provide an attenuation control (up to a factor of 1,000) which permits selection of the optical triggering threshold. Direct fiber optic coupling to the sensing photodiode results in increased efficiency of light transfer over that of earlier models, and up to four times the triggering sensitivity.

TRW Instruments, 139 Illinois Street, El Segundo, Calif. [371]

Voltmeter/ratiometer sets stability record

A differential d-c voltmeter and d-c ratiometer carries a 0.002% accuracy spec, with stability of 1 part per million per hour (of range), and 5 ppm per day (also of range). Null meter resolution is 0.2 ppm of range, on all ranges. These specifications, it is claimed, set new standards for the limit of the art in today's commercial technology among differential voltmeters.

The new instrument comes in two versions: model 3420A is for a-c line operation only; model 3420B is for line or self-contained battery-powered operation. Both carry the same basic specifications.

To make 0.002% accuracy meaningful, the models have six-digit decade dividers, plus the usual last-digit meter, and ±10 μv full scale sensitivity. All this is said by the manufacturer to be unique to these differential voltmeters.

Ratio capability is a further exclusive feature. The ratio of two applied d-c voltages can be determined to six significant figures, with four ranges available. The divider accuracy of a resistance divider may be measured with similar precision.

On the lower two ranges, unknown voltages are nulled against an internal source. Minimum input resistance, fully off null, is 10 megohms. It reaches more than 10^{11} ohms at null. On the higher two ranges, input resistance is 10 megohms ±0.05%.

Model 3420B, battery-powered, may be truly floated. This completely isolates the instrument from any ground system in the equipment being measured, so ground loop signals cannot deteriorate the measurement and readings may be taken above ground while maintaining full accuracy.

During a-c line operation, common mode rejection is 150 db for frequencies of 60 hz and higher, 140 db for d-c common mode signals.

Model 3420A differential voltmeter/ratiometer is priced at $1,175. Model 3420B (battery-powered) is $1,300. Delivery is expected to be from stock beginning early in August.

The Hewlett-Packard Co., 1501 Page Mill Road, Palo Alto, Calif., [372]

Portable VOM protected against burn-outs

A portable volt-ohm-milliammeter, model 630-APLK, has a transistorized switching circuit that guards against accidental burn-outs, provides comprehensive overload protection and virtually eliminates bent pointers, burned-out resistors, shunts and coils, and changes in accuracy due to overheating.

The meter will aid test and design engineers, systems designers, quality control personnel and original equipment manufacturers.

Featuring high sensitivity of 20,000 ohms per v d-c and 5,000 ohms per v a-c, the VOM has an accuracy of ±1½% d-c and +3% a-c guaranteed in horizontal position. The unit works with frequencies through 500 khz. A single, easy-to-read selector switch minimizes changes of error when changing ranges, and a mirror-backed scale insures accuracy by eliminating parallax.

The meter, equipped with a polarity reversing switch, is protected from stray magnetic fields by the patented self-shielded Barring magnet movement design. A special diode network across the meter protects the meter movement against instantaneous transient voltages. A rugged 0- to 50-μa suspension meter movement provides consistently reliable meter readings.

The transistorized switching circuit battery, with extremely long life, is easily checked by using the X100 ohms range. Model 630-APLK also features flush mounted controls, jacks and meter and a special meter-shorting on the off position for high damping when the tester is in transit.

Weighing 5 lbs, the meter is encased in durable black molded plastic with a clear, unbreakable plastic scale window and is $3\frac{11}{32}$ x 5½ x 7½ in. The 630-APLK comes with batteries, leather carrying handle, 50-in. banana type leads and test prods with removable alligator clips.

A variety of leather carrying cases and an accessory a-c ammeter adapter with long lead attachment are available. Price is $95 and delivery is 30 days.

The Triplett Electrical Instrument Co., Bluffton, Ohio, 45817. [373]

Highly regulated floating power supply

Model 215A floating power supply has been added to INCOR's line of instrumentation amplifiers and signal conditioners. Its features include 0.005% line and load regulation, excellent time and temperature stability and a continuously variable 0 to 15 v, 200 ma output.

A remote sensing Nul-Balance circuit requires only 1 μa of current, thus eliminating all errors due to sensing lead line changes.

Noise to ground of less than 0.5 μv peak, isolation of better than 10,000 megohms, and 5 pf are provided. Price is $130.

Companion signal conditioning units provide bridge balance and shunt calibration. Their price is $65.

All units are furnished complete with case and connector suitable for bench use, or up to 10 may be mounted in a 3½ in. high, 19-in. long rack adapter. The rack adapter is priced at $90.

Instrumentation Amplifiers & Supplies, Inc., 29 Newtown Rd., Plainview, L.I., N.Y., 11803. [374]

Signal conditioner provides 14 channels

A portable signal conditioner is designed for use with magnetic tape recorders in airborne or ground applications. Called the NY-1200, the conditioner has 14 channels, including shunt calibration, in a 17-pound drip-proof case. Also available is a 7-channel model, plus a model with 7 amplifying channels and 7 storage channels.

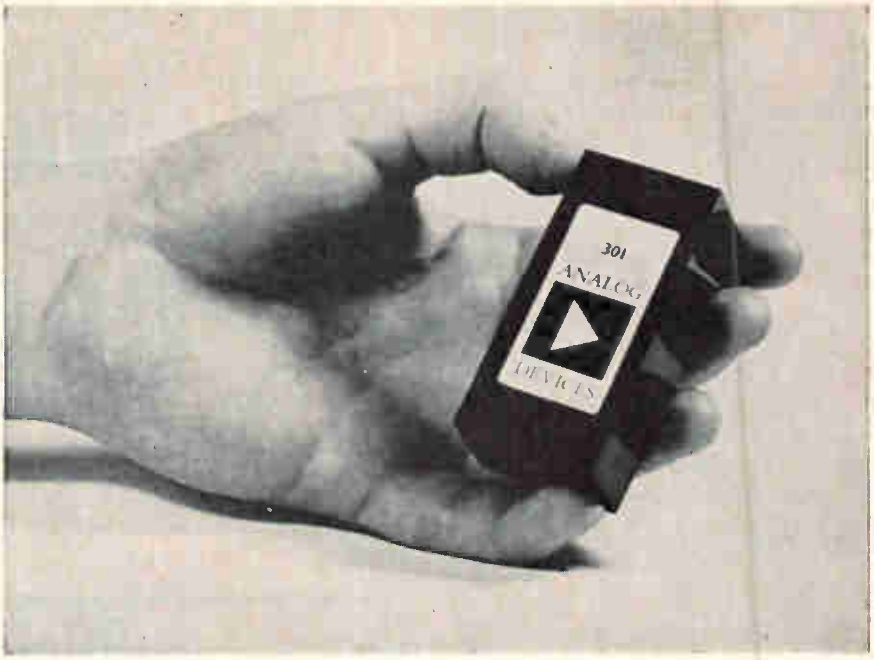
The basic unit is designed for strain gage and thermocouple signal conditioning. Modules, including line driver modules, are also available for accelerometers and capacitive type transducers.

Each channel module has its own d-c/d-c converter to isolate input from output, an amplifier section, and a constant voltage source for transducer excitation. This self-contained module design eliminates ground loop problems. Although each channel is designed to work from raw 28 v bus lines, it will accept 22 to 34 v d-c and still provide proper signal conditioning stability.

