How MOS devices fail 106
Measuring rejection ratios more accurately 116
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The HP 3300A Function Generator gives two simultaneous outputs (sine, square or triangle) across a frequency range of 0.01 Hz to 100 kHz. Mix or match your output signals with individually selectable function and amplitude controls. Price, $650; HP 3301A Auxiliary plug-in, $30.

The HP 3302A Trigger / Phase-Lock plug-in lets you phase-lock any two functions to an external periodic signal. Phase can be controlled over a $360^\circ$ range. Control single or multiple bursts with an external signal or the front panel manual trigger. Price, $225.

The HP 3304A Sweep / Offset plug-in provides a linear sweep adjustable in frequency and width within any decade over the entire frequency range. Variable dc offset of ±16 Vdc is provided for each function including the internally generated sawtooth—which makes hard-to-get driving functions readily available. Price, $265.

The HP 3305A Sweep plug-in lets you sweep up to four decades without switching ranges. It sweeps logarithmically in any of three overlapping ranges for narrow or wide band testing between adjustable start/stop limits. Use the manual sweep for close inspection of any portion of the trace or for accurate frequency identification.

The 3305A's continuously adjustable sweep time of 0.01 to 100 seconds is slow enough for accurate response testing of high-Q devices and fast enough for good visual displays of wide band response. For ease of automated testing, either the frequency or the sweep trigger can be externally controlled. Price, $975.

Get the function generator that best fits your measurements. Consult your catalog and order by calling your nearest HP order desk. For data sheets, write to Hewlett-Packard, Palo Alto, California 94304. Europe: 1217 Meyrin-Geneva, Switzerland.
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Communications 94 PCM: A global scramble for systems compatibility (cover)
Nation-to-nation differences in such characteristics as line rates and coding could decrease the effectiveness of interconnected systems; but the imminence of pcm satellites is impelling all parties to try and thrash out differences
William Bucci, Associate editor

Circuit design 103 Designer's casebook
- Pair of source followers keep a voltmeter steady
- Minimizing common-mode errors in a variable-gain amplifier
- SCR shift register can take a lot of noise

Integrated electronics 106 How reliable are MOS IC's?
As good as bipolars, says NASA
Although failure mechanisms differ for MOS because oxide is a functional part of the device, tests indicate failure rates running at 0.016% per 1,000 hours
Leon C. Hamiter Jr., National Aeronautics and Space Administration

Instrumentation 116 Common-mode rejection ratio: what the spec sheet doesn't say
Some critical assumptions, which aren't always true, lurk behind the test circuits recommended by amplifier makers
Frederick Gans, IC Metrics Inc.

Systems engineering 120 Computer simulation plays key role in design of satellite earth stations
Systems approach offers solution to complex politico-technical interface problems in ground terminals of global communications network
Lee B. Zahalka, GT&E International Systems Corp.

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Hooray for pay tv

To the Editor:

I read with considerable interest your article concerning Zenith Phonevision [May 26, p. 123]. While the article as a whole was substantially correct, I feel obligated to take issue with one point.

On page 124 you state: "Eavesdropping . . . is prevented by varying the video coding . . . " And further, on page 128: "Finally, Zenith's decoders were proved effective, with no known instances of encoded signals being unscrambled by privately built equipment." It is my belief that there were four groups of electrical engineers near Hartford who were trying to build their own decoder. Two companies represented were Hamilton Standard, and Pratt and Whitney Aircraft. Two of the four groups succeeded in decoding the audio, with varying degrees of audio quality.

In January, I successfully operated a "privately-built" decoder for both audio and video. While results were not perfect—due to some video smear and an incorrect component—it was viewable.

I decided to build a decoder as a senior project. However, I was told by the head of the electrical engineering department that it was not acceptable since "There was nothing to it, since all that was necessary to do was to hook a bunch of parts together."

In any event, my hat is off to the people who developed the Phonevision system. A lot of thought and hard work went into the system, and I wish them well with it—as I feel that it is about the last hope for relief from the garbage that is put out on commercial television. Perhaps some competition will improve network programming.

I noted that in your article you were careful to divulge no exact technical data. I feel much the same way, since it would hardly be fair to tell all while the system is in commercial use. There is some effort involved in building your own unit, however. My decoder, while largely composed of integrated circuits, would, if built discretely, involve somewhat in excess
All the advantages of tantalum... at low cost!

Type 196D Dipped Solid-Electrolyte Tantalex® Capacitors

Here's a capacitor design that admirably fills the need for low-cost yet dependable solid tantalum capacitors suitable for printed wiring boards. Straight leads as well as crimped leads are readily available to meet your manufacturing needs.

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Tiny Type 160D/161D Tantalex Capacitors are sealed within a polyester film tube with tightly-bonded epoxy fill, so the assembly is both electrically insulated and highly resistant to moisture. They are available with axial leads as well as in single-ended construction.

Offering extremely high capacitance per unit volume (for example: 0.25 µF @ 20 VDC in a case only .065” D. x .125” L), Tantalex Hearing-aid Capacitors let you select from a broad range of ratings in five different case sizes.

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The 1863 for production and inspection testing of insulation

This versatile new "leak detective" is a high-performance megohmmeter priced at only $385*. Five test voltages (50, 100, 200, 250, and 500 V) cover the range specified by most MIL and EIA Standards for testing the insulation resistance of mica-, glass-, paper-, ceramic-, and plastic-dielectric capacitors. The 1863 is equally suitable for insulation-resistance investigations on cables and electrical machinery; its 50-kΩ to 20-TΩ total resistance range covers most insulation specifications.

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Another hundred dollars give you an even more versatile investigator, the Type 1864 Megohmmeter. It has an additional resistance range and 200 test voltages from 10 to 1000 V (1-volt steps from 10 to 109; 10-volt steps from 110 to 1000 V). The 1864 is an excellent instrument for low-voltage leakage (resistance or current) investigations of diodes, transistors, and aluminum and tantalum electrolytics. Its resistance range is from 50 kΩ to 200 TΩ. Price: $485*.

**Both have these features:**
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For complete information, call or write General Radio Company, W. Concord, Massachusetts 01781; telephone (617) 369-4400. In Europe: Postfach 124, CH 8034, Zurich 34, Switzerland.

*Prices apply only in the U. S. A.
Readers Comment

of 218 transistors. Of course, this is not the most efficient design by any means, but it gives some feel for the circuitry involved. Needless to say, it’s not a weekend project.

Henry J. Laguillon
Southampton, Mass.

Always helpful

To the Editor:
I would like to call your attention to the article “Rotating disks and drums set peripheral memories spinning” by Michael French [May 26, p. 96]. In it, I am quoted [p. 97]; while the quote is accurate, the company division referred to is wrong. We are the Magne-Head rather than the Magnefile division of the General Instrument Corp. Magnefile is a competitor of ours.

Richard J. Martin
Director of Marketing
Magne-Head division
General Instrument Corp.
Hawthorne, Calif.

Two sorts of ZIP

To the Editor:
Thank you for the notice given to the Post Office’s Symposium on Pattern Recognition [May 12, p. 34]. We wish to take exception, however, to certain connotations inherent in this article.

Many readers would assume that the Philco-Ford reader, discussed at the symposium, was for machine imprinted ZIP Codes and not for uncontrolled handwritten ZIP Codes. Philco-Ford’s numeric script reader is a research project and is entirely different from the 10 alphanumeric operational optical character readers now in the field.

The performance figures quoted, 45% to 47%, are correct for the numeric script reader. Our OCR’s, however, maintain an average acceptance rate on the order of 75%.

Edward M. Reilley
Director
Research and development
Post Office Dept.
Washington, D.C.

Granger multicouplers let one antenna serve two or even four HF transmitters simultaneously without interference or interaction. Each transmitter functions as if it were the only one in the circuit. Efficient . . . save on antennas and ground space.

Granger balun transformers provide the most efficient way to transfer power from transmitter to antenna. Efficient . . . use economical 600 ohm lines on the long runs from transmitter to antenna and still get the 50 ohm coax connections where you need them.

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Let G/A baluns and multicouplers help make you an efficiency expert in designing new HF systems . . . or improving older installations. Write for complete data.
Who's Who in this issue

Zahalka

Well-traveled is the word for Lee B. Zahalka, who wrote the article on computer simulation's important role in ground station design that starts on page 126. A Johns Hopkins graduate, he has accumulated over 20 years experience in military, commercial, and aerospace systems work which has taken him as far afield as India, Spain, Italy, Australia, Thailand, Mexico, and a host of other countries.

Bucci

Advanced technology is associate editor Bill Bucci's beat; the latest result of his coverage, a cover story on pulse-code modulation's growing pains, begins on page 94. A 1954 graduate of Columbia University, Bill has worked at Stevens Institute of Technology and the Bell Telephone Laboratories as a technical press relations specialist; he was an assistant editor at the Bell Labs Record where he wrote about laser pem, high-capacity co-axial pem, and related subjects before joining Electronics.

Gans

Vice presidencies are a typical dream for many engineering students. Frederick Gans, author of the piece on common-mode rejection ratios (page 116), has made it, but is still hitting the books in pursuit of a master's degree in electrical engineering at the Polytechnic Institute of Brooklyn. Currently vice president for product development at the IC Metrics Corp., Gans earned his B.S. at Columbia University in 1966. Before joining IC Metrics last summer, Gans worked at Grumman's Microelectronics Laboratory where he helped to write a proposal for standardizing linear IC definitions used as a basis for MIL STD 883.

Hamiter

Reliability has been the professional preoccupation of Leon C. Hamiter Jr. during his National Aeronautics and Space Administration career. Currently chief of the parts and microelectronics branch at the Marshall Spaceflight Center's quality and reliability assurance lab, he wrote the article on metal oxide semiconductor reliability (page 106). Jay Farley, manager of reliability and quality assurance at American Micro-systems, and Don Drum, manager of reliability and quality assurance at General Instruments' Microelectronics division, contributed to both the NASA project and the article.

Electronics | June 23, 1969
There's no better way to meet today's new circuit design challenges than with RCA's "building block" linear IC's. Evaluate them now for RF, IF, AF and DC amplifiers; sense amplifiers; multi-function circuits; Schmitt triggers; balanced multi-channel circuits and many others. Work with the RCA QK2202 Linear Array Sampler—a box full of linear integrated circuit "building blocks."

There are 10 types (23 devices in all) of virtually unlimited flexibility. You get high-gain amplifiers; differential amplifiers; Darlington and multi-transistor arrays, and diode arrays. You get wide design capabilities—from DC to 500 MHz. Of course, you get thorough documentation—technical and applications data—Linear IC Manual—mounting and connection techniques information—and a copy of ST-3895, "Design Ideas for RCA Linear Arrays."

In short, you get all you need to build your skills with RCA's dependable linear array "building blocks." Your RCA Distributor has RCA QK2202 Linear Array Sampler kits at $37.95 (optional distributor resale price). Get yours—and get started—now.

RCA Electronic Components, Harrison, N.J. 07029

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Now...from GR Industries
...a totally new breed of system control computer
You have never seen a computer like this before

The GRI 909 is the first truly innovative approach to computer architecture since the general-purpose computer was first applied as a control device. It goes beyond traditional design to provide a new level of power and flexibility. A true system controller, it provides the only logical answer to many of the basic problems that face system designers...problems like these:

PROBLEM #1
The Real World Interface
In spite of claims to the contrary, the typical small computer is designed primarily as a calculating device, not as a controller. The system designer, after describing his system functionally, must either transcribe his design into the non-functional language of the computer with all its expressed and implied constraints, or turn over the programming responsibility to a specialist whose background usually is not related to the system application. Result: substantial expense, long delays and occasionally, built-in software limitations.

No problem with GRI-909
The GRI 909, designed as a system controller, is organized functionally. ALL data registers, whether associated with the processor, firmware options or input/output devices, are equally accessible to the system designer. ALL data registers may be incremented, shifted or algebraically tested: the traditional arithmetic operator, with its associated registers, is optional. The GRI 909 programming language is tailored to the functional organization of the processor itself. Input/output devices are operated with the same basic language code. The system designer can both design a system and implement its application in this functional language.

PROBLEM #2
The Data Flow Maze
Conventional computer architecture is designed around an instruction repertoire, with maximum computing power as the major criterion. The input/output instructions are a secondary consideration and instruction power is limited. The flow of data in and out is impeded by the implied operations of the instructions. Free communication between internal computer elements and external devices is not possible.

No problem with GRI-909
Here the problem is solved by extending the I/O bus system into the heart of the central processing unit itself. Data is free to flow directly between devices external to the computer and the arithmetic unit, memory, or any of the internal registers without stopping along the way in special accumulators. This free direct flow cuts down on time consumed in moving data about, and reduces or eliminates the need for temporary storage. A unique advantage is GRI 909's ability to perform certain simple operations—increment, complement, shift left or right—on the fly.

PROBLEM #3
The Black Box Hang-Up
Once a computer is selected the system designer is locked into a pre-established set of capabilities. The CPU is essentially a black box, and there is little that can be done to alter its basic structure. If the system requirements change to include say a "hardware multiply", or "hardware square root", or "hardware byte swap", or "hardware anything", the only alternative is to go to a bigger, more expensive computer possibly requiring a complete new interface design with all new software.

No problem with GRI-909
The GRI 909 has provision for the addition of firmware options. And by firmware we mean, not merely the substitution of read-only memory for software, but a broad range of hard-wired plug-in functions which can replace a variety of software routines. This gives the system designer complete freedom to adapt the computer to changing system needs, and to evaluate trade-offs between speed and economy in individual cases.

Basic characteristics

The GRI 909 cannot be fully evaluated in conventional computer terms. But for those who like to play the numbers game, the following characteristics are listed:

- Full Cycle Time: 1.76 µsec for a 16-bit word
- Memory Reference Instruction: 32K directly addressable—not page oriented.
- Memory Addressing Modes:
  A. Direct Mode: Single Address Instruction, 32 bits (16 bit op. code, 16 bits address)
  B. Immediate Mode: 32 bits (16 bit op. code, 16 bits data)
  C. Deferred Address Mode: One level of indirect addressing with 32K of auto-indexable locations
  D. Every device in the system, both inside and outside the computer, is directly addressable by programmed instructions.
- Memory access channel is available on the same data and control lines as the programmed input/output channel (t/0 rate: 1.76 µsec/word). No DMA multiplexer is required for multiple DMA devices.
- Priority interrupt system has full capability to be used as a single channel interrupt or as a full hardware interrupt at the option of the system designer.

The GRI 909 with 4K 16-bit words of memory and ASR33 Teletype sells for under $10,000. Basic units start at $3600.

August deliveries will include: basic assemblers which can be assembled in the GRI 909 or the IBM 360, programming aids, math routines and utility routines.

Let us tell you more — Because GRI 909 is a completely new breed of computer, it is impossible, here, to cover its many unique features and their implications for the system designer. If you build control or instrumentation systems let us tell you what GRI 909 can do for you. For a copy of our new brochure write to:

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Electronics | June 23, 1969
Applications Power*

FETS IN TUNABLE FILTERS

Problem: To design a low cost, lightweight voltage tunable filter.

Solution: Use FETs as Voltage-Controlled Resistors (VCRs). Here is one approach:

With this circuit you can have a tuning range up to 20:1 with a roll-off of 12 dB/octave. Weight is in the ounce-plus region and size is about 1/5 cubic inches. Here are the design conditions and equations:

- $R_{in} > 10X_c$
- $R_s < 0.1X_c$
- $R = R_s + r_s$
- $M^2 = C_s / C_c$
- $r_s = \text{FET drain-source resistance}$
- $1 - V_{ds} / V_r$
- $f_s = r_s$ with $V_{ds} = 0$
- $\omega_n = \text{Corner frequency}$
- $1 - V_{os} / V_b$
- $r_s = \text{MC}$

* If you need a voltage tunable filter, and cost, size, weight and low power consumption are important considerations, give us a call for fast applications assistance. That’s applications power: Products and service! Ask for Extension 19.

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Who’s Who in electronics

Lowell

His business card reads, “A. C. Lowell, Chairman of the Board, L-Squared Industries.” The initials of his newly formed company—LSI—suggest that Art Lowell won’t be out of the semiconductor business for long. Lowell, 50, resigned as Autonetics’ director of microelectronics applications and advanced products three months ago to join Joseph Leaming, president of both L-Squared Industries and Electronics Development Corp. The latter firm specializes in equipment, such as frequency-modulated up-down converters, for the fast-growing community antenna television (CATV) industry.

Electronics Development expertise is the wedge that Lowell expects L-Squared will use to move into the world of the “wired community” overseas. He hopes to have a commitment shortly for a demonstration model of a wired community antenna television (CATV) industry.

Lowell plans to build, in a separate joint venture with still another undisclosed partner, a 35,000-sq.-ft. plant to make the memories. The irrepressible Lowell hopes to have the first devices off the lines by February.

Recognizing his own unbounded optimism, which he labels “the Lowell factor,” he admits that “everything has to break right for the Lowell factor to work right.” This means getting the semiconductor facility on stream, locking up the commitment for the overseas wired-community demonstrations, and forming a foreign corporation—a majority of which would be held in the U.S.—to operate an overseas manufacturing facility for L-Squared Industries.