Frequency response of the NY-1200 is d-c to 20 khz (flat 1 db). Operating temperature is 0° to 50°C, and operating altitude is 70,000 ft.

Nytron, Inc., 795 San Antonio Road, Palo Alto, Calif. [375]

Operational d-c paramp cuts noise



Low-noise and drift with superior common-mode rejection are just a few of the benefits claimed for a parametric amplifier circuit incorporated in the Analog Devices Inc. model 301 d-c differential operational amplifier.

The device achieves substantial power gain in its first stage—43 decibels—without active amplifying devices. Instead the 301 uses a passive, balanced varactor bridge which effectively eliminates the inverse frequency (1/f) noise that is characteristic of transistors or tubes at subaudio frequencies. As a result, the noise current of the 301, referred to the input, is only 0.01 picoampere, and the noise voltage 1 microvolt peak-to-peak over the frequency range from d-c to 1 hertz.

Because of the high quality silicon varactors used in the bridge, the unit has an input offset current of 1 picoampere and a drift of 0.06 picoampere/° C at 25° C, at least an order of magnitude better than operational amplifiers made with field effect transistors, the company says. It also has a common-mode voltage rating of ±300 volts d-c which is equivalent to that of vacuum-tube amplifiers and about 15 times that of solid-state amplifiers of this type. In addition, the amplifier has a common-mode input impedance of 10^{12} ohms coupled with a common-mode rejection ratio of 10^8. Differential input impedance is 10^{10} ohms.

Model 301 can resolve very small signals, operate from high source impedances over wide dynamic signal ranges, integrate or store charges over long periods and tolerate high common-mode input levels. The device is small—2.8 inches by 1.3 inches by 0.95 inch—and is designed for mounting on printed circuit boards.

Like the conventional microwave paramp, the circuit of the 301 amplifies by varying the reactance of nonlinear elements, in this case silicon varactor diodes, by pumping them with a high-frequency voltage source. Amplification of this type is relatively free of internal noise. The varactors are incorporated in a bridge circuit which is excited by an internal 10-Mhz pump oscillator. The bridge configuration can be balanced to zero output when there is no signal input. With an input signal, the bridge is unbalanced, producing an output at pump frequency proportional to the unbalance. After additional low-noise a-c amplification, the output is demodulated in a phase detector to restore correct polarity, and receives additional gain in a final d-c amplifier stage.

The device should find a variety of applications in analog computers and instrumentation.

Specifications

Current drift	0.06 pa/°C
Noise	$1\mu v$ and 0.01 pa
Voltage drift	$30\mu v$/°C
Gain	10^6
Output	±10v at 20 ma
Common mode voltage	±300v d-c
Price	$198.00

Analog Devices, 21 Fifth Street, Cambridge, Mass. 02142 [381]

Bench welder control acts as power switch

A solid state, bench welder control panel is designed for precision a-c resistance spot welding applications. The CR175 welding control functions as an electronic power switch that provides synchronous timing of ½ to 27 cycles and controls the magnitude of the welding current by the phase-shift method. This provides a more gradual heat-control adjustment than is obtainable by taps on the welding transformer. It also avoids the need for controlling magnitude of current by means of a series impedance.

At full heat setting the welding current is initiated at the power factor angle of the welder load. This control disconnects the welding transformer from the supply circuit after a preset number of cycles of weld current, and at a zero point on the current wave.

A new cycle counting technique,

utilizing the characteristics of the unijunction transistor, provides simple but accurate timing and synchronous full-cycle conduction. For any given spot length (number of cycles of weld current), the effective weld current can be varied by retarding or advancing the instant the scr's begin to conduct current during each half cycle.

The time range selector switch is used in conjunction with the weld time thumbwheel switch. A setting of ½ cycle on the selector switch indicates ½ cycle of weld current at any setting of the weld time thumbwheel switch.

The control is available in two models, with maximum 1-cycle current ratings of 55 amps and 270 amps, respectively. Each model employs two scr's as power switches and features internal fuse protection. Over-all dimensions of both controls are 7.5 in. high, 5.5 in. wide and 13.5 in. deep. The cover requires an additional 3 in. of height for removal.

The external power supply can be 50 or 60 hz at 115/230 v.

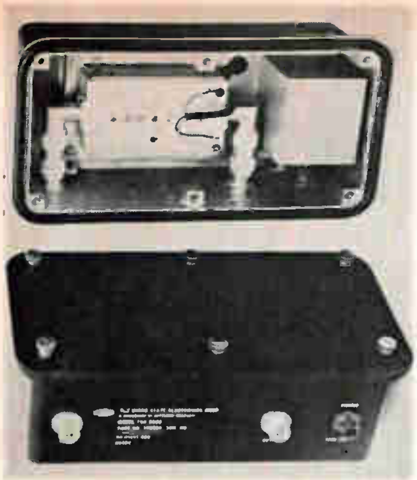
The new unit may be used wherever precision-timed switching of a-c power is required, and where magnitude of power delivered to a load from standard industrial power sources requires accurate control or programing.

Specific areas of application for the controls include resistance welding of small parts, cyclic control of heating or lighting loads, temperature control of molten liquids or platens (when used in conjunction with temperature sensing elements), or any application requiring a-c power pulsing, timed application, or magnitude modulation.

The General Electric Co., General Purpose Control Dept., Bloomington, Ill. [382]

Transistor amplifier for airborne use

Gain of 25 db with a noise figure of 3 db or less over a frequency range of 225 to 300 Mhz is offered in a new transistor amplifier. The model TQN 2230 is enclosed in a



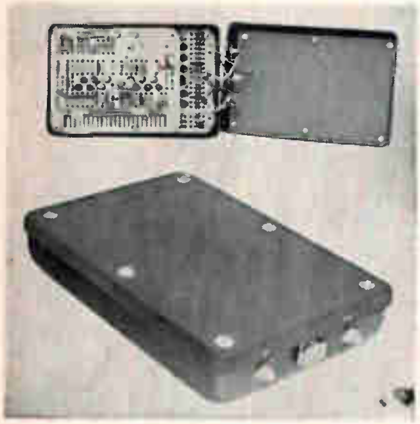
waterproof case and is designed especially to meet the extreme environmental requirements of airborne installations. Its high reliability is demonstrated by a mean time between failure of 50,000 hours.

The amplifier has a saturation level of —30 dbm of power input and has a limiter to protect it from a maximum r-f input power of 2 watts c-w. Third order intermodulation products are at a level of less than —90 dbm output. The unit is unconditionally stable and has no oscillation even when subjected to extreme mismatching from an input bandpass filter.

Drive power to the amplifier is 115 v a-c, 400 hz, and input and output connectors are through type N fittings in 50-ohm line.

Micro State Electronics Corp., 152 Floral Ave., Murray Hill, N. J. **[383]**

Log amplifier offers 5-decade compression



Model 157 logarithmic amplifier compresses 5 decades of current input into a voltage output according

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New Subassemblies

to the equation, $E_{OUT} = K \log I_{IN}$. Designed and packaged for spaceborne applications, the solid state unit is suited to most amplitude-compression requirements.

The standard log amplifier provides 100 db (100,000 to 1) of signal compression, yielding full scale output of 5 v at 25 ma. Model 157 can also be supplied on special order with full scale output for 80, 60, 40, or 20 db compression.