Pragmatists in Congress have long claimed that NASA gives costly space programs like Apollo and unmanned planetary probes the nod over practical programs in the area of space applications. Now NASA is responding to that criticism by elevating Leonard Jaffe, formerly director of space applications programs, to a new post: deputy asso-
Ideal
Constant Current

Like Having 2,500,000,000 Ohms in Series With
2,500,000 Volts

Unlike many so-called "constant current" sources, the new CCB Series has the necessary high impedance, non-capacitive output. There is essentially no stored energy to dump, delaying response to programming or load changes. Patented Guard Circuit allows the output voltage to be monitored, externally, without degradation. Further, the new CCB Series permits you to preset current and voltage before connecting your load.

Two models are now available: the 6177B at 0-500 mA, 0-50V; the 6181B at 0-250 mA, 0-100V. Either can be remote programmed (resistance or voltage) with an accuracy of 1% or better.

Other operating features are: Transient recovery time of less than 200 µsec for output recovery to within 1% following a full load change; programmed speed of less than 500 µsec. from zero to 99% of programmed current output; resolution of 0.02% of the range switch setting; rms ripple less than 80 ppm of range.

Both Constant Current Sources are 3½" high half-rack size, weighing 10 lbs., and are priced at $425.00. For additional specifications, contact your local HP sales office or write: Hewlett-Packard, New Jersey Division, 100 Locust Avenue, Berkeley Heights, New Jersey 07922. . . In Europe, 1217 Meyrin-Geneva.

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Circle No. for details 515

Additional Constant Current/Voltage Models
For Higher Current . . . less sophistication

Circle 516
Circle 517
Hadron's LPM Series represents a unique solution to the laser applications problem - its modular construction and easily exchangeable work fixtures make it equally useful for various industrial applications as well as for general laboratory applications. The versatile, reliable LPM is a fully integrated system, where the laser head, optics, and power supply are all contained in one small (24" x 18" x 12"), lightweight (125 pounds) unit. The interlocking of work fixtures minimizes radiation hazards in industrial applications. Closed-circuit television provides for viewing and setting up where required. Q-switched operation provides for synchronization.

Engineered to meet precision production tool standards, special emphasis has been placed on:
- Reliability
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- Versatility

Available in Q-switched as well as normal mode configurations, the LPM system is a proven tool not only for precision microfabrication but also for the balancing of small gyros, motor rotors, as well as watch balance wheels.

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A rugged easily removable laser head provides for long maintenance-free operating life. Flashlamp replacement does not necessitate optics realignment.

The water-cooled LPM laser provides an energy up to 5 joules, a pulse width of 800 microseconds, and a repetition rate up to 1 pulse per second.

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**Who's Who in electronics**

Jaffe

---

ciate administrator for applications. In addition, Jaffe will be acting director of the Earth Observations Programs Office which will include such programs as the emerging Earth Resources Technology Satellite program, Tiros, Nimbus, the new synchronous meteorological satellite, and sounding rocket programs. Slated for the directorate in the new organization is Richard Marsten, currently manager of advanced programs technology for the RCA Astro-Physics division. Marsten will head the Communications Program Office and be charged with navigation and traffic control satellites, geodetic satellites, the Applications Technology Satellite program, and activities in support of Comsat.

On your mark. Says Jaffe of the new position: “The higher level of organization is recognition on the part of NASA of the increasing importance of space applications.” Jaffe sees the 1970’s as the time when the big push will finally be made in such areas as data-relay satellites, and broadcast and navigation satellites. The pacing item, according to Jaffe, is the beginning of the Earth Resources Technology Satellite program. On a more mundane level, Jaffe says that the new organization will also mean a larger staff in the Space Applications Office and more money for research in the area of potential space applications programs.

Jaffe, an EE, has been with NASA since its inception, and was with its predecessor.
Convert your present scope into a curve tracer: $595.00*

The first plug-in unit that transforms an existing scope into a curve tracer—at 1/2 to 1/3 the cost!

U-Tech plug-in
Model 681: $595.00*. For use with Tektronix 560 series Oscilloscopes.

U-Tech plug-in
Model 682: $615.00*. For use with Tektronix 530, 540, 550, 580 series Oscilloscopes.

U-Tech Console
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Now you can expand your present Oscilloscope to include curve tracer capabilities. U-Tech plug-in and console units enable any X-Y Oscilloscope to display the dynamic characteristics of both NPN and PNP transistors, N Channel and P Channel junctions, FETs, MOS-FETs, bipolar, unijunctions, diodes, tunnel diodes and SCRs.

So, if it wasn’t in the budget before, now it can be, and even if you were planning for a curve tracer, you can now buy two, possibly three, of these units for the price of any other characteristic curve tracer.

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☐ Yes, send me curve tracer model __________________________

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Name: ___________________________________________ Title: _______________________

Company Name: __________________________________________

Company Address: _________________________________________

City: __________________ State: ______ Zip: ___________

*Prices apply to purchases and shipments within U.S.A. from Salt Lake City, Utah.

Electronics | June 23, 1969

Circle 17 on reader service card 17
Several hundred thousand unfair advantages.

There you are, busting your back trying to beat another company to market with a new, improved electronic Thing.

Everything looks good — up to the point where sub-assembly X has to be connected to board B. And you've never seen a connection like that before.

What do you do now? Take an R&D break? Give a connector-maker a panic call, and half your budget, to develop a special?

Sweat not. We're sitting over here with several hundred thousand different connectors. Most of them were specials, once. Many of them are patented. And all of them are ready. Now.


Because they're ready, you get a jump on your competitor while he re-invents one. Because they're standard, you put your Thing together for less money than he can. It may be unfair. But it's fun. And profitable.

But what if we don't have a standard for you? Still no problem. Because, with hundreds of thousands of different connectors already behind us, your special will just be a not-quite-standard. So we'll be able to save a lot of time and R&D, too.

We have several pounds of catalog, containing more information about connectors than you probably care to have. So don't just send back a reader information card. Call, write, wire, or TWX us, and tell us either your specific problem or your general field of interest. We'll send you the pertinent few ounces.


ELCO Connectors

Circle 19 on reader service card
Everyone talks corrected reliability,
here's the way it looks.

Switches under glass.

The heart of every AE correed is a reed switch consisting of two overlapping blades. For protection, we seal them inside a glass capsule. But only after we pull out all the dirty air and pump in a special, pure atmosphere. That way there's no chance of contact contamination or oxidation. Ever.

Notice our terminals are one piece. A special machine delicately forms them to precision tolerances. It's a lot of work, but one-piece terminals have distinct advantages over the two- and three-piece kind.

For one thing, there's no extra joint so you're always assured of a positive contact. Also, one piece terminals are more reliable when the correed is used to switch low-level analog signals. That's because thermal EMF is reduced to practically zero.

A different kind of bobbin.

Since we go through so much trouble with our correed capsules, we designed a special bobbin to protect them.

It's molded of glass-filled nylon. (You know how plastic chips and cracks.) Moisture and humidity have no effect on this stubborn material. No effect means no malfunctions for you to worry about. No current leakage, either.

Running the full length of the bobbin are a series of slots. They pamper the capsules and keep them from getting damaged or jarred.

And to help you remember which terminal is which, we mold the terminal numbers into the end of the bobbin. You can read them at a glance.

Little things mean a lot.

Reliability means that we pay attention to the little things. Like the tiny pressure rods we use in every miniature correed. They're placed at each end of the bobbin, across the one-piece terminals. What they do is prevent stresses from being transmitted from the terminals to the reed blades. This keeps the contact gap right on the button. All the time.

The contacts are normally open. To provide them normally closed, we employ another little device—a tiny magnet. It's permanently tucked into a slot next to the reedcapsule. The magnetic action keeps the contacts normally closed.

Coiled by computer.

Once all the parts are secure in the bobbin, we cover them with protective insulation. Around this, we wind the coil. You can be sure the coil winding is correct. It was all figured out for us by computer.

Our next step is to protect the coil. We do that with more protective insulation.

A coat of iron.

On top of the insulation goes a layer of annealed iron. It acts as a magnetic shield and minimizes interaction between coils. Also, it improves the sensitivity of the entire unit. A coat of iron is standard on all AE correeds.

Finally comes super wrap.

To wrap it all up, we use some very special stuff. A layer of mylar laminated material. It's so tough we guarantee it to withstand all cleaning solvents known to man.

It's attention to detail that helps us keep our miniature relays miniature. Now we're just waiting to show you how perfectly it measures up to your specifications. Automatic Electric Company, Northlake, Illinois 60164.
Diverse exposure at radiation conference

Their titles alone indicate that one of the more intriguing aspects of the annual conference on Nuclear and Space Radiation Effects—July 8-10 at University Park, Pa.—should be the roundtable discussions. Two are planned: "System prediction—fact or fancy?" and "Device hardening—its need and practicality." The former will delve into the problems involved in developing a general computer program that can be used to predict the radiation effects for just about any system, and thus avoid having to generate a new model for each new system. The latter will explore the provocative question: Should the program engineer develop new devices that are radiation hardened and then try to get manufacturers to build them; or, should he try to adapt the system to accommodate the use of existing hardware and devices?

To provide some diversity, the banquet talk will be on the subject of biological oscillations. In it, Edmond Dewan of the Air Force’s Cambridge Research Laboratories will cover the natural rhythms of human and animal bodies and discuss the interesting possibility of using human brain waves as electrical inputs to control a computer.

The conference boasts, in addition to roundtables, seven technical sessions on a wide range of topics. Several papers will treat the displacement effects in semiconductor materials and devices. They’ll examine the effect of fast neutrons on transistors and concentrate on how to overcome some of the difficulties when using junction field effect transistors. Another fairly comprehensive session will focus on the problems of charge buildup in insulating layers, and on surface effects. And several papers will cover new surface preparations that minimize these effects in transistor, integrated circuit, and metal oxide semiconductors.

Other sessions will deal with the radiation effects in circuits and systems, energy disposition and dosimetry, and transient ionization effects. Also, a special symposium will include two topics: The potential of field ion microscopy in the investigation of radiation effects, and the breakdown of organic materials under irradiation.

For information contact D.K. Wilson, Bell Telephone Laboratories, Whippany, N.J. 07981

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Calendar


Conference on Applications of Continuous System Simulation Languages, Association for Computing Machinery, IEEE; Sheraton-Palace Hotel, San Francisco; June 30-July 1.

Aviation and Space Conference, American Society of Mechanical Engineers; Statler Hilton Hotel, New York; June 30-July 2.

Computer Science and Technology Conference, University of Manchester Institute of Science and Technology; London, England; June 30-July 3.


Conference on Measurement Education, IEE; University of Warwick, Warwickshire, England; July 8-10.

Conference on Nuclear and Space Radiation Effects, IEEE; Pennsylvania State University, University Park, Pa.; July 8-11.

International Conference on Medical and Biological Engineering, International Federation for Medical and Biological Engineering, Joint Committee on Engineering in Medicine and Biology, IEEE, Instrument Society (Continued on p. 24)
A logic approach for systems having special little wrinkles

If your logic-system design matches up end-to-end with someone's standard products, fine. But if there's a peculiar little wrinkle in there — one that defies pre-packaged answers — we're your people. We supply standard products, and help smooth out wrinkles, too.

For products, we offer PHILCOLOGIC Micromodules in today's most advanced logic module design. Unique three-dimensional format accepts all existing IC's, discretes, and hybrid combinations. Size is only a fraction of PC-card modules.

Compatible logic lets you freely intermix both digital and analog functions on a common chassis.

For speedier troubleshooting, they offer front access to all input/output terminals as test points. For quicker replacement, color-coded labels identify logic type and family at a glance. For higher reliability, a rugged mechanical design proved in service at NASA Manned Space Center.

And down-to-earth prices.

For wrinkle smoothing, we offer brainpower. It comes in when your system requirement departs the beaten path. Our customer-aid engineers get paid for keeping up with the rapidly changing world of logic, which comes in handy when you need a trail blazed across uncharted design territory. The PHILCOLOGIC Support (PS) design service is available to all our logic module customers.

Product and support system Data File 155 rounds out the story. For your copy, write Product Sales Manager, WDL Division, Philco-Ford Corporation, Mail Station C-41, 3939 Fabian Way, Palo Alto, California 94303. Or call (415) 326-4350, extension 5981.
Knock it off its pedestal and win a job at Bell & Howell!

For two years we've tried to top the VR 5000. So has the competition. But the VR 5000 was so far ahead of its time — in concept, performance, reliability — that even our best human and magnetic heads have been unable to surpass it.

And no other instrumentation recorder has been able to equal it. Admittedly, several others have come fairly close. But being close doesn't put you on a pedestal.

If you'd care to accept the challenge, or would just like the facts about the world's finest instrumentation recorder — call our nearest office. Or write Bell & Howell, Pasadena, California 91109. Ask for Bulletin Kit 3302-X1.

Meetings

(Continued from p. 22)

of America, American Society of Mechanical Engineers, American Institute of Chemical Engineers; Palmer House, Chicago; July 20-25.

Annual Conference on Engineering in Medicine and Biology, International Federation for Medical and Biological Engineering, Joint Committee on Engineering in Medicine and Biology, IEEE, Instrument Society of America, American Society of Mechanical Engineers, American Institute of Chemical Engineers; Palmer House, Chicago; July 20-25.


Seminar on Case Studies in System Control, IEEE; University of Colorado, Boulder; Aug. 4.


Third Annual Contemporary Filter Design Seminar, University of Missouri, Columbia, Mo.; Aug. 5-8.


Western Electronic Show & Convention (Wescon), IEEE; Cow Palace & San Francisco Hilton Hotel, San Francisco; Aug. 19-21.

Symposium on Programming Languages Definition, Association for Computing Machinery; San Francisco; Aug. 24-25.


ACM National Conference and Exposition, Association for Computing Machinery; San Francisco Civic Center; Aug. 26-28.


Electrical Insulation Conference, IEEE; Sheraton-Boston Hotel & War Memorial Auditorium, Boston; Sept. 7-11.

European Microwave Conference, IEE; (Continued on p. 26)
The QUALITY is Allen-Bradley—the price is COMPETITIVE! This new Type W variable resistor is a commercial version of the Type G control.

This Type W variable resistor features a solid, hot-molded resistance track for long operating life. Life tests show less than 10% resistance change after 50,000 complete cycles. Noise level is low initially and actually becomes less after normal use. Furthermore, the resolution is essentially infinite, and the low inductance permits operation at high frequencies where wirewound controls are useless.

The Type W control, while only $\frac{1}{8}$ inch in diameter, is immersion-proof. The shaft is sealed with an “O” ring, making it watertight at that point.

Rated $\frac{1}{2}$ watt at 70°C, the Type W can be operated at 120°C ambient with zero load. Nominal resistance values are from 100 ohms to 5.0 megohms.


*Standard unit with plain bushing and hardware. 20% tolerance in 1,000 piece quantities. Price subject to change without notice.
Meetings

(Continued from p. 24)


Convention of the Society of Logistics Engineers; Cape Kennedy Hilton Hotel, Cape Canaveral, Fla.; Sept. 9-10.


Short courses

Probability and Random Processes for Engineers and Scientists; University of Michigan, Ann Arbor; July 7-18. $400 fee.

Fundamentals of Remote Sensing; University of Michigan, Ann Arbor; July 14-25. $350 fee.

Principles of Imaging Radars; University of Michigan, Ann Arbor; July 21-Aug. 1. $350 fee.

Call for papers

Conference on Magnetism and Magnetic Materials, IEEE, American Institute of Physics; Benjamin Franklin Hotel, Philadelphia, Pa., Nov. 18-21. Aug. 18 is deadline for submission of abstracts to Dr. H.C. Wolfe, American Institute of Physics, 335 E. 45 Street, New York 10017.

Fall USNC/URSI Meeting, IEEE; University of Texas at Austin, Dec. 8-10. Sept. 22 is deadline for submission of abstracts to Dr. Alfred H. LaGrone, Engineering Science Building 535, The University of Texas at Austin 78712.

International IEEE/G-AEM Symposium, IEEE; University of Texas at Austin, Dec. 9-11. Sept. 22 is deadline for submission of abstracts to Dr. Alfred H. LaGrone, Engineering Science Building 535, The University of Texas at Austin 78712.
"ALLEN BRADLEY HOT-MOLDED RESISTORS ENHANCE THE QUALITY STANDARD OF OUR DATA-RECORDERS."

Mohawk Data Sciences Corporation

The time reduction achieved by the MDS Data-Recorder method of computer input preparation demands continuously reliable operation. And this in turn demands the highest standards of performance from each and every component.

Allen-Bradley fixed composition resistors were a natural selection. Made by an automatic hot-molding technique—developed and used exclusively by Allen-Bradley—A-B resistors afford the ultimate in uniformity. From resistor to resistor—year in and year out—physical and electrical properties are unvarying. Predictable. Always of the highest order.

Performance records are equally excellent. For example, Allen-Bradley hot-molded resistors meet the requirements of the new MIL-R-39008A Established Reliability Specification at the highest level—the S level. And this is true for all three ratings—the 1 watt, ½ watt, and ¼ watt—and over the complete resistance range from 2.7 ohms to 22 megohms.


Mohawk 1101 Data-Recorder permits transcribing of data from source documents direct to ¼" computer magnetic tape.

Typical printed circuit board used in the MDS 1101 Data-Recorder, showing the extensive use of Allen-Bradley hot-molded ¼ watt resistors.

A-B hot-molded fixed resistors are available in all standard resistance values and tolerances, plus values above and below standard limits. A-B hot-molded resistors meet or exceed all applicable military specifications including the new Established Reliability Specification at the S level. Shown actual size.
Sealed.
Our ARINC-type connectors are environmentally sealed. And intermateable with existing types, too. The whole family—every configuration in every type. Standard, high density, and coaxial.

Is sealing important? Yes! Because it assures the protection of the electronic equipment in aircraft from dust, moisture, fluids and other harmful conditions. An additional reliability factor is the crimp, snap-in, contacts with dual-spring socket design for electrical integrity under conditions of shock and vibration. Contacts are removable for easy maintenance.

When it comes to communications and navigation equipment, reliability and maintainability are vitally important. Just write for information on our ARINC-type connector improvements and we’ll tell you all about them. Industrial Division, AMP Incorporated, Harrisburg, Pa. 17105.

TOOLING: An AMP-TAPETRONIC* Stripper/Crimper in your plant strips and terminates wire in a single machine. Tape-mounted pin and socket contacts can be terminated at rates of 1200 to 1500 per hour.

*Trademark of AMP INCORPORATED

Sealed.

Sealed.

Sealed.

Sealed.
Just arrived. Series 54H/74H. The fast ones.

Just about the fastest saturated logic circuits around. Series 54H/74H from Sprague. The whole family. Flip-flops and all.

Use them in arithmetic and processing sections, where speed really counts. Mix and match them with Sprague's standard Series 54/74.

Get off to a fast start with Sprague Series 54H/74H.

Call Sprague Info-Central (617) 853-5000 extension 5474.

Or call your Sprague industrial distributor. He has them on the shelf.

For complete specifications, circle the reader service number below.

Sprague Digital ICs. Illustration: Series 54H/74H in flatpack and DIP

<table>
<thead>
<tr>
<th>TYPICAL CHARACTERISTICS</th>
<th>GATES</th>
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-55 to +125°C
0 to +70°C

Electronics | June 23, 1969
The case for an open market

To help close the technology gap that exists between themselves and their U.S. counterparts, European companies are opting for mergers. The gap is underscored by this statistic: 90% of installed computers in Europe, including Britain, were designed and developed in the U.S. or by subsidiaries of U.S. companies. Thus, to a great extent, mergers make sense. But there’s also a trend in Europe toward government protection of domestic companies. And should this trend continue, it could prove harmful to Europe’s electronics industry.

Companies like Britain’s Marconi and Elliott Automation, to name but two, have merged so that they could pare costs through volume production and establish a broader financial base. (Moreover, such mergers have led to layoffs of layers of managers and technologists. Thus, in almost a single swoop, merged companies have improved their financial positions by further reducing overhead and have eased Britain’s shortage of engineers too.) Britain has also enacted legislation that favors domestic companies, and the government itself “buys British.” Nevertheless, there remains a dark cloud over the horizon: Britain’s domestic market may be too small to support even the merged companies.

A far more plausible solution to the plight of European industry would be its cultivation of the international market. Progressive companies are already moving in this direction. In the U.K., Plessey has its eye on the overseas market for ICs. Derek Roberts, general manager of Plessey’s IC operations, predicts that the company will manufacture some of its ICs in the U.S., perhaps through an arrangement with a U.S. company. Roberts says, “We’ve got to attack the American market or regard ourselves as second string and shut up shop.” And German engineers are only half joking when they talk of an electronics product having a “Volkswagen effect.” Valvo may have this idea in mind as it pushes ahead with plans to develop specialized linear ICs for color TV. The ICs, the company believes, will be marketable in the U.S. either directly or as part of television sets built by companies like Grundig. French companies too, are eying the world markets, starting off on a selective basis and eventually hoping to move in on a grand scale. FNIE (France’s equivalent of the EIA) is studying the export market for telecommunications and medical electronics gear. And the same is being done by CEFAR, which is primarily concerned with the exports of measurement, control, and instrumentation products by its member companies. Technical managers at West Germany’s AEG-Telefunken foresee “international interest groups” comprising device and equipment manufacturers in specific fields (automotive electronics, for example). In this approach, informal alliances, not mergers, would prevail. This would circumvent the legal complications usually associated with mergers that cross national boundaries.

Such mergers are fraught with problems. Aside from the language barriers, laws and tariffs differ among the nations that make up the European community. Notwithstanding, some experts believe mergers are a condition of survival.

André Charguéraud, president of Diebold Europe S.A., insists that mergers should be given priority since they’ll bring “sound competition within a free-enterprise world and also pave the way toward a true European economic community.” Charguéraud notes that European governments have committed more than $500 million to the computer industry alone. In Britain, the government supports cooperation between ICT and English Electric; in Germany, the government backs cooperation between Siemens and AEG-Telefunken; in Holland, the government is assisting Philips’ entry into the computer field; and in France, the government is helping sponsor the entry of CSF and CSTH into the field. But, says Charguéraud, really aggressive competition must await mergers of the successful computer companies on a Europe-wide basis. Such mergers, he believes, would benefit even the U.S. computer manufacturers through open international competition—competition that would not be unduly biased by artificial protection of smaller computer companies.

It’s difficult to fault governments for helping businesses getting started, but these businesses should be able to sustain themselves without continuing protection. In their zeal to close the gap, European central governments may become overly protective and erect trade restraints that hurt those very companies they intend to help. A classic disadvantage of protective tariffs and embargoes is that they beget counter-tariffs and embargoes. The Japanese, for example, got off to a flying start in electronics under the umbrella of government protectionism. But they now find this protectionism backfiring. This policy has spurred angry resentment in the U.S., probably Japanese industry’s No. 1 customer. It is likely that Japan will voluntarily restrict some of its exports to this country. Far more desirable, however, would be the liberalization of Japan’s policies concerning imports and capital investments. Restrictions that favor an industry are usually easier to enact than to rescind. Whole economies can rise or fall as a consequence, and the political pressures to continue protective barriers can be overwhelming.

A free-trade policy for the electronics industry is imperative; it would speed electronics toward its destiny as an all-pervasive international business.
New complementary NPN/PNP power transistors from GE.

Color-molded to end assembly mix-up.

Now available in volume from General Electric... two new 1-amp and 3-amp pairs of low-cost complementary power transistors. These NPN/PNP pairs feature low saturation voltage, excellent gain linearity and fast switching... all in a sensible package, at a sensible price. GE's flat silicone-encapsulated power tab package is rugged enough to withstand hard use, and with the new narrow leads (25 mils), can easily be formed to either TO-66 or TO-5 configurations. To help eliminate NPN/PNP confusion during your assembly, each type is molded in distinctive color. No need for separate storage and production facilities for each type.

GE's new complementary power transistors are ideal for any class B audio application—everything from auto radios, tape players to televisions and stereo phonographs—from 3 to 20 watts output. These new NPN/PNP pairs are also well suited for use as drivers for higher power transistors, regulators, inverters, motor controls, lamp controls, solid-state relays, core drivers and many other applications. The 2.1W P_T free air rating allows simple printed circuit board assembly with no additional heat sinking. With added heat sinking, as much as 12W power dissipation can be achieved. Performance at these levels is everything you'd expect from General Electric, leader in power semiconductors.

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</table>

*Types available with T_d=20 min. @ 2A/1V

For more information on these and other General Electric semiconductor products, call or write your GE sales engineer or distributor, or write General Electric Company, Section 220-72, 1 River Road, Schenectady, N.Y. 12305. In Canada: Canadian General Electric, 189 Dufferin Street, Toronto, Ont. Export: Electronic Component Sales, IGE Export Division, 159 Madison Avenue, New York, N.Y. 10016.
Radiation Inc., which specializes in integrated circuits for the military market, now plans to move into the commercial and industrial IC market. The Melbourne, Fla., company has broken ground for a plant that will increase manufacturing space by one and a half times. Radiation will continue to use its dielectric isolation process to make all its IC's—the process separates circuit elements on a chip with a thin insulating layer of silicon dioxide—rather than the p-n junction isolation usually used. Dielectric isolation provides resistance to nuclear radiation (in fact, the firm claims to have 50% of the radiation-hardened IC market), but the company has long maintained that the process offers advantages in nonmilitary applications too—higher frequency and lower leakage, for instance.

Now, with backing from Harris Intertype, the company has the resources to expand into these other markets. Rather than second source other IC manufacturers, Radiation will develop a proprietary product line.

The long-awaited 715 operational amplifier linear integrated circuit from Fairchild Semiconductor [Electronics, May 12, p. 34] won't be alone when it's introduced at application seminars across the country in August: nine other linear IC's will be unveiled at the same time.

Linear IC marketing manager Mike Markkula says no other firm has ever before introduced as many as 10 linears at once, but he's touting technology rather than quantity. There will be at least seven op amps, some of them duals; one uses dielectric isolation for radiation resistance. There will also be an a-c power-control system incorporating a complete zero-crossing system in one package to cope with radio-frequency interference, a dual sense amplifier, and a color demodulator for television sets.

One of the devices, the 735 op amp, dissipates less than 100 microwatts vs. 50 milliwatts for Fairchild's own 741, which Markkula says is the industry standard today.

The two small computers introduced by Scientific Data Systems in March as the company's first entries in the minicomputer market are actually being made for SDS by Computer Automation Inc., a 2-year-old Newport Beach, Calif., outfit formed by two ex-employees of Varian. While this isn't the first time such a procedure is being followed—some of the Westinghouse Electric Co.'s process-control computers used in the experimental transit expressway several years ago were made by Univac—it's not an everyday practice.

The new SDS computers, 16-bit parallel-bus machines, were designed jointly by SDS and CAI engineers, but the bulk of the software was conceived by CAI. SDS calls the machines CE-16 and CF-16 and considers them peripheral equipment. The reason for having them made elsewhere, says SDS, is based on "optimum allocation of resources"—including development dollars and available manpower.

CAI, meanwhile, makes and markets its own line of four small computers, two eight-bit and two 16-bit machines.
... which foresees market sag as buyers resist unreliability

While the president of Computer Automation Inc. expects the minicomputer market to proliferate for a while—both in products and new firms to make them—he warns that the future could hold a downcurve.

Behind David Methvin’s prediction is the fact that the market now is “very big, money is available, and the market is very forgiving.” Methvin says that buyers expect their equipment to be heavily debugged, but the downcurve will come when they become more sophisticated and less tolerant of poor reliability. Methvin’s advice to a company poised to jump into the mushrooming small-computer arena: “Start with a simple design, don’t push the state of the art anywhere, use less power at less speed than you may be able to get, and give yourself enough room in the cabinet to dissipate heat well. And you can’t spend too much money on quality control, particularly in aging integrated circuits.”

Pentagon pushing to break up package

The Defense Department already has leaped on criticism of overruns in the C-5A program as a reason to scrap the McNamara total-package procurement concept, first applied in the construction of that giant transport. Now, the Pentagon brass has come up with a second.

Total package estimates include lifetime spare parts and maintenance, yet Air Force experience with maintenance estimates and actual costs are proving so far—particularly with electronic systems—that massive overruns are inevitable. So the DOD wants to drop maintenance estimates from system cost projections on the ground that such estimates can’t be reasonably determined in advance when new hardware is involved.

At the same time, the military, concerned with high electronics failure rates, is pushing for tougher contract regulations. Of the reliability problem, Gen. Jack G. Merrill of the Air Force Logistics Command says, “There has been enough improvement in the state of the art in electronics in recent years to give us much greater life in electronic systems, radios, and other gear than we are now getting. We are being plagued with high failure rates of even 25 hours between failures. We ought to be getting 2,500 hours between failures.”

RCA to expand semiconductor plant

RCA will spend $17 million within the next year to expand its semiconductor operation at Mountain Top, Pa., in the heart of the Keystone State’s coal-mining country, to manufacture thick-film integrated circuits.

Among the devices to be built at the plant are the recently introduced developmental 100-watt hybrid power amplifier now being built in sample qualities at Somerville, N.J. The amplifiers, slated for high-quality audio use, are scheduled to cost $80 apiece.

Wadsworth leaving FCC for Intelsat post

First to step down from the FCC under the new Administration may be James J. Wadsworth, who will resign as a commissioner to become a roving ambassador for the U.S. delegation to Intelsat. Wadsworth’s departure date coincides with the expiration date of Rosel Hyde’s term. Hyde, FCC chairman is expected to stay on for at least a few months to give President Nixon more time to select a successor.

Since both Wadsworth and Hyde are Republicans, President Nixon won’t be able to change the FCC’s political makeup until June 1970, when Democrat Kenneth Cox’ term expires. It’s most unlikely for the President to name Democrats to the politically sensitive commission.
HYBRID MICROELECTRONICS

New video amplifiers pack power into small package.

Versatile amplifier has 700 mW output in a one-inch-square package.

You’ll find a lot of applications for our versatile new MS-100 and MS-100A wideband video operational amplifiers. With varying associated circuitry you can use them as buffer amplifiers, video detectors, phase detectors, line drivers or as straight general purpose video amplifiers.

The high power capability of 700 mW (DC or squarewave) and small size (1.0” x 1.0” x 0.2”) offer a unique combination. Designed primarily for video applications, these plug-in units are capable of driving 10 Volts peak-to-peak into a 50-ohm transmission line.

Both amplifiers offer a 0 to 20 MHz bandwidth, high impedance differential inputs and DC coupling with low offset and temperature drift. Both positive and negative outputs are available. The MS-100A offers a faster slewing rate—180 volts/µs as compared to 100 volts/µs for the MS-100 model.

Both types offer output short circuit protection and an operating temperature range of −55°C to +80°C.

These wideband amplifiers are only part of our growing list of off-the-shelf hybrid microelectronic devices. And we’re able to provide complete support for design of custom modules as well.

Our long experience in film and packaging technology allows us the flexibility to develop many variations on our basic designs as well as develop completely new designs to your specifications. Why not discuss your design problems with our engineers?

Typical wideband amplifier specifications

<table>
<thead>
<tr>
<th></th>
<th>MS-100</th>
<th>MS-100A</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open loop gain</td>
<td>50</td>
<td>50</td>
<td>dB</td>
</tr>
<tr>
<td>Slewing rate</td>
<td>100</td>
<td>180</td>
<td>volts/µs</td>
</tr>
<tr>
<td>Max. output voltage</td>
<td>±12</td>
<td>±12</td>
<td>volts</td>
</tr>
<tr>
<td>Power out (max.)</td>
<td>700</td>
<td>700</td>
<td>mW</td>
</tr>
<tr>
<td>Open loop output impedance</td>
<td>33</td>
<td>33</td>
<td>ohms</td>
</tr>
<tr>
<td>Input impedance (differential)</td>
<td>9.0</td>
<td>4.0</td>
<td>K ohms</td>
</tr>
</tbody>
</table>

CIRCLE NUMBER 300

This Issue in capsule

Integrated Circuits
MSI simplifies binary-to-decimal conversion.

Diodes
How planar diode arrays save you time and money.

Television
Square corners are “in” for ’69 set design.

CRT Modules
New 12-inch monitor fits popular niche.

Circuit Modules
‘Dual in-line pac’ cuts module cost.

Manager’s Corner
What it takes to stay ahead.

EL Displays
Two-input power supply drives EL devices.

Wideband amplifier with 700 mW output is housed in one-inch-square package.
INTEGRATED CIRCUITS

**MSI simplifies binary-to-decimal conversion.**

Use of functional arrays cuts package count from 11 1/3 to 4 1/6.

Here’s a simple way to decode 4-bit binary code into 16-line hexadecimal. It uses four SM-223 demultiplexer arrays and 1/6th of an SG-383 hex inverter. An SM-163 4-bit binary counter is used here to illustrate driving of the system. The circuit arrangement is shown in Fig. 1.

The outputs of the demultiplexers are the “true” states of the decimal number. That is, when a particular number is decoded, its corresponding output is at logic “1”. All other outputs are at logic “0”.

Propagation delay to any output is about 22 ns. This speed easily allows decoding at a 20 MHz rate. Thus, the system is compatible with the high-speed SM-163 4-bit binary counter or with discrete flip-flop counters.

An inverter is included between the $2^3$ output of the SM-163 and $F_1$ of the first SM-223 demultiplexer to generate the $2^4$.

If a hex inverter such as the SG-383 is used, maximum package count will be 4-1/6. Using conventional gates, the most efficient design requires 11 1/3 packages when the false states of the four input bits are not available. In the conventional design, 8 dual 4-input gates and 3 1/2 hex inverters would be required.

It’s our SM-223 demultiplexer array that makes the package savings possible. Using internal gates which are designed for high speed rather than drive capability, the SM-223 can produce outputs in less than 12 ns.