Frequency response is flat from d-c to 0.25 Mhz. To assure low d-c drift, the log amplifier is chopper-stabilized and temperature-compensated for O°C to + 50°C. Model 157 log amplifier occupies less than 27 cubic inches of space and consumes only 3 watts of power.

Missouri Research Laboratories, Inc., 3109 Locust St., St. Louis, Mo. [384]

Clocked delay module for computer memories

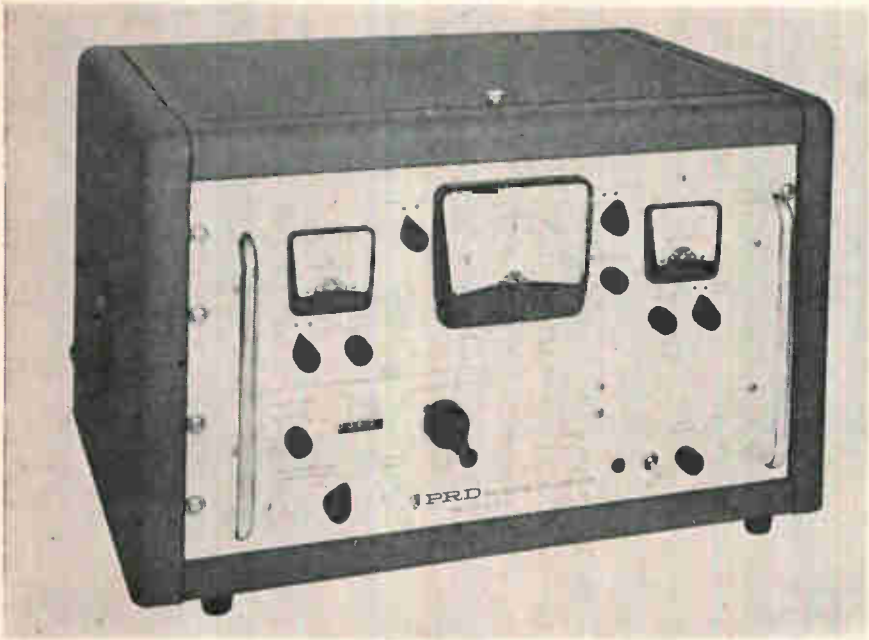
A fully-clocked 5,000-μsec delay module operates a 1 Mhz return-to-zero and is available with delay line and write-read circuitry mounted integrally in one enclosed package. The unit features clocked nonreturn-to-zero input and output, case-enclosed circuitry and cast aluminum case design. Principal applications are with computer memories.

The model 400 delay module has a 6 v d-c ± 10% power supply. Input signals are 0 to 0.45 v for logic 0 and +3 to + 6.6 v for logic 1. The output signal is identical to the delay except for the delay.

Sealectro Corp., Mamaroneck, N.Y., 10543. [385]

New Microwave

Receiver measures 100-db attenuation



A 30-megahertz test receiver measures attenuation up to 100 decibels to an accuracy of within a half decibel. The manufacturer, PRD Electronics, Inc., Westbury, N.Y., a subsidiary of the Harris-Intertype Corp., claims that the accuracy—for this dynamic range—surpasses by 0.35 db any comparable instrument on the market. The 915-A receiver—an improved version of PRD's 915—has a better circuit design and very stable noise source to measure signal levels as low as 120 db below a milliwatt.

The use of external mixers and local oscillators to heterodyne the input signal to the receiver's 30-Mhz frequency permits measurements at 10 Mhz to 40 gigahertz. An automatic frequency control circuit keeps the mixer output at 30 Mhz—the frequency of a reference oscillator in the receiver.

The receiver can calibrate signal generators and measure modulation characteristics of tactical air navigation (Tacan) signals. It can also measure field strengths for microwave relay surveys and is used in tuned reflectometer measurements. In more conventional laboratory applications it can measure noise levels, pulse amplitudes and both large and small standing-wave ratios.

The substitution method determines attenuation of a device such as a filter. A calibrated attenuator adjusts receiver output for null indications—once when the filter is not present in the signal circuit and again when it is present. Attenuation is the difference in dial indications.

A design similar to the Dicke radiometers used in radioastronomy makes the 120-db sensitivity possible. The receiver switches between the signal and reference oscillator channels so that the 30-Mhz carrier is square-wave modulated at the 38-hertz switching rate. After this signal is synchronously detected, the output is integrated in a filter centered at 38 hz with a passband of 0.8 hz. The passband establishes the receiver's noise bandwidth and its narrowness reduces the effect of noise on attenuation measurements. Mixer noise balances out before measurement by adding noise to the reference channel. Noise from the internal noise source is added until the receiver's null meter indicates equality between the noise from the mixer and reference channels.

The design characteristics make the receiver sensitive to signals as low as 10 to 12 db below the input noise level. To make measurement

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New Microwave

easier, a ranging switch automatically increases the sensitivity of the null meter when the signals and reference channel levels move within 1 db of each other. The attenuator can be removed for calibration by the National Bureau of Standards.

Specifications

Designation	Microwave receiver type 915-A
Input frequency	30 Mhz
Frequency coverage (with external mixers and local oscillators)	10 Mhz to 40 Ghz
30 Mhz calibrated attenuator	
Scale	0-100 db
Least division indication	0.02 db
Insertion loss at zero	25 db
Accuracy	±0.05 db per 10 db
Maximum cumulative error	0.25 db
30 Mhz amplifier	
Bandwidth (3 db)	2 Mhz
Noise figure	2 db
Power	115/230 volts ±10%, 50-60 hz
Mounting	Cabinet or 19-in. rack
Weight	About 35 lb.
Price (without local oscillators or mixers)	$2,800

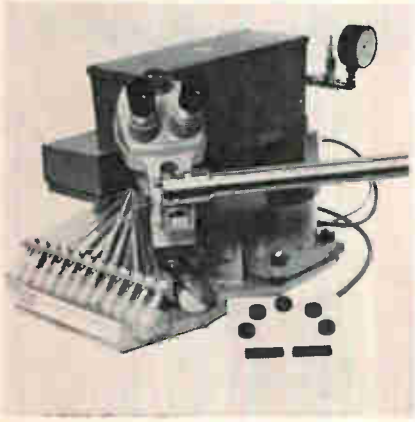
PRD Electronics, Inc., 1200 Prospect Ave., Westbury, N.Y. [391]

Coaxial adapters provide low vswr

Broadband precision coaxial adapters are announced. These male and female d-c to 18 Ghz adapters are a ruggedly constructed two-piece assembly with a stainless steel body and connectors. The critical dimensions of the connector inner contact depth is held to tolerances less than those required by the National Bureau of Standards or applicable MIL specs.

Model 1513 adapters provide a low vswr, low-loss transition from male-to-male type N and female-to-female type N coaxial line connectors. The broadband design provides a vswr below 1.15 over the complete coaxial waveguide frequency range of d-c to 18 Ghz, including the 12.4 to 18 Ghz band usually reserved for waveguide. The adapters are small and rugged and are intended for use both in the laboratory and in the field. Weinschel Engineering, Gaithersburg, Md. [392]

Dice inspection and sorting machine



A semiautomatic machine has been developed to replace the tedious hand sorting of semiconductor dice which have been electrically probed and color-coded in wafer form. The dice are automatically fed and positioned in the field of view of the microscope so that the operator can rapidly detect the color of the probe test mark, inspect the die for physical faults, or observe that the die is upside down and must be recirculated.