The logic arrangement of the SM-223 is shown in Fig. 2. The demultiplexer array consists of two decoding sections. In one section, the data input may be steered to any one of four identical outputs under control of two selection variables. In the other section, another data input may be routed to either of two identical outputs depending on the state of one selection line. The output inverter/drivers provide the “true” state of the input data allowing direct entry into subsequent stages without extra gate inversion.

The logic diagram of the SM-163 4-bit binary counter is shown in Fig. 3. The circuit consists of four J-K flip-flops interconnected as a binary (1248 code) up counter. The flip-flops are synchronously clocked through two input AND gates. These eliminate the need for restrictive clock waveform requirements.

A logic “0” on the RESET input causes all four outputs to go to logic “0”. A logic “0” on any SET line causes the corresponding output to go to a logic “1”.

Both the SM-163 and SM-223 are available in 14-lead flat packs or in Sylvania’s ceramic 14-lead dual in-line plug-in package.

**CIRCLE NUMBER 301**
TELEVISION

Square corners are "in" for '69 B&W set designs.

Ever see a 15-inch B&W tube with 100-square-inch viewing area? You can see it now in our modern bold-look tube.

You can get that new look in your new TV set designs and you can get more usable viewing area by designing around Sylvania's new 15ADP4. Both the bold look of this tube and its larger viewing area come from the squared-off-corner construction that says "modern design."

And these are not the only features of our new 110° 15-inch tube. Its compact design and short overall length shrink cabinet size. The 15ADP4 also incorporates the 1 3/8" diameter neck that reduces your drive circuit requirements. T-band implosion protection comes as a standard feature.

Of course, our new tube incorporates all the same advances in tube design, materials and production techniques that have made Sylvania monochrome tubes the standard of the industry.

The Sylvania tube line, in fact, is one of the broadest in the industry. And our production flexibility allows custom design modifications to be made at minimum cost. Whether your need is off-the-shelf or custom design, Sylvania has the people who know how to handle the job.
CIRCUIT MODULES

'Dual In-Line Pac' cuts module cost.

New line of multilayer modules achieves high speed and low noise using dual in-line ICs.

We've got a whole new series of digital logic modules that combine low cost with the dual in-line integrated circuit package which has speed and noise properties similar to modules using flat packs.

The "Dual In-Line Pac" family is available in a wide variety of universally arranged gates and flip-flops. Included in the line of 48 modules are general gates, select gates, memories, registers, clocks, counters, decoders, drivers, and other functional types. All are capable of utilizing the 33 MHz speed of the ICs.

The circuit boards, each with positions for up to 12 IC packages, are of four-layer laminated construction. The boards utilize "buried" power and ground planes and two signal boards for lowest possible noise. Noise level is minimized by a module inductance of less than 1 nanohenry. The power/ground plane provides a built-in decoupling capacitance of 1000 pF.

Electrical interconnection from ground and power planes to the IC pins is made directly via plated-through holes. All circuit connections are terminated in a single 40-pin NAFL connector. The modules can be nested on 0.350" centers.

All modules undergo a 100% final electrical performance test to a specified test procedure. In addition, the circuit boards receive a 100% continuity test at 28 Volts and a 100% high pot test at 500 Volts before assembly.

A typical member of the "Dual In-Line Pac" family is the module type G20 shown in the photograph and logic diagram. The G20 module is a 12, 2-input gate inverting standard drive module. It is provided in eight different electrical configurations to give a variety of temperature and drive characteristics.

As with all the modules in the line, the G20 uses Sylvania's tried and proven SUHL logic circuits. The large number of device types available in this line gives us a wide flexibility in module design and permits many variations.

Our circuit board design is also compatible with other types of ICs and discrete components as well. We'll be glad to design custom modules to your exact specifications. Let us look at your designs. We'll show you how it can be realized in module form at lowest cost.

CIRCLE NUMBER 303

Dual-in-line modules provide a fast logic at lowest cost.

Logic diagram of G20 inverting standard drive module with twelve 2-input gates.

NOTE: TP REFERS TO TEST POINT. OTHER NUMBERS ARE PIN NUMBERS.
EL DISPLAYS

Two-input power supply drives EL devices.

Compact solid-state package provides 250 V, 400 Hz power from AC line or battery.

Although power requirements for electroluminescent devices are extremely low, the power supply should be designed specifically for the purpose. EL devices exhibit a capacitive loading characteristic, and care must be taken in the design of the power supply to provide protection against excessive current transients.

A special transformer design in our new PS-10 EL power supply provides this needed protection. The PS-10 is the first of a series of special power supplies designed specifically to handle electroluminescent loads. It can operate from either a 117 V AC, 60 Hz, line or from a 12 V battery. Nominal output voltage is 250 V AC at a frequency of 400 Hz. Maximum EL load current is 25 mA peak-to-peak.

The PS-10 can drive up to 10 square inches of electroluminescent panel at a 20% power factor with less than 10% decrease in output voltage or frequency. This is equivalent to driving 29 one-inch numeric characters fully illuminated or 8 two-inch characters fully illuminated.

The compact solid-state power supply is mounted in a 2 1/2" x 3" x 5 1/2" metal cabinet. The AC input is supplied by an integral line cord. For battery operation, a phone-jack type connector is used. When the battery jack is plugged in, the AC rectification circuit is disconnected. This arrangement provides a fast and flexible means of changing power sources as needed.

CIRCLE NUMBER 304

Specifications of EL power supply

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC input voltage</td>
<td>117V AC 60 Hz.</td>
</tr>
<tr>
<td>AC output voltage (nominal)</td>
<td>700V P/P</td>
</tr>
<tr>
<td>AC output frequency (nominal)</td>
<td>400 Hz</td>
</tr>
<tr>
<td>Maximum EL load current</td>
<td>25 mA P/P</td>
</tr>
<tr>
<td>Dimensions</td>
<td>2 1/4&quot; x 3&quot; x 5 1/2&quot;</td>
</tr>
<tr>
<td>Mounting position</td>
<td>Any</td>
</tr>
</tbody>
</table>
DIODES

How planar diode arrays save you time and money.

Arrays of 2 to 16 diodes can cut core-driver assembly time, give ultrafast switching capability.

You'll find outstanding benefits in both performance and production by using our core-driver diode arrays.

In performance, you get high forward conductance, fast recovery, low capacitance, and tight tolerances. In production, you reduce your labor costs, shorten assembly time and cut external wiring in the manufacture of computer memory-core driver systems.

Take, for example, our popular 8- and 16-diode arrays. Both types of array are available in common cathode and common anode configurations. These units have a forward current rating of 300 mA and a power rating of 300 mW per diode.

As for speed, reverse recovery time is a maximum of 60 ns, even under extreme switching conditions of a forward current of 300 mA and an I.R of 30 mA. Typical values for recovery time of I.R and I.F, switching from 300 mA to 30 mA is 35 ns.

The manufacturing process used to produce these arrays results in diodes which have closely matched electrical characteristics over a wide temperature range.

The 8-diode arrays are available in 10-lead flat packs or dual in-line plug-in packages. The 16-diode array is also available in a flat pack configuration or in a 14-lead plug-in package. All of these arrays are designed to meet MIL-S-19500 standards.

Other core-driver diode arrays are available from Sylvania in units from 2 to 16 diodes connected as common cathode or common anode.

### Maximum ratings at 25°C (each junction):

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reverse voltage, V_R</td>
<td>40 volts</td>
</tr>
<tr>
<td>Forward current, I_F</td>
<td>300 mA</td>
</tr>
<tr>
<td>Peak forward current, I_{FP}</td>
<td>1.0 amp (0.0</td>
</tr>
<tr>
<td></td>
<td>µsec, 25% D.C.)</td>
</tr>
<tr>
<td>Average power dissipation, P_{D}</td>
<td>300 mW (500 mW total package)</td>
</tr>
<tr>
<td>Junction temperature, T_{J}</td>
<td>-65°C to +150°C</td>
</tr>
<tr>
<td>Storage temperature, T_{ST}</td>
<td>-65°C to +300°C</td>
</tr>
</tbody>
</table>

Note 1. Pulse test ≤ 300 µsec, ≤ 2% duty cycle.

### Electrical characteristics at 25°C (each junction):

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward voltage drop, V_{R} (Note 1)</td>
<td>I_F = 300 mA</td>
<td>1.25</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Forward voltage drop, V_{R} (Note 1)</td>
<td>I_F = 500 mA</td>
<td>1.40</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Forward voltage drop, V_{R} (Note 1)</td>
<td>I_F = 800 mA</td>
<td>2.00</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Reverse current, I_R</td>
<td>V_R = 30 V</td>
<td>0.1</td>
<td>µA</td>
<td></td>
</tr>
<tr>
<td>Peak inverse voltage, PIV</td>
<td>I_R = 10 µA</td>
<td>40</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Capacitance, C</td>
<td>Ov = 1 MHz</td>
<td>6.0</td>
<td>pF</td>
<td></td>
</tr>
<tr>
<td>Reverse recovery, t_{rr}</td>
<td>I_R = 300 mA</td>
<td>50</td>
<td>nsec</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I_R = 30 mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R_L = 100 ohms</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CRT MODULES

New 12-inch monitor fills popular niche.

Universal display package meets a wide variety of needs from closed circuit TV to computer readouts.

Here's a 12-inch (diagonal) television monitor that gives you the most popular size display in a compact solid-state package. It can be used for computer terminals, airline status boards, stock-quotation displays, closed circuit TV, desk-type computers or anywhere else that a reliable high-quality display is required. And because we make it as a standard module, it means you get more performance for your money.

The module consists of circuit board, power supplies, and cathode-ray tube all packaged as a compact unit suitable for rack, console or cabinet mounting. Power supply for the module can be specified as either 117 V AC, or 22 V DC.

The display provides a standard 525 line raster and has bandwidth that is ± 1 dB from 15 kHz to 8 MHz. The composite video input signal can be from 0.5 to 1.5 Volts, peak-to-peak.

The standard module comes with a 12CSP4 cathode-ray tube with a gray filter faceplate and bonded-frame implosion protection. If that tube doesn't meet your requirements we can easily substitute one that will.

Because we make a wide variety of cathode-ray tubes and have first-hand knowledge of drive circuit requirements, you'll find it relatively easy to get a display module that fits your needs to a tee. We can also provide custom module designs for any size CRT and to meet a wide range of circuit requirements.

The 12-inch monitor is available with or without cabinet. With cabinet, it takes up a small amount of desk space. Dimensions are 13½” wide x 11½” deep x 12” high.

CIRCLE NUMBER 306

Use Sylvania's "Hot Line" inquiry service, especially if you require full particulars on any item in a hurry. It's easy and it's free. Circle the reader service number(s) you're most interested in; then fill in your name, title, company and address. We'll do the rest and see you get further information by return mail.
MANAGER'S CORNER

What it takes to stay ahead.

To remain a leader in a fast-moving field like electronics, a company must continually develop new products. To be a real innovator, such a company must develop new products even before the customer realizes that the need for the products exists.

We like to think of Sylvania as being the innovator in the industrial and military cathode-ray tube field. First of all, we have the organizational depth that makes such innovation possible. Our engineering staff has been closely associated with the development of CRTs for the home entertainment market. Here is where most of the innovations in CRTs have been made. New phosphor developments as well as improved processing techniques and materials are among our many developments in this field.

Our Industrial and Military Cathode-Ray Tube facility in Seneca Falls, N.Y. is able to translate these developments for use by our customers.

Secondly, we can draw upon the talents of the Sylvania manufacturing and marketing facilities to produce the special tubes we design and to tell us what the customer's needs are going to be.

As a result of these advantages the Sylvania I & M CRT Department has been able to lead the field in developing new products for the industrial and military user.

What are some of the new products which Sylvania has offered to the Industrial and Military marketplace?

Several years ago, as more and more display systems—such as ultrasonic testers—became portable, the need for a cathode-ray tube with a much reduced heater-cathode power was required. To fill that need, Sylvania designed the 1.5 Volt 140 mA heater. Today, it is the basis for many portable oscilloscopes.

In the display field, there has been a need for color without the problems and disadvantages of a shadow mask tube. Today, Sylvania can offer a multi-color display in almost any tube size with a resolution far superior to the standard TV type with a shadow mask.

There have been indications that the next generation of high density display tubes will require a new type of tube capable of higher brightness and higher resolution. Sylvania has just recently announced such a tube. It has seven beams with a common focus system and deflection yoke. In one horizontal sweep, it will generate one row of characters. The conventional tube requires seven horizontal sweeps to do the same job.

We have recognized in our display customers, a need to supply the tube and its immediate circuitry. To fill that need, a department has been formed which can supply, on custom specifications, an integrated display module which will include the tube, its mechanical mounting, its immediate power supply and deflection circuitry.

These are but a few of the new product needs which Sylvania has undertaken to fill in the marketplace.

The Industrial and Military Tube Department maintains its own development and production facilities, and we work closely with the Division's New Products Group to formulate new solutions. In addition, we can call upon the television-tube production facilities for large-volume production. With a total package capability like this, the I & M CRT Department is in an excellent environment to maintain its position as an innovator in CRT developments.

Alfred D. Johnson, Manager
Industrial & Military Cathode-Ray Tubes

This information in Sylvania Ideas is furnished without assuming any obligations.
with Fansteel’s SIL-PAINT™ and other conductive coatings. Custom formulations give you assurance of batch-to-batch repeatability...maximum conductivity...optimum solderability...superior adhesion...more parts coverage.

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Test our quick response. Specify Fansteel Sil-Paint and other conductive coatings. Be assured that you get only your formula...time, after time, after time. Electronic Materials Laboratory, 18201 South Santa Fe Ave., Compton, Calif. 90221. Phone (213) 638-7771.
Where extremely low-level signals must be measured in the presence of obscuring noise, the use of a PAR™ Lock-In Amplifier can often transform a complex and sometimes futile investigation into a routine test procedure. For example, Lock-In Amplifiers can be used to:

**IMPROVE BRIDGE SENSITIVITY TO ONE NANOVOLT (FS)**

A Lock-In Amplifier improves bridge sensitivity without over-driving the bridge circuit. Excite the bridge with the Lock-In Amplifier's internal oscillator and connect the external null detector termination to the signal input to get: (1) Measurements over frequencies of 1.5 Hz to 150 kHz. (2) Optimum noise figures using available preamplifiers with input impedances of several ohms to 100 megohms. (3) One nanovolt full-scale sensitivity for improved null accuracy and extremely low power dissipation in critical circuits. (4) A dc signal proportional to the off-null condition for use in modifying bridge parameters or as a recorder input. (5) Detection of in-phase (resistive) and quadrature (reactive) bridge components which can be nulled independently (and simultaneously, if desired).

**MONITOR OP AMP SUMMING JUNCTION VOLTAGES TO 10 NANOVOLTS**

The open-loop gain of op amps can be measured by monitoring the summing point voltage while operating the amplifier in its normal closed-loop configuration. The advantages of using a Lock-in Amplifier to make these measurements are: (1) Its self-contained oscillator serves as a signal source for the op amp over a wide frequency range. (2) Distortion and offset at the summing junction are minimized by the Lock-In Amplifier's high input impedance and low noise. (3) Summing junction voltages as low as 10 nanovolts can be measured and recorded to permit measurement of extremely high open-loop gains. (4) Phase shift can be measured.

If you have a problem unearthing low-level signals buried in noise, why not call on a PAR applications specialist. He may be able to show you a better way to dig. Call him at (609) 924-6835, or write Princeton Applied Research Corporation, P.O. Box 565, Princeton, New Jersey 08540.
Pinholes: Finding pesky flaws in oxide

Dielectric-layer defect detector made by Autonetics researchers shows promise as sampling tool for quality control in wafer production

For years, Philip Eisenberg has been talking about failure mechanisms in integrated circuits at various reliability symposiums. He maintains that defects in the dielectric—usually pinholes in silicon dioxide—are the major cause of rejections in both bipolar and metal oxide semiconductor IC's. A group scientist for special projects in the Research and Engineering division at the Autonetics division of North American Rockwell, Eisenberg recently did more than talk about oxide pinholes. He, along with Kenneth Brion, a member of the technical staff in the R&E division, put together a dielectric-layer defect detector that uses established principles to locate and mark pinholes.

Eisenberg has mountains of data on the reasons for IC failures as a result of his work on spotting and analyzing flaws in devices purchased for the Minuteman program. The work showed Eisenberg that the chief cause of pinholes is the differing thermal coefficients of expansion of the bulk silicon and the silicon dioxide. The oxide is usually grown at about 1,200°C, and silicon contracts more quickly than the oxide when the wafer cools. Resulting stresses cause cracks—which appear as pinholes—in the oxide, degrading it as a dielectric because metallization put down on top of a pinhole causes shorting through to active areas.

Gas test. One method to detect pinholes used sporadically by some IC manufacturers, according to Eisenberg, exposes the oxidized wafer to gaseous hydrogen chloride at about 1,200°C. If pinholes exist, the HCl will etch through the solution, through the oxide pinhole, and finally through the silicon, a stream of hydrogen bubbles appears at the pinhole. The operator scans the wafer through the microscope, looking for bubble sites, after triggering a three-way switch (inspect mode, decorate mode, off) to the inspect mode. He may use a mechanical counter to determine if the pinhole incidence per square centimeter is acceptable. The test cell is mounted on an x-y stage, which the operator moves manually.