The operator dispatches each die to the sorter by pressing a color-coded push button on the control box. The unit is available with up to 16 sorting switches and corresponding parts collecting bins.

The actuation of any of these switches causes the machine to automatically index to dispatch the prior die and introduce a new die. It can handle up to 120 indexes per minute.

Numerical Control Corp., 3033 Jefferson St., San Diego, Calif., 92110. [401]

Bench-type IR oven 'cooks' resist bands

A bench-type infrared oven dries and cures photo resists, solder resists, etch resists, and protective coatings. Oven features include: high-speed drying and curing (typical time cycles range from 30 seconds to 4 minutes); uniform-heat infrared panels; and variable speed and temperature control, which allows for adjustment to virtually any drying and curing condition.

Its modular construction permits adding other units at low cost for higher production requirements, and includes an extendable conveyor. Curing is done two sides at once, because the boards travel through the oven in a vertical plane. Hooks for mounting boards on the chain conveyor are supplied.

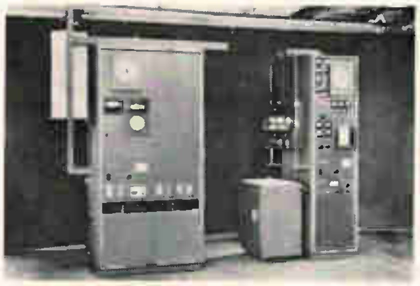
A release device at the end of the conveyor unhooks boards from the chain and prevents stacking up in the oven. The telescopic conveyor is easily extended from 6 to 9 ft.

The oven can also be supplied without the top hood and the conveyor. Cross supports are supplied for the top to provide for manually hanging the boards between the heaters.

Size of the oven is 26 in. high x 24 in. wide x 12 in. deep. The conveyor is 66 in. long. Power is 4 kw; 230 v for heaters; 115 v for conveyor motor. Controls include those for conveyor speed, heater temperature and line switch.

Infra-Red Systems, Inc., Route 23, Riverdale, N.J. [402]

Tube exhaust system features r-f heating



A complete system has been announced for exhaust, bakeout and activation of traveling-wave tubes and similar electron devices. Tubes are transported on carts with integral vacuum pump to either bakeout or activation stations. The activation stations feature r-f heating for outgassing gun structure and collector. Automatic cathode activation with vacuum interlock permits uniform processing at optimum rates.

The sytem can process approximately 5,000 tubes per year on two-shift operation. The modular design permits increase of capacity by adding increments at low cost. Stewart division, Watkins-Johnson Co., P.O. Box 543, Santa Cruz, Calif [403]

Machine develops and cleans wafers

Model 692 is an automatic photoresist developing machine utilizing standard developing and cleaning fluids.

Machine operation is simple. All that is required of the operator is to load a carrier of ten wafers into the machine, close the machine and push a button. The machine develops, cleans and dries the wafers; all within two minutes. One operator can operate two or more machines at a time.

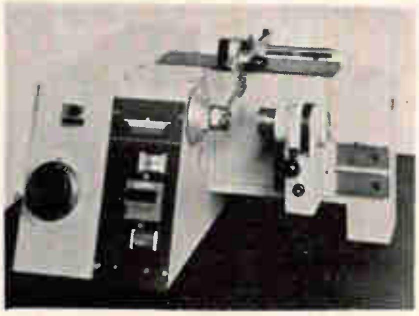
The 692 puts the wafers through five different operational cycles, including rinse and dry, and is capable of as many as 10 cycles where desired. All cycle times are preselected, adjustable, and accurate. Wafers are uniformly developed and come out clean.

Simple machine operation and minimum manual handling of wafers means less wafer scratching and breakage and higher yields. Operator functions are limited to loading wafers onto the carrier, placing the carrier into the machine, and taking it out again. Wafers can be carried between operations on these same carriers. Handling of wafers by the operator is kept to a definite minimum.

The model 692 can be ordered separately or with the Contamination Control, Inc., model 1235A clean fume hood.

Kulicke and Soffa Manufacturing Co., Fort Washington, Pa., 19034. [404]

Compact coil winder is fast and precise



A compact, bench-top coil winder, Meteor model ME307, has been introduced that incorporates many features heretofore found only in the larger Meteor models—ultra-high speed and precision, extremely quiet operation (even at 15,000 rpm), and quick setup. It is priced under $2,000.

Model ME307 will handle wire sizes from 0.0004 in. to 0.020 in. and will produce single-layer coil and a multiple-layer bobbin coil ranging from 0.008 in. to 4 in. in width, and up to 2 in. in over-all diameter. Two models are available: one has a d-c motor and foot-pedal speed control; the other has an a-c motor with automatic acceleration control. Either unit can be equipped with an electronic counter having a 1:1 ratio, or an electromagnetic counter with a 10:1 ratio.

Since there are no gears or cams to change, the new machines can be quickly set up for the production of commercial coils, instrument coils or relays.

Associated American Winding Machinery, Inc., 750 St. Ann's Ave., Bronx, N.Y., 10456. [405]

New Materials

Epoxy experimental kit for R&D projects

Cured epoxy resins may range from a hard, brittle material with a high tensile strength to a rubber-like compound capable of withstanding considerable thermal shock and flexing. Also, the adhesion between a cured epoxy and a given material may range from poor to superior.

These properties are largely determined by the type of epoxy resin; the curing agent used; the weight ratio of one to the other; the type and amount of filler used, if any; and the time and temperature of the cure.

The manufacturer is now offering an experimenters' epoxy kit to simplify the selection of the most desirable epoxy-curing agent-filler combination for the formulation of special purpose adhesives, coatings or encapsulating (potting) mixtures. The kit consists of an assortment of four types of epoxy resin, six curing agents, five fillers, and instructions, properties tables, and mixing and curing data.

Priced at $37.50, the kit is expected to find a wide market among researchers, fabricators, and designers of electronic components.

The Ring Chemical Co., 1112 Rosine St., Houston, Tex., 77019. [406]

Thermocouple alloys boast long life

Two new thermocouple alloys offer a life expectancy in generated atmospheres of from 500% to 1,300% longer than other materials and have substantially improved electromotive force stability and oxidation resistance, according to the manufacturer.

The new products are Tophel II (91% nickel, 9% chromium) for positive thermoelements, and Nial II (95% nickel, 5% silicon) for negative thermoelements. Both were designed for situations in which ISA type K couples are used.

The materials are said to eliminate two common complaints about standard K alloys. These are that in a protective atmosphere the positive leg fails as a result of drifting from its original electromotive force, and that the negative leg in an oxidizing atmosphere lacks necessary oxidation resistance.

Tophel II may be used to match ISA curves from 32° to 2,300°F. Nial II deviates slightly from the standard type K curve in the temperature range of 100° to 300°F. This is not likely to matter since thermocouples using the materials would not normally be used to measure temperatures below 500°F.

Stability tests of the two materials at 1,750°F in an exothermic atmosphere (15% hydrogen, 10% CO, 5% CO_2, 1% CH_4, 1% H_2O, balance nitrogen) for 1,000 hours show a drift of less than 10°F compared with a drift of 74° to 155° with standard materials.

Wilbur B. Driver Co., 175 McCarter Highway, Newark, N.J., 07104. [407]

Aerosol-packaged plastic mold release

Tech-Rel TR-101 aerosol mold release is announced. It is a release agent that has been subjected to extensive testing in both laboratory and production applications. It has been tested for transfer, compression and injection molding of epoxy, diallyl phthalate, nylon, polyethylene and other industrial plastics. The tests proved that Tech-Rel affords optimum release with negligible surface residue at room and elevated temperatures, according to the manufacturer.