If a permanent record is desired for later failure analysis through photography or other means, the operator switches to "decorate." This increases the electrical potential, accelerating the electrolytic action, causing the anode to be attacked, and forming charged particles that are transported through the solution. This is electrophoresis. The particles deposit around the defect as they follow the current path, distinctively marking the pinhole.

Spot check. Eisenberg recommends that the pinhole detector be used as a sampling tool is quality control, not for 100% wafer inspection. He says: "If you run 50 wafers through the furnace in the first oxidation, and the sampling shows the defect density to be way off, you can strip the oxide and save the wafers." Not only can the detector be a valuable research tool to help the user better understand why oxide pinholes occur, Eisenberg believes, but it will help the user refine the oxide-growing technique most suited to his process.

The detector, which can also pinpoint flaws in such dielectrics as silicon nitride, was first shown by Navan Inc., North American Rockwell's sales subsidiary, at the IEEE show last March; intent-to-buy forms were signed by 24 firms.
They were quoted an estimated price of $2,000 and received the option of buying 20 additional machines at Navan's eventual published price, less 15%.

Advanced technology

Smile—you're digitized

When the Air Force permitted CBS Labs to talk about its high-resolution laser-scanning system (part of Compass Link) used to transmit reconnaissance photos from Vietnam to the Pentagon in minutes [Electronics, April 14, p. 56], CBS officials were optimistic about the possibility of broader applications. A step in that direction has been taken with the modification of the laser scanner so that it can convert high-resolution photos for handling by a computer.

Called LIPS—laser image processing scanner—the system digitizes the image, then feeds the signal through a buffer to an IBM 360/40 computer. The computer processes the picture to emphasize fine details or improve the contrast. The reconstructed image is then read out of the computer onto photographic film. Thus, LIPS enables the photo interpreter to manipulate his picture to bring out any desired detail with a high degree of resolution.

Routine work. In operation, the interpreter tells the computer what areas he wants emphasized. For example, he could call for a routine that would bring out high-frequency detail. If the finished picture were unsatisfactory he could go to a routine that not only would emphasize high-frequency detail, but also would suppress or clean up large areas of black.

LIPS uses a sequential scan to attain a resolution of 100 lines per millimeter. It can digitize, or record from digital data, a 1.8-centimeter-square area in 15 minutes; that's at least twice as fast as conventional scanners such as those used on the Ranger moon probes.

CBS says the advantages of LIPS—high resolution and geometric fidelity, high-speed read-write rates, and operation in standard room lighting—can be used by map makers, meteorologists, or news organizations.

Avionics

Head-up hologram

With practical applications for holograms still in the few-and-far-between stage, the Office of Naval Research and IBM believe they have a holographic application that is both practical and unique: in a head-up, all-weather landing system.

The system—now at the laboratory model stage—employs a hologram of an aircraft carrier. The hologram is picked up by an infrared vidicon and projected on a crt cockpit display.

Feel free. The achievement is one of application in which a two-dimensional representation with the so-called six degrees of freedom encountered in a carrier landing, and full ranging capability, is produced without employing a computer. The demonstration model simulates an approach window two miles wide and a half-mile high and offers a 3.5-degree glide slope. The six degrees (glide-slope deviation, localized deviation, depression angle, bearing angle, roll, and slant angle) are achieved mechanically, electronically, and optically. For example, roll is achieved as the vidicon itself is rolled; glide-slope deviation is simulated by manipulating the hologram. In the model, the generated image allows a view which includes magnification of the holographic image of the carrier up to 16-to-1 and permits views including one below the deck of the carrier.

Currently, the project is in evaluation, but IBM has submitted a new proposal to continue the work. According to Lt. Comdr. Francis L. Cundari at the ONR: "The probability of continuing the program into the next phase is high."

The electronic systems center of IBM's Federal Systems division has proposed building an advanced
Shape up. Head-up holographic display, developed by IBM and the Office of Naval Research, would enable pilot to "see" carrier's deck despite zero visibility. System is in laboratory model stage.

system in which simulated approaches would be flown and a computer would analyze performance characteristics. Proposed technical refinements include better holographic resolution; reduction of the package size by substituting a solid state, gallium arsenide laser for the bulky helium-neon continuous-wave laser in the original. Dave Hanna of the IBM team says, "By reducing the package size we would be ready for actual flight testing in the next stage."

In case. Pilot acceptance could be a problem, however, just as it is with any significant technological change. But, Cundari says, "Even if it never gets into the cockpit, we have a very valuable tool for simulation training."

Developing a simulator before proceeding with system development helps overcome user objections and would, of course, require less funding—a significant consideration in the present time of tight money.

Whichever direction the program takes, ONR proponents are convinced they have a winner. "Results so far have exceeded our expectations," says Cundari, "and we have proven such a system is feasible. The next thing we've got to do is prove applicability."

Package size of an operational system could be cut to one cubic foot, according to the Navy, short-circuiting the argument that it would become a problem in aircraft already loaded with avionics. Alternatively, the system could be placed in the carrier and the image would then be transmitted to the aircraft.

"Ideally, this system would be linked in a one-to-one relationship with the real world and be perfect for bad weather operations," says Cundari.

Beyond Cains

The $3 million Navy contract to develop the first six Cains (carrier inertial navigation system) has officials at Litton's Guidance and Control Systems division optimistically eyeing $200 million in follow-on business.

Cains, designated AN/ASN-92, will be installed in the Navy's E-2C, F-14, S-3A, and A-6E aircraft. The first six systems will be delivered in 1970 for the E-2C and F-14. The system aligns an aircraft's inertial navigator with the carrier's inertial system, using a radio link, eliminating flight deck clutter: bulky umbilicals carrying information to aircraft inertial navigators from the carrier's [Electronics, Oct. 30, 1967, p. 44].

Roland O. Peterson, Cains program manager for Litton, says that the system will be Government-furnished equipment in future Navy aircraft, and that there is no indication the Navy will seek a second source. Litton will reap the reward for the two years of company-sponsored research and development by producing all five basic Cains elements, including the inertial platform and mount, computer, control and display unit, power supply, and converter-amplifier unit for adapting the system to specific aircraft.

Litton's LN-15 inertial navigation system will be used. Minor modifications will speed reaction time of the platform to meet requirements for quick alignment of the system.

Already at work. The LN-15 is installed in the OV-10 Mohawk and other Army aircraft, and is being used as a reference source aboard B-52's for the Air Force's short range attack missile (SRAM). Existing data links, including the ASW-25B and ASW-27A already aboard some Navy aircraft, will be utilized. The complete system, weighing less than 100 pounds, is fully compatible with the Navy's versatile avionics stop test (VAST) for centralized shipboard checkout of avionics.

The digital interface for the radio link between the ship's computer and the aircraft is described by Peterson as "straightforward digital logic, with nothing glamorous about it."

Litton claims alignment requires less than one-third the time consumed by earlier systems, with improved accuracy. In the past, warmup and alignment times of from 20 to 75 minutes were required; the Navy has sought a five-minute alignment. Litton will say only that it has cut the time required "through thermal management of the inertial platform and a sophisticated statistical filter in the computer."

The Navy is expected to award
a separate contract next month for a calibration and maintenance console with computer capability and interface hardware to be used with both Cains and AN/ASN-90, and inertial system made by General Precision’s Kearfott Group for the Navy’s A-7E.

Manufacturing

Smog gets in your IC’s

Like other Californians, engineers at Fairchild Semiconductor in the Bay Area have learned to live with smog; they’ve come to regard it simply as an eye irritant. Its nuisance value, so they thought, is that it obscures scenery. Therefore it was with some surprise that the engineers learned smog can also ruin the transistors and integrated circuits they make.

They found that photochemical smog, the effect of sunlight on hydrocarbon combustion products, can cause “resist scum,” a polymerized-photoresist residue on silicon wafers that interferes with processing. The scum is formed when the photoresist on a silicon wafer is dried. When the wafer is put through the sequence of exposure, development, and etching to delineate the pattern for diffusion of dopants into the wafer, the scum remains in areas that should be completely clear.

Dopants can’t diffuse through the scum. And equally important, deposited metal interconnections won’t adhere to it. This results in devices that fall short in both geometry and performance.

The scum takes several forms. It can be a light to heavy webbing, a uniform or wrinkled film; or specks, swirls, or clumps scattered at random.

Detective work. Scum formation, of course, is a problem that has a variety of causes—too much heat during drying of the photoresist or stray light, for instance. But A.E. Engvall, a senior engineer at Fairchild R&D, noticed that even when the causes had been eliminated, the scum remained. “It would come and go,” Engvall says. “And it was more common in the summer and fall months. It would appear sometime in the afternoon, then disappear late in the evening.”

Engvall then ran tests with controlled amounts of ozone, and found that an identical scum was formed when his concentration of ozone equalled that of smog. Nitrogen dioxide, the other major constituent of smog, didn’t form scum.

Once the culprit had been isolated, the cure was simple: at the peak smog periods, perform photoresist application and drying in a smog-free ambience. “The best ways are with a nitrogen-ventilated hood or with a hood fitted with an activated charcoal filter,” Engvall says.

Selective. Smog doesn’t affect all photoresists. KPR and, to a lesser extent KPR-2, are sensitive. Others, such as KMER and KTFR, appear to be immune; they’re attacked by ozone but at much higher concentrations than occur in smog.

Engvall can’t pinpoint the chemical mechanisms that produce smog scum, but he believes the sensitizer plays a key role. (The chemicals used in photoresist technology include the photoresist itself, a sensitizer that’s premixed with the photoresist, and a solvent.) The ozone doesn’t act directly on the photoresist. Rather, the sensitizer induces a small amount of cross-linking of the photoresist molecules, and the ozone reacts with these to produce extensive polymerization.

Government

The colossus shifts

A communicator’s saw has it that it doesn’t make any difference how good your communication system is if you don’t have anyone to talk to. That recitation of the obvious is why U.S. diplomats trying to iron out an agreement for the International Telecommunications Satellite Consortium are backing off from some long-held positions. And a weakening of the U.S. position makes Intelsat more attractive to other countries and hence more successful.

While easing the U.S. stand, however, the negotiators are bargaining away some of the powers of the Communications Satellite Corp. (Comsat).

Under a five-year-old interim agreement, Comsat has been the system’s sole manager; now, the diplomats are saying they can live with an international secretariat to handle Intelsat’s administrative duties. According to the new U.S. approach, Comsat would be hired as technical manager of the system—a far cry from the total responsibility the company has enjoyed. A contract would be awarded to Comsat—probably for seven years—and would be renewable at the option of Intelsat’s governing board. The seven-year contract life
5 more electronic components tailored for designers

General Electric components are engineered for reliability and cost effectiveness. No other manufacturer offers such a wide selection of quality electronic components as General Electric. Specify GE in your designs.

General Electric's programmable UJT lets you control the key parameters

GE's D13T is a programmable unijunction transistor (PUT) with characteristics (V, R, l, I) that can be selected to fit your circuit. Just two circuit resistors give the D13T1 and T2 programmability which permits the designer to:

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- use base 2 as low impedance pulse output terminal
- use PUT in high volume applications.

Especially suited for long-interval timers, D13T2 features very low leakage and peak point currents. D13T1 is for more general use in high gain phase controls and relaxation oscillators.

Both are 3-terminal planar passivated PNPN devices in the low-cost plastic TO-98 case. Circle number 503.

New—Lodex® permanent magnets in microminiature sizes

When designs call for tiny (even less than 1 millimeter) permanent magnets, GE has the answer. GE can produce powerful microminiature magnets at low cost — and in complex configurations, too.

The magnets are made of proved Lodex material that consists of elongated single domain iron cobalt particles bonded in a lead matrix and pressed to final dimensions at room temperature without the use of high temperature fabrication or heat treatment. This exclusive process makes it possible to produce Lodex magnets in very small or intricate shapes meeting extremely tight physical and magnetic tolerances.

Close piece-to-piece physical and magnetic uniformity often eliminates the need for final testing of the end product. These GE magnets are often the perfect answer for such precise applications as reed switches or magnetic pick-ups.

For more information, circle number 504.

New transmitter design gives high performance to IFF and ATC transponders

GE's new C2003C transmitter is a Microwave Circuit Module (MCM) containing a master oscillator and power amplifier using planar ceramic triodes. It is just one of many MCM's now available from GE to help reduce design cycles, provide retrofit and lead to improved system performance.

Other benefits include:

- meets performance and military requirements of the transmitter portion of IFF transponder
- significantly smaller than earlier designs
- permits two transmitters to function in space formerly used by one
- light-weight simplified heat sinking
- excellent frequency stability with wide variations in antenna VSWR.

For more technical information on this and other MCM's from General Electric, circle magazine inquiry number 506.

GE makes the only 150-grid relay that performs the AND-logic function

GE's 3SBR 4-pole relay is the only one available that performs the AND-logic function without any additional circuitry or components. Nine different input conditions control the relay's operation.

Other benefits include:

- meets performance and military requirements of the transmitter portion of IFF transponder
- significantly smaller than earlier designs
- permits two transmitters to function in space formerly used by one
- light-weight simplified heat sinking
- excellent frequency stability with wide variations in antenna VSWR.

For more technical information on this and other MCM's from General Electric, circle magazine inquiry number 506.

Rechargeable nickel-cadmium batteries give design flexibility—long life

Get lasting battery power and versatility suitable for many industrial and consumer applications. Types include sealed, pressure-relieved and vented cells. Custom designs to your specifications are also available.

Nominal ratings range from 0.1 amp-hours to 4.0 amp-hours in sealed cells and up to 160 amp-hours in vented types at the one-hour rate.

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285-52
was offered to accommodate the Intelsat 4 satellites scheduled to have that life span.

**Split up.** As technical manager of the 68-nation consortium, Comsat would be charged with design, development, procurement, and operation of the satellite system including the telemetering necessary to keep it functioning. The secretariat-administrative manager, on the other hand, would handle the day-to-day operation of the consortium, budgeting, planning, and housekeeping jobs.

Until the recent turnaround, the United States fought to maintain Comsat’s role as the system’s manager. This issue was the main stumbling block in a meeting of Intelsat countries earlier this year toward working out a permanent agreement.

The shift in U.S. position, if approved by the Intelsat countries, will cost Comsat in prestige, but will not seriously affect its revenues. Comsat, which participated in the talks, is not expected to fight the shift, apparently in the interest of unity.

**Aiming high.** U.S. negotiators have briefed representatives from 19 countries since the new position was drafted. William W. Scranton, head of the U.S. delegation, has made two trips to Europe to signal the change in U.S. position. Scranton stresses that his first criterion throughout the talks will be the continued high competence and growth of Intelsat and that the U.S. is eager to achieve a quick agreement. He also says that the positions are not totally frozen and that changes can be made.

The formulation of U.S. policy is important. Through Comsat, the U.S. owns slightly more than half of Intelsat’s stock. With an American company running the consortium, with its headquarters in Washington, and with the system built around U.S. made space hardware, many countries resent one-country domination.

**Drop veto.** Most U.S.-proposed modifications involve U.S. domination. Negotiators are willing to give up the U.S. veto over Intelsat actions in the governing board and perhaps grant one-man, one-vote decision making in the general assembly.

At earlier meeting, the U.S. was silent on the subject of regional systems, but the delegation was clearly against them. Now, the U.S. might be willing to accept some carefully governed regional systems if they are geographically compact, technically coordinated, and not economically harmful to Intelsat.

The U.S. is now bowing to the wishes of several member countries who want a change in Intelsat’s legal personality—from a partnership to a corporate-like entity.

**Follow the MOL**

While the Air Force professed surprise when the Pentagon canceled its manned orbiting laboratory (MOL), and NASA officials were privately joyful over having the only remaining space station project in town, both organizations must have seen the handwriting on the wall. Not only was Congress viewing military spending with growing trepidation, but Washington officer's clubs were alive with speculation about which military systems would be liquidated in the Nixon Administration's campaign to get the Safeguard antiballistic-missile system approved by Congress. [Electronics, June 9, p. 37].

But NASA, now seemingly in the pilot's seat, still faces some problems. Though House passage earlier this month of the space agency's fiscal 1970 authorization included a Nixon-requested boost to $75 million from $9 million for the space station, appropriation—the vote that puts the money where the authorization is—still must come. And that may run into flak in the Senate from defense spending critic Stuart Symington, former Air Force secretary, who reversed field with the MOL cut. One of the Missouri Democrat's biggest constituents, the McDonnell Douglas Corp., stands to be hurt most by the chop because it held a $700 million contract for the space lab plus another $200 million for modification of Gemini modules for the effort. What’s more, 7,200 of its employees are affected.

**A chance.** Space electronics hardware makers may eventually come out winners, however, since the Pentagon says it wants to keep about $225 million of the $300 million sought in fiscal ’70 MOL money for other space programs—unmanned reconnaissance and tactical communications satellites carrying heavy instrumentation—plus the MOL experiment package (being handled by General Electric) which is likely to be turned over to NASA for its Apollo applications program (AAP).