The aerosol-packaged release agent uses Genetron as a propellant to assure ultrathin uniform coatings, resulting in plastic reproductions of the finest detail.

Price for a sample 10-oz can is $2 each; for a case of twelve 10-oz cans, $1.75 each.

El-Tech Manufacturing Co., Inc., 416 East Church Road, Bridgeport, Pa., 19405. [408]

Sticks like epoxies, conducts like silver

Two solders now available combine the excellent adhesive properties of epoxies with the electrical conductivity (0.01 ohm-cm-max) of silver. Dynaloy 320 features fast-set, whereas Dynaloy 325 offers an effective working time of 3 to 4 hours.

Both epoxy-silver solders offer ease of mixing (1:1 mix ratio) and cure to form a tough, highly conductive bond. Special manufacturing processes assure uniform conductivity and adhesive strength from lot to lot. The solders already are finding wide usage in the electronics industry where they offer decided advantages over metallic solders—room temperature set and ease of application.

Dynaloys 320 and 325 are available in 2-oz polyethylene squeeze bottles or glass jars, as well as in 8- and 32-oz bulk containers.

Dynaloy, Inc., 408 Adams St., Newark, N.J., 07114. [409]

New Books

Differential equations

Analogues for the Solution of Boundary-Value Problems: International Tracts in Computer Science and Technology and their Application, Vol. 13
B.A. Volynskii and V. Ye Bukhman
Pergamon Press, 460 pp., $15

The ability to solve partial differential equations is required of virtually all engineers and physicists. Typical of the broad range of problems encountered is the need to solve to the Schroedinger wave equation in solid state physics and variants of the heat equation in rocket motor design. Since the unknown variable can be a function of both time and space coordinates, initial time conditions as well as spatial-boundary values are required to arrive at a solution.

Few of the equations of interest can be solved by analytic methods. Since numerical methods involve a considerable expenditure of time and labor, a variety of machine approaches have been employed. These include digital and analog computers as well as direct analogs. This book is concerned with the approximate solution of boundary-value problems using one class of direct analog—the impedance mesh.

While perhaps not intended as such by the authors, this work may be considered as two separate books. The first is a treatise on approximate solutions for partial differential equations with spatial and time boundary values. Included are the problems of electrode graphitization, laminar fluid flow past objects, magnetic and acoustic field tracing and the efficient exploitation of oil fields.

The authors provide a comprehensive discussion of the mathematical principles for solving boundary value problems and a comparison of similarities and differences of finite difference methods, integral solutions and the Monte Carlo techniques. Network analogs that satisfy various classes of partial differential equations are developed, with a number of specific cases given in detail. At this point an error analysis is made, along with means for improving accuracy of the electrical simulation.

This first portion of the book is an excellent reference for the practicing engineer. There is particularly good coverage of ways to formulate finite differences to improve the accuracy of the approximations.

If a fault is to be found in the first part of the book, it is in the bibliography. The authors give only 11 references, all of them Russian. This probably indicates a lack of familiarity with Western sources. However, this sort of intellectual parochialism is not restricted to Eastern authors since few American bibliographies include European sources, much less Eastern European. Thus, S. Fifer's book, "Analogue Computation," which gives 73 references on the same topic, is also limited.

But significant topics, such as Vichnevetsky's analysis of truncation errors in the finite difference representation of partial differential equations, are not covered. In a similar manner, the extensive use in the United States of hybrid computers (digital/analog) in the solution of such equations by an iterative representation of cells is not mentioned.

The "second" book is mainly concerned with measurement techniques and construction details of special-purpose Russian machines that use network analogs. Its contents will be of little interest to the practicing engineer and of only passing interest to students of computer science. The concluding chapters treat briefly other direct analogs, possible future developments to accelerate solutions and means of defining variable-boundary conditions in the solution of nonstationary boundary-value problems.

In summary, half of the volume is useful reference for engineers with graduate-level engineering math, including at least an elementary understanding of partial differential equations. It certainly belongs in industrial libraries. The second half of the book can be ignored.

Emanuel Katell
Electronic Associates, Inc.
West Long Branch, N.J.

Technical Abstracts

Glass in space

Effects of space radiation on refractive properties of optical glass

I.H. Malitson, National Bureau of Standards, Washington, D.C. and M.J. Dodge, Frankford Arsenal, Philadelphia

One of the major considerations in designing cameras and television systems for use in outer space is the effect of space environment on focus and picture geometry. Many navigation and guidance systems, such as star trackers, require a pointing accuracy not to exceed one second of arc.

A change of two or three units in the sixth decimal place of refractive index, corresponds to a change of one second of arc in angular deflection of light rays in these systems. Thus a careful evaluation of the refractive properties of glass components should be made when designing systems for application in the space environment.

In a recent study, performed jointly by the National Bureau of Standards and the Naval Research Laboratory, different types of glass were evaluated to determine their refractive indexes after exposure to cobalt 60 and electron radiation in the wavelength region from 4,000 to 7,000 angtroms.

This study, supported by the National Aeronautics and Space Administration and the Department of Defense, was made on glass exposed to 10^6 rads of Co^{60} gamma radiation, and 10^{15} e/cm at 2.0 meV. This is estimated to be the integrated electron flux equivalent to that encountered by a space vehicle during one year of orbit in the radiation belts that surround the earth.

The tests were performed on borosilicate, flint, barium crown glass and fused silica. Cerium-protected specimens of borosilicate and flint glass were also included in the tests. The glass specimens were in the form of 60° prisms and were approximately 10 millimeters thick.

Cobalt irradiation of specimens was performed at the National Bureau of Standards gamma ray laboratory. The radiation source consisted of a series of 12 cobalt 60 rods, 15 inches long, arranged in a cylindrical configuration at the bottom of a 10-foot-deep pool of water. The specimens were placed in a water-tight stainless steel can and lowered into the center of the array of rods where they remained for the time required to receive the desired dosage.

The Naval Research Laboratory performed the electron irradiation with a Van de Graaff generator.

Results of the tests for radiation-exposed borosilicate, barium crown, and flint glass were as follows:

- Refractive index can change by as much as 2 in the fourth decimal place in unprotected glass, and by 6 in the fifth decimal place in cerium-protected glass, as a result of exposure to gamma and electron radiations;
- Unprotected specimens turned brown after radiation, whereas cerium-protected specimens remained uncolored;
- Values of refractive index change erratically with time after irradiation in the unprotected glasses, and changes diminish with time. In the protected glasses, the radiation-induced index changes appear to remain constant with time;
- After exposure to electrons, the protected flint glass and the unprotected barium crown glass developed an electron discharge pattern, known as Lichtenberg figures, that result from the discharge of trapped electrons through the glass. The paths of the discharged electrons can easily be seen by localized cracking of the glass. Specimens of fused silica showed no appreciable change in color or refractive index after exposure to 10^8 rads.

The conclusion arising from the study is that for high-resolution cameras and television systems to be used in a radiation environment and which are unattended for long periods of time, index changes of the magnitude observed may result in serious degradation of image quality.

Presented at the Annual Conference of Photography, Science and Engineering, San Francisco, May 9-13.

New Literature

Portable signal conditioner. Nytron, Inc., 795 San Antonio Road, Palo Alto, Calif., 94303, has published a four-page brochure on the NY-1200 portable signal conditioner including illustrations and specifications.
Circle **420** on reader service card

Temperature detector. The Marin Controls Co., 917 Marine View Ave., Belmont, Calif., 94002 has released a data sheet on its solid state temperature detector, series 307, which will permit accuracies of better than 0.1°F. **[421]**

A-c converter. Dana Laboratories, Inc., Irvine, Calif., 92664. Application data sheet 563 discusses use of the model 615A a-c converter in scanning systems involving a-c measurements. **[422]**

Variable air capacitors. Johanson Manufacturing Corp., 400 Rockaway Valley Road, Boonton, N.J., offers a catalog describing the 3900 series high Q variable air capacitors, suitable for applications from vlf to uhf. **[423]**

Ultrasonic equipment. Gulton Industries, Inc., 3860 North River Road, Schiller Park, Ill., tells of ultrasonic equipment for soldering, drilling and cleaning in bulletin ULT. **[424]**

Solid state receiver. Defense Electronics, Inc., Rockville, Md. Bulletin TR-711 contains a complete description of a modular constructed, solid state telemetry receiver. **[425]**

Soldering instrument. Westinghouse Electric Corp., Scientific Equipment Dept., P.O. Box 8606, Pittsburgh, Pa., 15221. A two-page data sheet describes the redesigned Positerm soldering instrument, a versatile device that has cool tips, adjustable solder feed, and can be used either as a gun or as a pencil. **[426]**

Pressure transducers. Sparton Southwest, Inc., P.O. Box 1784, Albuquerque, N.M. Product description and detailed specifications on a series of pressure transducers are contained in product data sheet 1, 11, 14, 15 and 17. **[427]**

Energy storage capacitors. The General Electric Co., Schenectady, N.Y., 12305. GEC1595 is an eight-page, illustrated application and specification guide that features capacitors for oscillatory and nonoscillatory duty. **[428]**

Tape programers. Industrial Timer Corp., Route 287, Parsippany, N.J., 07054. Bulletin 107 describes a new series of direct-reading punched tape programers. **[429]**

Fixed coaxial attenuators. Weinschel Engineering, Gaithersburg, Md., offers a four-page data sheet covering models 3 and 4 miniature, precision, fixed coaxial attenuators, ranging from d-c to 18 Ghz. **[430]**

Microwave tubes. Sperry Electronic Tube division, Sperry Rand Corp., Waldo Road, Gainesville, Fla., has available a catalog designed to aid microwave engineers in choosing the correct tubes for a system. **[431]**

Subminiature switch. MicroSwitch, a division of Honeywell, 11 W. Spring St., Freeport, Ill., 61032. Bulletin 51SM describes a new UL, CSA listed 5-ampere subminiature switch with center-plunger location. **[432]**

Selenium contact protectors. Edal Industries, Inc., 4 Short Beach Road, East Haven, Conn., 06512, has issued a two-page catalog sheet describing its series R selenium contact protectors and arc suppressors. **[433]**

Adapter. Acopian Corp., Easton, Pa., 18042, has published bulletin 366B describing an adapter that permits instant conversion of an unregulated plug-in power module into a metered laboratory type of power supply. **[434]**

H-f antenna selection. Granger Associates, 1601 California Ave., Palo Alto, Calif., 04304 offers a full-color chart designed to help choose an antenna to meet nearly any combination of environmental and transmission requirements in the 2- to 32-Mhz range. **[435]**

Microvolt-ammeter. Keithley Instruments, Inc., 12415 Euclid Ave., Cleveland 6, Ohio. An engineering note describes the model 153, which measures from 5 μv full scale to 1,000 v and from 5 x 10^{-12} amp full scale to 0.1 amp. **[436]**

Microwave components. Microwave Associates, Inc., Burlington, Mass. The 120-page catalog C-15 contains specifications on more than 4,000 products, indexed for easy reference. **[437]**

Pulse equipment. General Radio Co., West Concord, Mass., offers a 12-page illustrated brochure on pulse generators and associated equipment. **[438]**

Electromechanical servos. Kearfott Products division, Aerospace group, General Precision, Inc., 1150 McBride Ave., Little Falls, N.J., has published a catalog describing a variety of miniature electromechanical servos. **[439]**

Ratio instrumentation. Astrosystems Inc., 521 Homestead Ave., Mount Vernon, N.Y. An eight-page brochure deals with a line of ratio instrumentation, including decade ratio transformers, programable ratio transformers, programable synchro and resolver bridges, and programable synchro standards. **[440]**

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Electronics Abroad

Volume 39
Number 14

Great Britain

Glove-compartment printer

A small strip printer that has made life easier for public-utility maintenance crews may become an added occupational hazard for criminals in Britain.

The Midlands Electricity Board recently completed field trials of a vehicle-mounted printer, linked to a very high frequency radio network ordinarily used for two-way voice communications. When a crew is out of its truck making repairs and can't be reached by voice call, the dispatcher puts the message on the printer. The printout rate is 300 to 400 words a minute.

British police authorities followed the Midlands tests with considerable interest because they see the glove-compartment printer as a way of calling patrol cars without tipping off crooks astute enough to tune in on the police band. Without the printer, the high-speed data signals would be difficult for anyone to fathom. Decoding would become nearly impossible for outsiders because the police would make daily code changes.

Dispatch. Voice scramblers would accomplish much the same purpose; in fact, police in several cities in the United States already use scramblers. However the printer system has an added advantage: it can transmit "all cars" messages faster than they can be read by a dispatcher. A 30-word message, for example, takes about 4½ seconds.

Ferranti Ltd. developed the system. The central station unit—suitcase size—operates with a standard punched tape and converts the 5-hole teletype code into printer code at a rate of 40 characters per second. The encoder costs $6,000.

For the $300 glove-compartment unit, Ferranti eliminated metal type keys. Instead, a 5-by-5 matrix of needles prints the messages on metal-coated tape. The decoding circuits in the printer energize the needles selectively as the ¼-inch-wide tape passes. Arcing between the writing-needle points and the metal coating burns legible characters into the tape.

West Germany

Bus control by bits

Urban bus riders around the world face similar rush-hour frustrations. Even the best-laid schedules falter as traffic jams build up in the streets and queues stretch out at bus stops. Then the buses clump up, making matters worse.

To hold to their schedules as closely as possible, many bus operators in the United States and elsewhere have turned to two-way radio. When drivers lag in their schedules, they flag a dispatcher who tries to figure a way out of the jam. The Paris rapid transit system is trying out a plan that keeps track of buses using curb-mounted receivers to pick up code signals transmitted by buses as they pass [Electronics, Jan. 24, p. 191]. The most ambitious effort at bus control, though, seems to be the one mounted by the Hamburg transport company, Hamburger Hochbahn Aktiengesellschaft.

Printer-recorder in dispatching center of Hamburg bus company shows where each bus on a route should be and where it actually is.

HHA has begun large-scale tests on a system that automatically plots bus positions alongside a time-distance diagram representing the bus' schedule. The plot for each bus is made once every two-and-one-half minutes from code signals radioed to a central control. So far, HHA's system keeps tabs on 18 buses. Results have been so encouraging that the company plans to extend the system to include 300 buses over the next two years. N.V. Philips Telecommunicatie Industrie, an affiliate of N.V. Philips Gloeilampenfabrieken of the Netherlands, developed the equipment.