Meanwhile, the Apollo applications program, which paralleled the MOL in time and use of already developed hardware, was just barely alive. At least half the originally scheduled missions have been canceled and only five missions still remained—an orbiting workshop, the telescope mount, and three revisits to the original craft. The workshop was originally scheduled for launch in 1968 and the telescope mount for 1969. Both schedules slipped at the same time that hardware and experiments for the programs were cut. The latest schedule from NASA had the first Apollo application mission going in 1972—as late as January of this year NASA was still planning to put the workshop up in 1971.

**Hard look.** As MOL was canceled, NASA was in the midst of a reassessment of its Apollo applications. Says a NASA spokesman, “The budget situation of recent months has introduced uncertain- tainties into our plans for AAP. Several plans are being examined to determine new ways of saving money while still keeping the program alive.” He points out that one plan under consideration at NASA is to launch the workshop and the telescope together on a Saturn 5 booster, as opposed to the present plan which calls for sending each mission on a separate Saturn IB. Such a plan would also eliminate the need for rendezvous and docking of the two craft.

Ironically, the day before the MOL was canceled and during NASA's period of reassessment, NASA received study proposals from three firms for its multibillion-dollar proposed orbiting na-
I've been itching for a FORUM on molded cable assemblies. I say you can't beat the solder or screw connected assemblies when it comes to fast repairs in the field.

How about less repairs to begin with? Failure incident rates have proven to be less with molded cable assemblies. Pull tests show why molded assemblies are 50%-100% stronger than soldered plugs. Solder types, like the one shown in fig. 1 (bottom) broke at forces as low as 24 lbs. In fact, in the tests we've run, the cable itself broke before it would pull out of the molded plug.

But when it does break, you're finished. That could mean expensive equipment down-time unless it can be quickly repaired.

Let's say the molded assembly does break. If you clip off the damaged plug and replace it, you're still better off than with solder or screw type connectors. You want better aspirin; we say, eliminate the headache in the first place.

Repair costs can be expensive, too. Especially, if the connection is poorly soldered and shows up as an intermittent defect. Add this to the possibility of non-molded plug handles coming loose from vibration, poor shielding from moisture and contaminants, or excessive strain due to plug and cable size mis-matches and you've got yourself a potential profit-killer.

O.K., I'll have to concede your point as far as the cable-plug connection is concerned. But, you'll have to admit that when the molding holds the plug parts together, plastic cold flow can loosen the plug tip and kill reliability.

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Fig. 2. shows how we start with a one-piece tip rod, connector and insulators, with the rod solidly staked into the tip terminal. After soldering the center conductor, a bridge sleeve is crimped around the cable and connector flange prior to molding. No tip loosening, no cable strain.

I'm almost convinced. Now give me the bad news about the cost of molded cable assemblies vs. solder or screw types.

Brace yourself. Think of what it costs your company to order, stock, assemble and test the cable assemblies you're now using. Compare your total costs with the price we'll quote for a comparable molded cable assembly, and you'll be money ahead. And that doesn't even include the cost-savings you'll get from the added reliability of our molded cable assemblies.

That's great for phone and phono plugs, but we often get into some pretty oddball applications where we need a different type of connection.

You name it, we can produce it. Most of the time, one of our standard straight or right angle phone or phono plugs, microphone connectors or extension jacks will do the job. If not, Switchcraft has the know-how and high production machinery to run an economical, custom-molded unit to your specs. Just circle the reader service number for more info on these standard and custom made molded cable assemblies.

Sounds good, but how can my staff get further technical details on specific applications that back up what you've just told me?

Simple. Have them join the FORUM by writing their questions or comments on your company letterhead. We'll send our "Forumfacts on Molded Cable Assemblies" handbook, and also add their name to our TECH-TOPICS mailing list. Every other month, they'll receive this engineering application magazine that we're sure will be useful and interesting to them. 10,000 design engineers can't be wrong!!
tional space station to be launched in 1975 [see related story on p. 149]. Says a NASA official: "You can look at it in one of two ways. It's either a bad omen for the space station or a good one. I'll take the biased view that it's good, as Congress may be more attuned to a big space station if fewer small ones are flying."

Consumer electronics

Picture image?

Now that both RCA and Zenith Radio Corp. have brought out their brighter color television picture tubes, industry observers are playing a new game called "Spot the Coincidence." For RCA's Hi-Lite [Electronics, June 9, p. 136] and Zenith's Chromacolor are strikingly similar. Both have black masking around the phosphor dots to absorb ambient light; both use nonstandard phosphor dot diameters to achieve a vastly brighter picture and improved contrast.

Says Zenith's Sam H. Kaplan, codeveloper of Chromacolor, "We patented our process back in 1964, and have spent more than $5 million in research and development since we began working on its design in early 1960, and we intend to see that it's not infringed upon." RCA's Charles W. Thierfelder, manager of tv picture tube engineering, acknowledging the similarities, points out: "In the scientific field it's not unusual for parallel research efforts to be carried out without the knowledge of either party."

On the track. Although RCA has revealed very little information about its changes in the basic shadowmask system, it's known that both companies altered at least their phosphor dot sizes, developed new phosphors, and built a more efficient electron gun. For example, conventional phosphor dots are larger in diameter than the electron beam. This provides a guard band to prevent color tinting, and makes it easier to establish and maintain white field color purity.

Zenith, essentially, interchanged the beam-dot size relation while maintaining the same guard band. It has made the tube's phosphor dots smaller while increasing the shadowmask opening to accommodate a wider beam. Hence, while maintaining essentially the same active phosphor areas as in the conventional tube, the Zenith screen area is 50% blackened by the deposit of the light-absorbing material. This permits use of a glass faceplate with much higher light-transmission properties, thereby producing a brighter picture with increased contrast.

The use of brighter rare-earth red phosphors such as yttrium oxide and gadolinium oxide, which are 60% brighter than previously used phosphors, allows the effective areas of each color dot in a red-green-blue triad to be sized for the individual phosphor efficiency. Thus, the beam current need not be reduced to obtain color balancing by equal currents. In addition, each manufacturer claims to be using a new gun with improved spot size for sharper pictures under all brightness conditions.

Although Admiral and Sylvania have also announced tubes they say are 100% brighter, neither will reveal technical details.

Communications

Getting pale

The effect of a high-level Pentagon decree to review U.S. strategic communications systems, both operational and planned, has already been felt by potential contractors for the Navy's Project Sanguine, an extra-low-frequency network--below 100 hertz--for worldwide secure shore-to-ship communications for submarines.

Scheduled to move to contract definition last month, Sanguine, say Navy insiders, may not request proposals for contract definition until September. But some contract competitors—among them GE, RCA, Westinghouse, and Sylvania—are getting nervous about trying to hold project teams together until the fall. All the Navy Electronic Systems Command, which is running the program, will say is that there is money for Sanguine in the budget—an estimated $20 million for fiscal 1970—and that an award for contract definition will be completed this year.

Tests. RCA is acknowledged leader in the race with a $4.3 million award to set up and operate a Phase I test facility at the proposed Wisconsin site in Chequamegon National Forest. Those tests are expected to be completed this year, although the slippage in the follow-on awards is likely to hold up subsequent efforts—including construction of the large-scale Phase II test facility in 1970 and the test program planned for the following year.

Also hanging fire is a separate rfp for a development contract for Sanguine receiver design and spec-
Bell Laboratories engineers M. I. Cohen and B. A. Unger have developed experimental techniques for using lasers in certain delicate thin-film integrated circuit work: machining circuit patterns, making "gap" capacitors, trimming tantalum thin-film resistors and monolithic quartz resonators, and cutting masks for circuit fabrication.

Our experimental system (above) combines a solid-state YAG (yttrium aluminum garnet) laser, manual positioning of the circuit, and television observation. The optical part of the system was developed by Western Electric's Engineering Research Center, located at Princeton, New Jersey.

The high spectral purity of the continuous-wave YAG laser, invented at Bell Laboratories, lets us focus the light to a very small spot for precision cuts less than 5 microns (1/5 mil) wide and resistor trimming accurate to better than 0.1 percent. And, through Q-switching, the YAG laser produces high peak power at high repetition rates—over 1,000 pps—giving us the cutting speed necessary for practical circuit work.

Laser beams pass through any transparent atmosphere or material and can be accurately concentrated onto tiny areas. With the proper wavelength, we can machine components inside a transparent encapsulation without damaging it. Also, since we can regulate cutting depth, we can "micromachine" thin films without harming underlying materials.

To make capacitors, for example, Cohen and Unger use a laser to cut (vaporize) a narrow gap between conductors. In gold conductors on sapphire or alumina substrates, they have cut gaps from 5 microns to 600 microns wide with good control.

Similarly, Bell Labs engineers have adjusted thin-film quartz crystal resonators to frequencies as precise as one part in $10^9$. The laser vaporizes part of the thin-film electrode, raising the resonator frequency to the desired value.

By removing hairline shorts, we have also repaired expensive integrated circuits that could not be reclaimed by standard techniques.

Pioneered at Bell Laboratories and Western Electric, laser micromachining is already in pilot and volume production use at Western Electric and other major integrated circuit manufacturers.

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The 2508 RX Meter is a self-contained RF bridge that reads impedance in terms of $R_L$ and $X_L$ from 500 kHz to 250 MHz. It consists of an accurate, continuously tuned oscillator, Schering bridge, amplifier-detector and null indicating meter.

Ruggedly constructed, the 2508 bridge assures the user of the stability necessary for precise measurements. A front panel control adjusts the RF excitation signal to as low as 20 mV, permitting measurement of input and output "Y" parameters of transistors with the accessory 13510A Transistor Test Jig, and use of the bridge for other low-level measurements. Another accessory, the 00515A Coax Adapter Kit, provides a convenient means for adapting the bridge terminals to type "N" connectors for measuring devices with coaxial connections.

The 2508 RX Meter is especially useful in determining electrical characteristics of devices and circuits such as inductors, capacitors, transformers; and filters. Price: $2050.

For complete information and a copy of the 2508 Technical Data Sheet, contact your Hewlett-Packard field engineer or write: Hewlett-Packard, Green Pond Road, Rockaway, New Jersey 07866. In Europe: 1217 Meyrin-Geneva, Switzerland.

### Contracts

**Valhalla for hardware**

Though the odds are overwhelmingly against finding life on Mars, NASA has not been deterred from committing almost a billion dollars to investigation of the idea. Two flights have been there, two Mariner spacecraft are on their way to a midsummer Martian orbit, and two more Mariners are scheduled to go in 1971. Currently NASA is busy committing half a billion dollars to the most ambitious Mars venture to date: Project Viking.

The program entails launching two spacecraft in mid-1973, each consisting of a Surveyor-type soft lander mated to a Mariner-1971 class orbiter.

Viking is now getting into full swing. NASA and Martin/Denver are negotiating to build the two soft landers and act as technical integrators for the program. The Martin contract, to come by October 1, is estimated to be in the neighborhood of $280 million. Meanwhile, NASA has decided to give its Jet Propulsion Laboratory the job of constructing the two 6,000-pound spacecraft that will orbit Mars and deposit the 1,000-pound landers on the planet's surface.

The program will involve most of NASA's unmanned space centers. Langley Research Center will handle lander development and act as overall program manager, and the Lewis center will handle the Viking Titan 3D/Centaur launch vehicles. Ames Research Center is now at work on sophisticated life-detection equipment—earlier this year it gave Ball Brothers Research Corp. and the Bendix Corp. contacts for instrumentation development.

**U.S. Reports**

**Trepidation.** As one industry source says, "All they have to do is report that Sanguine could cause cancer in birds or make deer sterile and we're dead."

Though the threat of such a development is viewed as impossible by engineers following the program, the Navy does have plans to develop a specially-shielded cable for use with the Sanguine transmitters. Currently plans have the cable laid out and buried in a north-south/east-west pattern that will create a 150-square-mile underground checkerboard with individual and separate power generators at each point of intersection.
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31,000 feet... heavy traffic ... ugly weather over the Plains. This isn't the time for "noise" in the radar. But, no sweat! RCA's exciting new AVQ-30X Weather Radar is up front, sweeping the sky ... protected from EMI by 39 special ERIE filters. No other airborne radar has ever approached the single or dual system reliability of the AVQ-30. From the start, RCA has called on the outstanding research and component capability of ERIE TECHNOLOGICAL to help in the development of this great new unit. Proof, once again, that it pays to bring ERIE in early.

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Shave delivery time on TI’s DTLs by placing big orders with us. You can now get your big orders for TI’s plastic DTLs filled faster. Just contact us directly. Availability of these devices is such that we are primed to accept and handle large DTL orders without delay (and we still welcome small orders). Because TI makes 20 DTL circuit types in the dual-in-line plastic package, we can provide exactly the functions you need. You can count on economy and reliability. Some 1700 users have put more than 30 million TI plastic devices into tough jobs for a total of 30 billion operating hours. Big order or small, for the wide choice in dependable DTLs delivered fast, try us.

General Purpose Diodes — TI’s big 12 sub for hundreds. Here’s how to save considerable work and worry selecting general purpose diodes. There are more than 1000 general purpose diodes in the world today, yet a mere dozen TI types—1N456-58, 1N482-85, 1N645-49—will do the lion’s share of the work. TI’s big 12 come in low- and high-conductance types. The low conductance diodes are now of planar wafer construction, giving higher stability and lower leakage in the pico-amp range. For TI’s data sheets on these 12 workhorse general purpose diodes, circle 320 on the Service Card.

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and water-detection systems, equipment for organic analysis, a TV camera, and meteorological equipment.

As the negotiations for the lander are concluded Martin will be lining up its subcontractors. According to Jakobowski, the only member of the team besides Martin that has been determined thus far is RCA, which will handle communications. A Martin spokesman says that it will be about six weeks before it starts getting subcontractors in line, as it still has to work out exact specifications for the lander with NASA.

Meanwhile, NASA’s Langley has just asked for bids on the support-services contract for Viking. It will include data management, mission assurances, configuration management, test planning, project administration, and mission design. In all, 37 firms have indicated interest in bidding.

Space electronics

Moon measure

How high the moon? Well, we're going to find out.

When Apollo 11 lands on the moon this summer the astronauts will leave behind a two-foot-square array of fused silica corner reflectors. It will form one end of an optical tape measure that will permit laser ranging to accuracies of about 1.5 meters. Even the best data now available is uncertain by hundreds of feet and, consequently, so are the characteristics of the moon's orbit.

A lunar laser observatory was built about 40 miles north of Tucson especially for the experiment by the Air Force Cambridge Research Laboratories in Bedford, Mass. Although NASA funded most of the observatory's construction, AFCRL’s Donald H. Eckhardt will be principal investigator.

The observatory’s equipment already is being tested. A key element is a ruby laser capable of 10 joule, 10-nanosecond pulses built and installed by the Hughes Aircraft Co. The laser pulses will pass through a 60-inch telescope built by the University of Arizona. Although the 10-foot pencil beams of light will have expanded to a diameter of about 2.5 miles at the moon, the corner reflectors will return enough light to enable timing of the pulses' round trip using a cesium clock accurate to 10 nsec.

Refinement. The aim of the experiments is refinement of the lunar orbit which though nearly circular, varies by about 14,000 miles between apogee and perigee. By measuring during many orbits, usually at lunar night to prevent the reflections from being drowned in sunlight, the AFCRL crew expects to get the data needed.

Instrumentation

Failure ferrets

Now that its first phase study showed the effectiveness of techniques proposed to increase system reliability, the Navy has just launched Phase II of its portion of the triservice experiment to increase mean time between failure. It will take 12 months, says Walter Stender of the Electronic Systems Command, compared to three months for the initial phase.

Under the program, originated by the Directorate of Defense Research and Engineering, the Navy says it has established statistical and technical evidence of methods aimed at reliability gains using AN/PPS-6, a Marine Corps tactical radar, as a study base. This is the General Instrument 36-pound, backpack, noncoherent-pulse, doppler unit operating at X band.

The Air Force is running a comparable program using its AN/ARC-34 airborne uhf command transmitter, while the Army is testing its AN/VRC-12 forward area tactical radio. Both, like the PPS-6, are operational systems.

Tests on PPS-6 production units showed an average of 621 hours before failure, indicating a calculated mtbf of 1,570 hours for systems overall.

In its eyes. To achieve a calculated mtbf of 58,800 hours—an
essentially failure-free system in the Navy's eyes—the second and third phases of the program will seek to eliminate as many discrete components as possible by using multichips and monolithic integrated circuits and by substituting high-reliability components developed to NASA specs for the remaining discrete parts.

Additionally, says Stender, there will be overstress testing to guarantee proper design derating for environmental stands of temperature, vibration, and shock; strict parts screening; and use of MIL STD 217 to qualify microcircuits. The Navelex engineer emphasizes, however, that present performance prediction for IC's under 217A "are not only inadequate, but misleading" because of rapid advances in circuit development.

Highest failure rate of modules in the 1,870-hour mtbf calculations for the PPS-6 were in the magnetron and klystron, according to Stender, "of which the magnetron appears to be the most critical unit in the system." (Battery failures were not counted as they're replaceable.)

In general, the Navy feels failure-free radar has been prevented by microwave power sources, high-voltage modulators, scan motors, and waveguide plumbing subsystems.

A solid look. Thus, a design approach beyond the General Instrument system is also being looked at. It's a 25-pound RCA pulsed radar similar to RCA's AN/PPS-9, a continuous wave unit. It contrasts with the PPS-6 in that it uses all-solid-state power generation; stripline power distribution; and all-substrate-mounted solid state, duplex-printed circuit antenna and receiver. RCA, under a Navy test study completed late last year, calculated mtbf at 6,300 hours.

Though the Navy believes it is making headway in its effort to cut logistics support of systems like the tactical radars—costs which sometimes run to 100% of initial hardware costs over a 10-year life span—it recognizes that much more data is needed.

In Phase II, new systems will be built using the new, tighter specs developed from Phase I, and these will be submitted to operational and environmental tests with an eye to determining cost of ownership on the basis of which have fewer failures.

Then comes Phase III, a six-month effort to demonstrate reliability of equipment within the limited test time to meet the 10,000-hour goal. After that, says Stender, "We'll just dump some of these units into operating commands and see how they perform in real life."

For the record

No more needles. The John Fluke Manufacturing Co., a prime digital voltmeter holdout, will show its first digital model at Wesecon (August 19 to 22). Fluke's dvm doesn't have dual-slope integration circuitry—Weston Instruments claims the dual-slope technique as its own. So by using another approach, Fluke expects to avoid licensing problems.

Irresistible. Insiders say that the Bendix Corp. sold its semiconductor operation to Solitron Devices because the division wasn't bringing in the kind of profit Bendix management expected. But Russell D. O'Neal, the new president of Bendix Aerospace-Electronics, says that isn't so. His explanation: "They made us an offer we couldn't turn down."

Full speed ahead. Monsanto intends to get into the automatic industrial controls field by acquiring the Fisher Governor Co. despite objections by the Federal Trade Commission's merger division. At the same time, Monsanto will reorganize its electronics business into a separate division.

Taming the blue yonder. The Federal Aviation Administration has added automatic altitude readout to its Common Instrument Flight Rules Room at New York's Kennedy International Airport. It was accomplished through the activation of a computerized alphanumeric radar subsystem. The added electronic capability reduces the verbal communication neces-
and now...

UNITRODE invents the 12 amp UCR—
the industry's first fused-in-glass SCR.

It has so many superior features it deserves to be called “something else”.

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- Forward current 12A
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AND NARROWS THE GAP
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Both picoammeters are packed with convenience features designed to minimize operator error and maximize performance. Stable to 0.5% of full scale per week, they make low level measurements accurate to 0.2% almost routine. And provide variable display rate to 24 readings per second. But isn’t that what you’d expect from a firm with years of analog picoammeter design experience? And an industry-wide reputation for quality? Like Keithley.

See if you don’t agree we have the best digital approach to picoampere level measurements. Call your Keithley Sales Engineer for demonstration and details. Or contact Keithley Instruments, Inc., 28775 Aurora Rd., Cleveland, Ohio 44139. In Europe: 14 Ave. Villardin, 1009 Pully, Suisse. Prices slightly higher outside the U. S. A. and Canada.

KEITHLEY

U.S. Reports

sary between pilot and controller. In December, the automatic altitude readout will be installed at the first enroute center for the National Aerospace System in Jacksonville, Fla.

Pushbutton. RCA has installed what it says is the first computer-controlled production system in the consumer electronics industry. A Spectra 70/45 is being used initially to direct design, material control, assembly, and testing of tuners for stereo sets; eventually, it will control manufacture of other items, including television receivers.

Drop at a time. A high-speed printer, to be used by comput­ers over conventional voice-grade phone lines, has been introduced by the A.B. Dick Co. Called the 960 Videojet, the printer is a non­impact type that utilizes a stream of ink droplets to put out 250 char­acters a second on ordinary busi­ness forms; it can automatically answer a Dataphone subset, print the transmitted data, and terminate the call. The company envisions immediate application in time­sharing networks, remote batch processing with local print require­ments, message-switching systems, news wire services, and as a local line printer for use with small com­puters. The 960 will compete for sales with similar printers, such as ITT’s Inktronic.

Detective. A $55 pocket-size de­tector that can find static charges or leakage current in medical elec­tronic equipment will be marketed this fall. Developed by Roveti Sys­tems and made by the Daniel Woodhead Co., the device can detect current as small as 5 micro­amps; a diagnostic instrument with as little as 15 µamp leakage can stop a man’s heart. The detec­tor operates on standby duty for about a year on a 9-volt battery. In operation, the hand-held de­vice’s antenna is passed closed to the equipment being checked. A go, no-go signal is registered when it detects a potential hazard. Other detectors, costing around $200, are bulky and have to be plugged into the medical electronic equipment.
By now everyone knows that Stewart-Warner has the broadest line of 930-type DTL's in the industry. But why is this line the preferred choice of military users?

First, there's our new policy for Group B environmental testing. We are now testing to the tough Class A level of MIL-STD-883 by subjecting all military-type production lots to this strict new IC standard on a continuous 6-week sampling basis.* But if you think that's enough, we don't.

So we also put our products through an exclusive triple testing program that ensures the uniform high quality of the line: 100% DC parameter tests at the wafer stage; another 100% classification testing after assembly and mechanical screening; and, at no extra cost, a third 100% testing prior to shipping.

What more could anyone want, except perhaps low price and good delivery? Well, just try us on price; and, for immediate off-the-shelf product delivery, call your local Stewart-Warner Microcircuits Distributor. Or for more information on our 930-type products and our hi-rel program, contact us or our local sales representative.

*Except for Reverse Bias Burn-in and Moisture Resistance Vibration.
We’ve made child’s play out of toroid selection for pulse transformers.
Indiana General's popped up with an end to trial-and-error spec'ing: the first and only toroids with specified characteristics for pulse transformer applications.

Not just the usual irrelevant magnetic properties, either. Each part is designed as a pulse component, and listed by its pulse inductance, pulse magnetizing current and ET product. All according to ASTM methods.

And thanks to our automatic high speed testers, we can guarantee all parameters. Every pulse transformer toroid we make is 100% pulse-tested to performance specifications. So reliability is assured, from samples to production quantities. And all toroids can be coated, to prevent the wire's insulation from being scraped when winding, or penetrated later.

Various toroid sizes from 0.080” are available. Tell us your pulse transformer core problems.

Indiana General Corporation
Electronics Division/Ferrites
Keasbey, New Jersey

Let's see how your pulse-rated toroids can make it easier for me. Attached are details of my pulse transformer core problems.

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We make it easy for the design engineer.
more data transmission applications for ANALOG SWITCHES & OP AMPS

* Applications Power . . . A broad product line, an extensive network of stocking distributors and an experienced applications team waiting to serve you.
Here are two more examples that illustrate the versatility of Siliconix driver/FET switch packages in data transmission systems.

<table>
<thead>
<tr>
<th>Functional Description</th>
<th>Channels</th>
<th>Type</th>
<th>Max. ( r_{\text{ON}} ) (ohms)</th>
<th>Switch Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPST</td>
<td>3</td>
<td>DG120</td>
<td>600</td>
<td>PMOS PMOS</td>
</tr>
<tr>
<td>DPST</td>
<td>2</td>
<td>DG122</td>
<td>600</td>
<td>PMOS PMOS</td>
</tr>
<tr>
<td>DPST</td>
<td>2</td>
<td>DG126</td>
<td>80</td>
<td>N</td>
</tr>
</tbody>
</table>

Two and three channel packages are available with various ON resistances to meet your specific requirements. Drivers accept standard DTL, RTL, or TTL logic inputs.

<table>
<thead>
<tr>
<th>Functional Description</th>
<th>Channels</th>
<th>Type</th>
<th>Max. ( r_{\text{ON}} ) (ohms)</th>
<th>Switch Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENABLE</td>
<td>2</td>
<td>DG110</td>
<td>600</td>
<td>PMOS PMOS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>111</td>
<td>600</td>
<td>PMOS PMOS</td>
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<td></td>
<td></td>
<td>112</td>
<td>30</td>
<td>N</td>
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<td>133</td>
<td>10</td>
<td>N</td>
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<td></td>
<td></td>
<td>134</td>
<td>40</td>
<td>PMOS PMOS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>147</td>
<td>600</td>
<td>PMOS PMOS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>148</td>
<td>40</td>
<td>PMOS PMOS</td>
</tr>
<tr>
<td>ENABLE</td>
<td>4</td>
<td>DG116</td>
<td>600</td>
<td>PMOS PMOS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>118</td>
<td>600</td>
<td>PMOS PMOS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>125</td>
<td>600</td>
<td>PMOS PMOS</td>
</tr>
<tr>
<td>ENABLE</td>
<td>5</td>
<td>DG123</td>
<td>600</td>
<td>PMOS PMOS</td>
</tr>
</tbody>
</table>

One of these driver/switch combinations may be used with your sample-and-hold circuit. These switches may also be used to implement your multiplexer/decoding functions.

Working on data transmission? Write today for complete data on any or all Siliconix driver/FET switch combinations and OP AMPS.

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GENERAL INSTRUMENT ADVANCED NITRIDE TECHNOLOGY PRODUCTS
the first static dual 16-bit shift register directly compatible with TTL, DTL and MOS is also the lowest priced* shift register

General Instrument's exclusive MTNS process has now been translated into a line of standard General Instrument LSI circuits.

The Dual 16-bit DC Shift Register is the first of the family of GIANTS (General Instrument Advanced Nitride Technology Products) to be introduced.

This giant step forward results in LSI devices which are totally compatible with TTL, DTL and MOS, and as in the case of the Dual 16-bit DC Shift Register, lower in price than any other such device available.

The well-known performance and reliability advantages inherent to MTNS devices are, of course, present in all GIANT LSI circuits. These advantages include: a reduction in the number of system power supplies required, the elimination of interface circuitry, a reduced parts count and fewer interconnections, lower power dissipation, increased operating frequency and an increased operating temperature range.

The most outstanding feature of General Instrument’s Dual 16-bit DC Shift Register—and of every standard GIANT product—is the exclusive VSL terminal, which gives the user a choice of interfacing directly with TTL/DTL or MOS (as shown in the block diagrams above).

This shift register contains two independent 16-bit DC to 2MHz shift registers constructed on a single monolithic chip utilizing MTNS P-Channel enhancement mode transistors. Independent single phase TTL/DTL compatible clock and data inputs are provided for both registers. Each shift register bit is implemented with a cross coupled flip-flop, so that data is stored indefinitely regardless of the logical level of the clock. Data on the input is sampled while the clock is at a “0” level and the register shifts on a “0” to “1” transition. Separate input data selector controls are provided on each shift register. They determine which of the two inputs shall be shifted into the register. Each shift register also has its own set input which forces all stages of the register to a “1” level.

Among the other features of the Dual 16-bit DC Shift Register are: power dissipation of 120 mW, full military temperature range of -55°C to +125°C, high input impedance, stable threshold over time vs. temperature, multiplexible inputs, the need for fewer packages compared to equivalent TTL/DTL circuits, and set control.

The General Instrument Dual 16-bit DC Shift Registers are truly GIANTS among shift registers. They are immediately available from your authorized General Instrument Distributor.

For full information write, General Instrument Corporation, Dept. D, 600 West John Street, Hicksville, L.I., N.Y. 11802.

(In Europe, write to General Instrument Europe S.P.A., Piazza Amendola 9, 20149 Milano, Italy; in the U.K., to General Instrument U.K., Ltd., Stonefield Way, Victoria Road, South Ruislip, Middlesex, England.)

* $7.50 each in quantities of 100 pcs. in a TO-72 package (GI part #SS-6-8212). Also available in a 16-lead dual in-line package (GI part #SS-6-8211) at $13.80 each in quantities of 100 pcs.
Sperry's PACT (Progress in Advanced Component Technology) Program is developing a fully-integrated transmitter/receiver/duplexer module for an airborne communications array at X-band. The program has contractual support from the Air Force Avionics Laboratory, USAF, Dayton, Ohio.

The function of the phased array system is to establish communications between aircraft and synchronous satellite repeater stations, which in turn are linked to a ground station network and to other aircraft. This makes it possible for the crew of an airplane to be in constant contact with anybody, worldwide. Handy for all sorts of missions and indispensable in the event of conflict.

Within the confines of each phased array element, which is less than an inch square and three inches long, is a complete transmitter/receiver/duplexer. Essentially composed of a signal source, a receiver, a mixer and an antenna, the module utilizes Sperry's advanced thinking throughout.

The rf circuitry is photo etched on metallized ceramic substrates 0.055 inches thick. Conductors are vacuum deposited gold on top of chromium. Follow-up plating produces half-mil thick strips. Transmission efficiency can be gauged by measuring rf energy loss, which, in this case, is no more than 0.15 db per inch.

Transmitter signals are generated by a Sperry Avalanche Transit Time Oscillator (ATTO), discussed in Progress Report #1. Energized by a DC voltage, the ATTO yields a 1-watt CW, X-band signal at an efficiency of 5%.

Sperry's gallium-arsenide Schottky-barrier diodes do the active conversion work in the receiver and the "rat-race" hybrid handles the signal with a single sideband noise figure of better than 6.5 db over a 12% bandwidth. (Sperry hybrid work was discussed in Progress Report #5.) Signal processing and control circuitry design has been materially aided by a Sperry-developed computer program.

May we hear from you about your system requirement?

For faster microwave progress, make a PACT with people who know microwaves.
Fireworks are everywhere in the capital even though July 4 is still two weeks away. While the Pentagon and the Congress are flailing away at each other, the White House, backed by the Budget Bureau, is anxiously seeking an accommodation on a variety of confusing issues, ranging from poor Pentagon program management and massive contract cost overruns to charges of the DOD’s overreaching its power.

While most of the attention is being focused on the larger issues such as ABM, the F-111’s Mark 2 avionics system, and the manned orbiting laboratory cancellation, other areas of controversy are in the making.

For one, the naming of the Defense Supply Agency to take over all Government procurement of standard electronic parts and components from the General Services Administration is expected to further antagonize Pentagon critics in Congress.

For their part, industry spokesmen, while generally favoring centralization of parts procurement for all—including civilian—agencies in one shop, agree that the selection of the DSA was poorly thought out and badly timed.

DSA officials, on the other hand, claim that critics of the new ruling have missed the point, and that only parts and components—not complete hardware packages or systems—will be affected when the changeover takes place on September 2.

NASA, meanwhile, is moving quickly in hopes of cashing in on the “Apollo fever” that has gripped the nation.

Coming off the glittering successes of Apollo’s 9 and 10, space officials are busily setting the stage for the most ambitious unmanned program yet proposed—the Grand Tour. The program, which would send unmanned probes to the outer planets in the late 1970’s, could carry a price tag of better than a billion dollars.

Design studies are already being conducted at the Jet Propulsion Laboratories. Now, NASA wants to get outside studies rolling.

NASA’s chief, Thomas Paine, hopes to sell the Administration on the program by first convincing the Space Task Group, headed by Vice President Agnew, that the Grand Tour would prevent the U.S. from falling behind the Soviet Union in space exploration. Another argument is that the planets won’t be in line again for such shots for about 180 years.

One omen that portends well for new NASA programs: the House earlier this month voted the agency $3.9 billion for fiscal 1970. And that’s more than was recommended by Presidents Johnson and Nixon.

How will the Grand Tour, if approved, shape up? The betting now is on two tours—one trip to Jupiter, Saturn and Pluto, and the other to Jupiter, for a second look, Uranus and Neptune.

Originally, the plan called for a single mission to Jupiter, Saturn, Uranus and Neptune. However, the feeling inside NASA now is that the dual-mission approach would, in addition to adding Pluto to the itinerary, yield data on three planets should one mission fail. Moreover, if both missions succeed, more data would be provided about Jupiter.

According to those opting for the dual-mission approach, two tours would cost only slightly more than a single tour of four planets.
The Navy's deep submergence rescue vehicle (DSRV) program may be next on the list of those being terminated, now that Sen. William Proxmire (D., Wis.) has gotten the Pentagon to admit that the cost of the Lockheed-built vessels has escalated to $80 million apiece from an initially projected $3 million figure.

Equally important to the fate of the program is the growing Congressional awareness that most Navy subs, when in trouble, sink below their maximum depth and—like the ill-fated Scorpion and Thresher—are crushed, leaving nothing for the DSRV's to rescue.

Should the Navy be obliged to scrub the program, sources say the Navy would like to divert the money to a sister project, the deep submergence search vehicle. Both programs have been starved for funds over the past two years because of Vietnam requirements.

Stationing the Bureau of Budget between the Pentagon and Congress is the closest thing to a response the White House has made to Capitol Hill criticism of the military. And the name to remember at the Budget Bureau as a growing influence on defense spending priorities is James R. Schlesinger, former Rand Corp. staffer, critic of a number of procurement policies, and now assistant director for military and international programs.