The system, admittedly, is expensive. HHA expects to spend around $750,000 for it. Return on the investment will come in part from a 50% cut in dispatchers now spotted at critical spots along downtown bus routes and from a reduction in the number of buses needed as a rush-hour reserve. Above all, HHA hopes faster rush-hour service will win more passengers and more fares.

No hands. Bus drivers don't have to get into the act for the automatic plotting of bus positions. A 10-watt central transmitter sends out binary coded signals that interrogate buses in sequence. A transceiver in each bus automatically responds each time it's called.

The response signals are decoded at a central control and displayed as dotted lines on a printer-recorder whose chart has preprinted on it time-distance diagrams for all buses on one route. The dispatcher, then, can spot schedule disruptions at once.

Thirty-two bits of information make up the calling code signal. Six bits identify the vehicle number and five bits the bus route. Synchronization, service, separation and checking bits compose the balance of the signal, transmitted at a rate of 300 bits per second. At that rate, the system could handle up to 1,152 buses—up to 48 buses on each of 24 routes.

When called in its turn, the bus transmits its position as a 29-bit code signal. None of the information identifies the bus; the calling sequence does that. So to make sure that the bus goes on the air only at the right time, the decoding circuits in the bus equipment see to it that there is no reply transmission unless both the bus' call signal and the one that preceded it have been recognized.

Since one bus is replying while the next one is being called, interrogation and response codes are transmitted on two different frequencies in the 160-megahertz band. Another pair of frequencies in the same band handles two-way voice communications.

Curbed. Position information for each bus comes from two sources: curbside marker transmitters and the odometer of each bus. The odometer feeds a pulse into a distance register in the transceiver for each 100 meters traveled. The position signal identifies the last marker transmitter signal picked up by the bus plus the distance traveled from that point.

Range of the induction fields put out by the marker transmitters is just seven meters. This prevents outbound buses running on one side of the street from picking up transmitter signals for inbound buses on the other side. A binary code identifies the markers; each marker transmits two of six preset frequencies between 20 and 40 kilohertz. Tuned circuits in the bus equipment pass the signal into a 6-bit store that is read out, along with the distance register, when the bus responds to an interrogation signal. Each time the bus passes a marker transmitter, the old data gets wiped out.

Switzerland

Well timed

Two Swiss research organizations will provide European scientists, and for that matter anyone else, with precision time anytime and almost anywhere it is needed.

The Neuchâtel Observatory has started experimental time-service broadcasts running round the clock and covering all of Western Europe. The Swiss Laboratory for Horological Research, also based in Neuchâtel, has come up with a specialized portable receiver to pick up the time signals.

Although there are some 40 stations around the world that broadcast time signals, none broadcasts time signals continuously and in the long-wave band the Swiss have chosen to get broad coverage. The Swiss time signals, transmitted at 75 kilohertz by a 25-kilowatt station near Geneva, can be picked up as far as 1,500 miles away.

Interruptions. Instead of modulating the carrier, the Swiss interrupt it for a precise 0.1 second interval at the beginning of each second. Minutes are marked by a double interruption. Eventually, the observatory plans to add a triple interruption to mark the hour and a quadruple one to mark noon and midnight.

Carrier frequency and interruption periods are derived from a rubidium frequency standard that was supplied by Varian Associates. The frequency standard, in turn, is calibrated against a cesium-beam atomic clock accurate to 2 parts in 10^{-11}. That works out to a gain or loss of less than a microsecond a day.

The receiver converts the unmodulated 75-khz time signal into either an audio tone or into pulses of 8 volts amplitude. Normal pulse duration is 0.1 second, but the pulse can be inverted to get a duration of 0.9 second. Accuracy is 0.5 millisecond.

The horological laboratory has a run of 100 prototype receivers in the works at Neuchâtel. However, four large watchmakers will take over to put the receivers into commercial production, slated to start before the end of the year. Market price for the receiver probably will be somewhere between $100 and $200.

Although the initial market looks fairly thin—observatories, geophysical institutes, seismic centers, watchmakers and industrial laboratories seem to be the most likely customers—it could develop in time. The Swiss foresee a line of receivers for commercial uses including synchronized clocks.

France

Trial balloons

While President Charles de Gaulle generated headlines around the world with his visit to a Russian launch site, French and American space officials went ahead quietly with plans for the second launch of a French satellite by an American rocket.

After a year of preliminaries, the National Aeronautics and Space Administration and its French equivalent, the Centre National d'Etudes Spatiales, agreed last month on a late-1968 launch for FR 2, a French satellite which will gather weather data picked up by 500 to 1,000 constant-altitude balloons. The French call their satellite-balloon project Eole, the Gallic name for the Greek god of the winds.

NASA will put the satellite into a 50° inclined orbit with a Scout launch vehicle from California's Vandenberg Air Force base. The satellite will fly over the balloons every 1½ hours, interrogating them as it passes. The data will be stored temporarily, then dumped out on command from the four ground stations of the French tracking network, stretching from France to South Africa.

The constant-altitude balloons will be fitted with electronic packages slung from them by cable. Along with temperature and pressure instruments, they will carry transponders so the satellite can pick up changes in balloon location. Aim of the Eole experiment is to determine if the satellite-balloon combination can gather masses of earth-wind data for long-range weather forecasts.

Japan

Electronic touch tuning

So far, Japanese transistor-radio makers have counted mainly on their low prices to make hay in the United States market. Now, one of the leaders of the Japanese contingent, the Matsushita Electrical Industrial Co., is about to take a fling at the market with $40 table-model receiver. The ticket is high for a set limited to the standard amplitude-modulated broadcast band, but Matsushita figures consumers will pay the premium for electronic touch tuning.

The electronic touch tuning is based on variable-capacitance diodes that Matsushita developed. The diodes have maximum capacitance of 250 picofarads; more important, their change-of-capacitance factor is 23, more than adequate to tune the entire 525 to 1605 kilohertz broadcast band. Diodes currently offered by U.S. manufacturers have ratios too low to do this [Electronics, June 27, p. 26].

Although two Matsushita diodes cost more right now than the conventional two-gang tuning capacitor they replace, the company maintains they are cheaper than the components needed for motor-driven automatic tuning. Eventually, Matsushita hopes to bring the price of the diodes down to where they'll cost less than a two-gang capacitor.

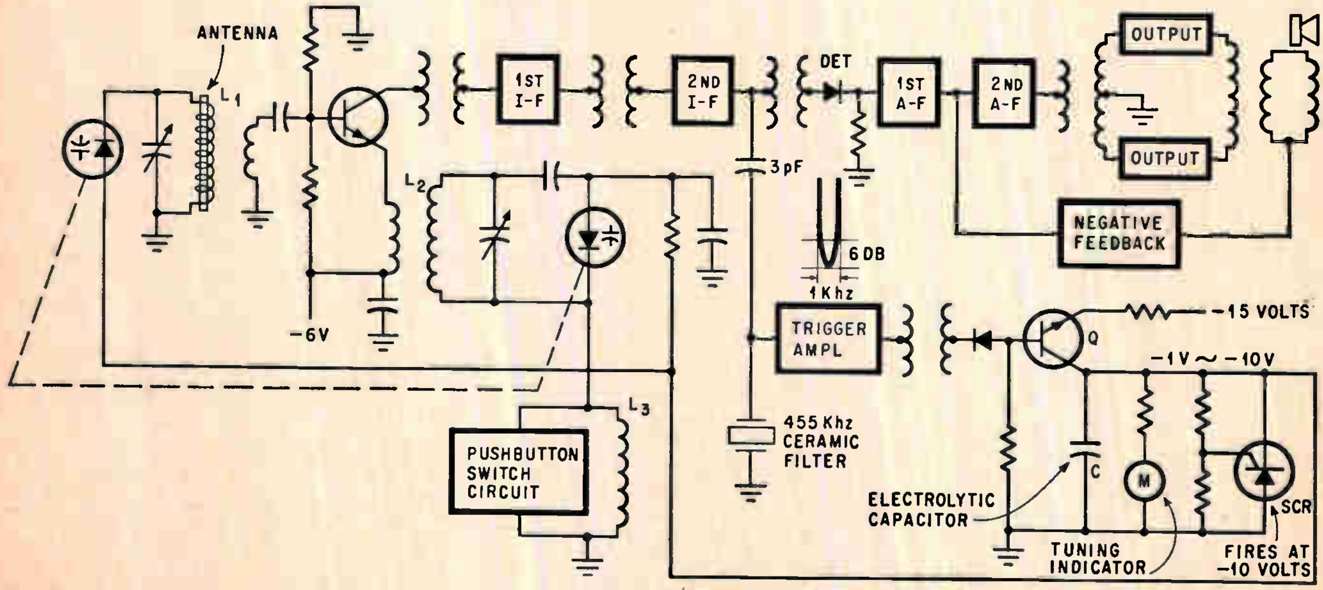
Fast sweep. For its electronic touch tuning, Matsushita uses two variable-capacitance diodes, one in the antenna circuit and one in the local oscillator circuit. An increase in the bias on the diodes from 1 volt to 10 volts sweeps the tuning circuits across the full a-m band in just three seconds under no-signal conditions. When a station is picked up, a trigger amplifier halts the sweep and holds the receiver locked onto the station until the touch-tuning pushbutton is pushed to restart the sweep.

Sweep voltage for the variable-capacitance diodes is picked off electrolytic capacitor C (see circuit schematic), charged from a —15-volt power supply through transistor Q. As long as there is no signal at the output of the i-f amplifier, transistor Q conducts and charges capacitor C. This sweeps the tuning circuits upward across the broadcast band.

Locked. When the tuning circuits pick up a station, a signal appears at the output of the i-f amplifier, which is connected to both the detector circuits and the trigger amplifier. Because of a narrow-bandwidth ceramic filter at its input, however, the trigger amplifier develops an output only when the detector circuits are accurately tuned to an incoming carrier.

An output from the trigger amplifier cuts off transistor Q. This halts charging of capacitor C and thus the sweep of the tuning circuits. Because there is resistance in parallel with capacitor C, it tends to discharge; but resultant detuning of the local oscillator diode cuts down the trigger amplifier output so that transistor Q will conduct just enough to recharge capacitor C. This feedback action keeps the carrier centered in the i-f bandpass range with a tuning error no greater than several hundred hertz, better than obtained normally with manual tuning. A voltmeter, calibrated in kilohertz and connected across capacitor C, indicates the frequency to which the station is tuned.

Change. A flick of the touch-tuning pushbutton restarts the sweep of the tuning circuits. The pushbutton circuit momentarily shorts coil L3. The lowered inductance kicks up the local oscillator frequency by about 20 khz and the



Simplified schematic diagram of Matsushita table radio with electronic touch tuning.

station is lost. The trigger amplifier then has no output to cut off transistor Q and the transistor starts to charge capacitor C, whose voltage is applied to the variable-capacitance diodes. The frequency jump of 20 khz is large enough to unlock the trigger amplifier but is not large enough to skip stations, which are spaced 50 kilohertz or more apart.

All the way. When the voltage across capacitor C reaches 10 volts, the set is tuned to the upper end of the broadcast band. At 10 volts, there is sufficient potential at the voltage divider to trigger the silicon controlled rectifier in parallel with capacitor C. When the scr conducts, it discharges the capacitor. The sharp drop in reverse voltage on the tuning diodes jumps the tuning circuits back to the low-frequency end of the band. Capacitor C then starts to recharge, sweeping the tuning circuits upward until a station is received.

If Matsushita's set designers hadn't taken a special precaution, there would be a drawback to their touch-tuning circuits: every time the set was switched off it would jump back to the low end of the broadcast band. To hold the tuning circuits at the frequency they are at when the set is switched off, there are two power supplies. One is very low level, just enough to power the r-f and i-f circuits. It stays on as long as the set is plugged into a line power socket but consumes practically no power. The larger supply for the audio circuits is switched on and off conventionally.

Austria

Instruments for growth

Offbeat origins are fairly common among electronics instrument makers but few can match that of the Anstalt fuer Verbrennungsmotoren (AVL) of Graz, Austria.

AVL started out shortly after World War II, under the wing of the Technical University of Graz, as a consulting engineering office specializing in Diesel engines. Over the years, AVL blossomed into the Research Institute for Combustion Engines (the English translation of AVL) and acquired an impressive worldwide list of clients. Its revenue last year totaled $2 million, 80% of it fees for engine research and development.

Along the way, AVL acquired a sideline—selling electronic test equipment it had developed for its own use. Now the sideline figures to become a mainstay. The company expects to hit a $4-million sales level by 1968, largely through a push on electronics. Says Hans List, the company's sprightly 70-year-old founder and owner, "We are going to develop electronics 10-to-1 against other activities here."

Staples. For its test equipment, AVL's market is all export. One of its bread-and-butter items is an elaborate test bench that records engine parameters like compression, torque, speed, vibration levels and fuel consumption. AVL builds these custom test rigs with standard transistorized modules that include amplifiers, trigger units, phase inverters, calibrating units, and power supplies.

The amplifiers were designed to match the quartz transducers used extensively in engine-parameter tests. Input impedances run high, up to 10^{14} ohms for a single-stage unit designed around a metal oxide semiconductor-field effect transistor. As you'd expect, AVL has developed an extensive line of quartz transducers. Their noteworthy feature is printed, rather than soldered, connections.

Breakout. To hasten the metamorphosis from Diesel design to manufacture of electronic instruments, AVL has started to break out of the engine-test-bench field. The company has high hopes for the accelerometer market. Already Swissair has fitted AVL units into the engines of its jet fleet to record vibration and acceleration data. An American airline may follow suit. The AVL accelerometers have a life of better than 3,000 hours and can handle acceleration to 10 g.

AVL also spilled out of the test-bench field with a peak pressure meter originally developed for engine work. By a slight design change, AVL engineers converted the meter for direct reading of internal ballistics in rifles. Special cartridges have quartz transducers fitted on them for testing; a second transducer is mounted near the muzzle of the gun barrel. Peak outputs of the transducers recorded on the meter indicate the impulse applied to the projectile.

Diesel expert Hans List has turned AVL into a fast-growing electronics instrument company.

AVL's research engineers have come up with so many ideas that the company ranks eighth on the list of Austrian patent holders—ahead of companies with sales 400 times greater than AVL had last year. Still, in an effort to broaden its line, AVL has gone into production on some non-company inventions. One is the Electrodorm, a machine developed at the Graz Medical Faculty to induce sleep by using white noise up to 20 kilohertz. Another is high-vacuum equipment developed at Graz to prepare samples for electron microscopy.

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