Schlesinger is touted as an advocate of increased competition at the prototype level as a means of giving the Government the most options—a view now also espoused by Defense research & engineering chief John S. Foster Jr.—plus licensing of production technology as a precondition for R&D contracts to preclude a developer from having a competitive edge in production award competition.

NASA will turn over its applications technology satellites 1 and 2 for satellite broadcasting demonstration experiments by the end of the year, but the big question is to whom. Thus far, three proposals have been made, but NASA expects to receive a few more before making a decision.

In its proposal, the Communications Satellite Corp. has offered to work with NASA and any potential ATS experimenters to provide a demonstration of domestic satellite services. Comsat is offering its ground stations, satellite expertise and, if needed, room on its Intelsat satellites.

The American Broadcasting Co. and Hughes have teamed up on a proposal to offer a demonstration of live tv news and public affairs broadcasting to Alaska. ABC would provide programing with Hughes offering to put a terminal in Alaska on a temporary basis.

The Corporation for Public Broadcasting, heading a consortium of educational tv interests, for its part, has proposed both educational radio and tv schemes employing ATS. Part of the tv proposal, entitled "The Satellite Cities Demonstration," would use the satellites to show how information on urban problems could get wide exposure.

The Navy Strategic Systems Project office has quietly made a $1.6 million award to MIT's Instrumentation Laboratory for additional work on the Polaris missile's guidance system. In view of MIT's self-imposed embargo on new classified research—in force until the college decides what, if anything, to do with its two big defense laboratories—the Navy points out that "this is not a new contract, but a modification of an existing one."

The QRC Series solves the specification/power/volume problem by utilizing all silicon, series regulator techniques with modern high speed transistor switching circuitry.

7 models, all available from stock, cover the voltage ranges of 0-20 and 0-40 Vdc at currents up to 30 amperes with prices starting at $350 for model QRC 40-4A.

Features include:
- ±0.005% voltage regulation for line and load changes combined
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For more information contact your local Sorensen representative or; Raytheon Company, Sorensen Operation, Richards Avenue, Norwalk, Connecticut 06856.

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The new Delco Radio DTS-701 and 702 NPN triple-diffused silicon high voltage transistors. They were designed for the tough requirements of off-line deflection in large screen TV.

However, they're built and tested for extra reliability in all high energy circuits. Proved by the surest peak energy capability rating in the business: Pulse Energy Testing.

And right now, they're available in both production and sample quantities.

Why will you want to use the Delco 701 or 702?

For the tough jobs—high inductive load switching or for circuits subject to transients or fault conditions.

For reduction of weight, size and component costs. Circuit complexity and number of components are reduced, so assembly costs go down, too. And fewer components mean higher reliability.

So now you know. The pioneer in high voltage silicon power has done it again.

For prices, samples or complete data, just call us or the nearest Delco Radio distributor listed below.
<table>
<thead>
<tr>
<th></th>
<th>DTS-701</th>
<th>DTS-702</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector to emitter voltage (V_CEE)</td>
<td>800V</td>
<td>1200V</td>
</tr>
<tr>
<td>Sustaining voltage (V_CEO (SUS))</td>
<td>600V min.</td>
<td>1000V</td>
</tr>
<tr>
<td>Emitter to base voltage (V_BE0)</td>
<td>5V</td>
<td>750V min.</td>
</tr>
<tr>
<td>Collector current (I_C)</td>
<td>500mA</td>
<td>3A</td>
</tr>
<tr>
<td>Base current (I_B)</td>
<td>100mA</td>
<td>1A</td>
</tr>
<tr>
<td>Power dissipation (P_T)</td>
<td>25W</td>
<td>50W</td>
</tr>
</tbody>
</table>

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DIVISION OF GENERAL MOTORS
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—SPEEDS THE WORK—SAVES MONEY, TOO!

GUDE-TIES CUT LENGTHS—Specifically produced for spot knotting these handy cut lengths of Gudebrod Flat Braided Lacing Tape are dispenser packaged for one hand, speedy withdrawal. Available in 6", 8", 10", 12", 15", 18", 20" and 22" lengths (other lengths on order). Meet or exceed MIL-T Specs, no-slip knots hold firmly without cutting insulation.

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GUDEBROD SWIVEL-TILT HARNESS BOARD MOUNT—Balanced, two dimensional action brings every section of the harness within easy reach. No stretching, no straining. Knots are tied in an easy, natural position. Cuts fatigue—speeds work.

Here you have the Gudebrod System “S” for spot tie lacing, based on the high quality, high speed Gudebrod Lacing Tape—if you’re interested in saving money while speeding the harness work, get in touch with us. (For continuous tying, ask about System “C”.)

Available also in other types of Gudebrod Lacing Tapes

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This is not a typographical error. Burndy's new printed circuit receptacle springs are clad to this thickness at point of contact.

Burndy has found a way to boost the reliability of ultraminiature connectors (.050" contact spacing) without unduly increasing the price.

Specially developed for a major computer manufacturer, the unusually thick gold coating is concentrated on the springs at point of contact. Applied by Burndy's special "cladding" method, it makes possible a pore-free diffusion-proof surface, unequalled for corrosion resistance. Formed of gold flashed beryllium copper wire, the clad spring provides a connection with unusually stable contact resistance.

Burndy also makes a full line of PSE printed circuit connectors with springs gold plated to .000030 minimum for less critical applications. Samples of both are available for comparison tests. Just write:

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NORWALK, CONNECTICUT

INTERNATIONAL SALES HEADQUARTERS AND MANUFACTURING FACILITIES:


Circle 75 on reader service card
Now from Philco!

MOS1024-bit read-only memory – 4-week delivery!

We'll write your bit pattern into our pM1024 memory, fast and accurately, through the aid of our computerized programs. Send us your pattern of 128 eight-bit words or 256 four-bit words and we'll deliver product in four to six weeks. The built-in chip select feature allows you to stack chips for any desired bit capacity.

The pM1024 chip contains address decoding, memory storage, and output buffers. High-speed output drive bipolar or MOS logic directly.

This high-speed MOS memory has a world of applications:
- lookup tables
- character generators
- microprogrammed computer instructions

- synced 8-signal waveform generators
- code converters
- and many others. Just turn your imagination loose.

The pM1024 is the highest speed, lowest power dissipation MOS memory available in production quantities today—at unit price competitive with any memory product on the market.

Want samples to check out circuitry? We can ship the pM1024 sine lookup table off the shelf.

Get complete facts now, from MOS Marketing, Microelectronics Div., Philco-Ford Corporation, Blue Bell, Pa. 19422.
Hot problem...cool solution.
IRRAVIN insulation won't melt, flow or shrink back.

This photo was made to demonstrate the solder iron resistance of IRRAVIN insulated hook-up wire, compared with ordinary PVC insulated hook-up wire. It's proof that low-cost IRRAVIN wire suits applications where heat, even direct hot solder iron contact, is encountered. IRRAVIN insulation won't shrink back, or deform. It stays in place to maintain insulation integrity.

IRRAVIN wire can be soldered in snug spaces, even when terminals are closely set. This, in addition to a small O.D., means space-savings, reduced rework and production time, less scrap.

To get the same product advantages of IRRAVIN wire you would have to specify wire that costs a lot more, two to three times more in fact! With IRRAVIN wire you not only save on time, space and waste...you save on the initial cost too!

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Use Series 54H/74H circuits in speed-critical sections of your systems. You get the benefits of the highest speed available in saturated logic.

In most systems areas, Standard Series 54/74 circuits offer the best speed/power ratio. And the complexity of MSI circuits provides substantial system cost and size reductions.

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Series 54/74

- SN5400N/SN7400N
- SN5400I/SN7400I
- Quad 2-input NAND gate

- SN5402N/SN7402N
- SN5402I/SN7402I
- Quad 2-input NOR gate

- SN5403N/SN7403N
- SN5403I/SN7403I
- Quad 2-input NAND gate with open collector output

- SN5404N/SN7404N
- SN5404I/SN7404I
- Hex inverter

- SN5405N/SN7405N
- SN5405I/SN7405I
- Hex inverter with open collector output

- SN543N/SN743N
- SN543I/SN743I
- Excess-3-to-normal decoder

- SN544N/SN744N
- SN544I/SN744I
- Excess-3-to-decimal decoder

- SN545N/SN745N
- SN545I/SN745I
- BCD-to-decimal decoder-driver with open collector outputs

- SN546N/SN746N
- SN546I/SN746I
- BCD-to-segment decoder-driver

- SN547N/SN747N
- SN547I/SN747I
- BCD-to-segment decoder-driver

- SN548N/SN748N
- SN548I/SN748I
- Excess-3-to-binary

- SN5491N/SN7491N
- SN5491I/SN7491I
- 8-bit shift register

- SN5492N/SN7492N
- SN5492I/SN7492I
- BCD-to-decimal decoder-driver with open collector outputs

- SN5493N/SN7493N
- SN5493I/SN7493I
- Dual 3-type edge-triggered flip-flop

- SN5494N/SN7494N
- SN5494I/SN7494I
- Four-bit binary counter

- SN5495N/SN7495N
- SN5495I/SN7495I
- 4-bit shift register

- SN5496N/SN7496N
- SN5496I/SN7496I
- 5-bit shift register

- SN54A0N/SN74A0N
- SN54A0I/SN74A0I
- 8-bit data selector/multiplexer

- SN54A0I/SN74A0I
- SN54A0I/SN74A0I
- 8-bit parity generator/checker

- SN54A5N/SN74A5N
- SN54A5I/SN74A5I
- Quad 2-input NAND gate

- SN54A6N/SN74A6N
- SN54A6I/SN74A6I
- Quad 2-input NOR gate

- SN54A7N/SN74A7N
- SN54A7I/SN74A7I
- Quad 2-input NAND gate with open collector output

- SN54A8N/SN74A8N
- SN54A8I/SN74A8I
- Hex inverter

- SN54A9N/SN74A9N
- SN54A9I/SN74A9I
- Hex inverter with open collector output

- SN54B0N/SN74B0N
- SN54B0I/SN74B0I
- Excess-3-to-binary

- SN54B1N/SN74B1N
- SN54B1I/SN74B1I
- Excess-3-to-normal decoder

- SN54B2N/SN74B2N
- SN54B2I/SN74B2I
- Dual 3-type edge-triggered flip-flop

- SN54B3N/SN74B3N
- SN54B3I/SN74B3I
- Quad 2-input NOR gate

- SN54B4N/SN74B4N
- SN54B4I/SN74B4I
- Quad 2-input NAND gate with open collector output

- SN54B5N/SN74B5N
- SN54B5I/SN74B5I
- Excess-3-to-binary

- SN54B6N/SN74B6N
- SN54B6I/SN74B6I
- Excess-3-to-normal decoder

- SN54B7N/SN74B7N
- SN54B7I/SN74B7I
- Dual 3-type edge-triggered flip-flop

- SN54B8N/SN74B8N
- SN54B8I/SN74B8I
- Hex inverter

- SN54B9N/SN74B9N
- SN54B9I/SN74B9I
- Hex inverter with open collector output

- SN54C0N/SN74C0N
- SN54C0I/SN74C0I
- Excess-3-to-binary

- SN54C1N/SN74C1N
- SN54C1I/SN74C1I
- Excess-3-to-normal decoder

- SN54C2N/SN74C2N
- SN54C2I/SN74C2I
- Dual 3-type edge-triggered flip-flop

- SN54C3N/SN74C3N
- SN54C3I/SN74C3I
- Quad 2-input NOR gate

- SN54C4N/SN74C4N
- SN54C4I/SN74C4I
- Quad 2-input NAND gate with open collector output

- SN54C5N/SN74C5N
- SN54C5I/SN74C5I
- Excess-3-to-binary

- SN54C6N/SN74C6N
- SN54C6I/SN74C6I
- Excess-3-to-normal decoder

- SN54C7N/SN74C7N
- SN54C7I/SN74C7I
- Dual 3-type edge-triggered flip-flop

- SN54C8N/SN74C8N
- SN54C8I/SN74C8I
- Hex inverter

- SN54C9N/SN74C9N
- SN54C9I/SN74C9I
- Hex inverter with open collector output

- SN54D0N/SN74D0N
- SN54D0I/SN74D0I
- Excess-3-to-binary

- SN54D1N/SN74D1N
- SN54D1I/SN74D1I
- Excess-3-to-normal decoder

- SN54D2N/SN74D2N
- SN54D2I/SN74D2I
- Dual 3-type edge-triggered flip-flop

- SN54D3N/SN74D3N
- SN54D3I/SN74D3I
- Quad 2-input NOR gate

- SN54D4N/SN74D4N
- SN54D4I/SN74D4I
- Quad 2-input NAND gate with open collector output

- SN54D5N/SN74D5N
- SN54D5I/SN74D5I
- Excess-3-to-binary

- SN54D6N/SN74D6N
- SN54D6I/SN74D6I
- Excess-3-to-normal decoder

- SN54D7N/SN74D7N
- SN54D7I/SN74D7I
- Dual 3-type edge-triggered flip-flop

- SN54D8N/SN74D8N
- SN54D8I/SN74D8I
- Hex inverter

- SN54D9N/SN74D9N
- SN54D9I/SN74D9I
- Hex inverter with open collector output

- SN54E0N/SN74E0N
- SN54E0I/SN74E0I
- Excess-3-to-binary

- SN54E1N/SN74E1N
- SN54E1I/SN74E1I
- Excess-3-to-normal decoder

- SN54E2N/SN74E2N
- SN54E2I/SN74E2I
- Dual 3-type edge-triggered flip-flop

- SN54E3N/SN74E3N
- SN54E3I/SN74E3I
- Quad 2-input NOR gate

- SN54E4N/SN74E4N
- SN54E4I/SN74E4I
- Quad 2-input NAND gate with open collector output

- SN54E5N/SN74E5N
- SN54E5I/SN74E5I
- Excess-3-to-binary

- SN54E6N/SN74E6N
- SN54E6I/SN74E6I
- Excess-3-to-normal decoder

- SN54E7N/SN74E7N
- SN54E7I/SN74E7I
- Dual 3-type edge-triggered flip-flop

- SN54E8N/SN74E8N
- SN54E8I/SN74E8I
- Hex inverter

- SN54E9N/SN74E9N
- SN54E9I/SN74E9I
- Hex inverter with open collector output

- SN54F0N/SN74F0N
- SN54F0I/SN74F0I
- Excess-3-to-binary

- SN54F1N/SN74F1N
- SN54F1I/SN74F1I
- Excess-3-to-normal decoder

- SN54F2N/SN74F2N
- SN54F2I/SN74F2I
- Dual 3-type edge-triggered flip-flop

- SN54F3N/SN74F3N
- SN54F3I/SN74F3I
- Quad 2-input NOR gate

- SN54F4N/SN74F4N
- SN54F4I/SN74F4I
- Quad 2-input NAND gate with open collector output

- SN54F5N/SN74F5N
- SN54F5I/SN74F5I
- Excess-3-to-binary

- SN54F6N/SN74F6N
- SN54F6I/SN74F6I
- Excess-3-to-normal decoder

- SN54F7N/SN74F7N
- SN54F7I/SN74F7I
- Dual 3-type edge-triggered flip-flop

- SN54F8N/SN74F8N
- SN54F8I/SN74F8I
- Hex inverter

- SN54F9N/SN74F9N
- SN54F9I/SN74F9I
- Hex inverter with open collector output
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Circle 84 on reader service card

Electronics | June 23, 1969
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- MC4006F, P BINARY TO ONE-OF-EIGHT LINE DECODER — a 3-input/8-output decoder. Inhibit capability provided by the enable line and allows decoder to be expanded for larger systems.
- MC4007P DUAL BINARY TO ONE-OF-FOUR LINE DECODER — a dual 2-input/4-output decoder consisting of high and low-level gates internally connected for minimum power consumption, maximum driving capabilities.
- MC4008L 6-BIT PARITY TREE — consists of eight 2-input Exclusive NOR gates connected to form an 8-bit Parity Checker/Generator and an extra 2-input gate for expansion capability.
- MC4010L DUAL 4-BIT PARITY TREE — three Exclusive NOR gates are connected together to form each of two 4-bit parity trees in one package.
- MC4011L 4-BIT SHIFT REGISTER — can be operated in the parallel or serial mode, determined by the logic state of the mode control input.
- MC5493L/ MC7493L 2-BIT FULL ADDER — each bit performs the logical addition of two binary numbers. The sum outputs, the carry output for the second bit, and Exclusive OR outputs for each bit are available. Look-ahead carry is provided internally.
- MC15482L/ MC17482L 2-BIT FULL ADDER — Exclusive OR outputs can be used for look-ahead carry when adding more than two bits.
- MC25482L/ MC27482L INVERTING/NON-INVERTING ONE-OF-EIGHT DECODER — has a 3-bit binary address with inversion control which selects the desired word for the 8-bit output.
- MC4038P SEVEN SEGMENT CHARACTER GENERATOR — can directly operate low-voltage lamp indicators, enable inputs can be used for automatic blanking.
- MC4039P BINARY TO TWO-OF-EIGHT DECODER — has two enable inputs, transforms any 4-bit binary number to a 2-of-8-bit coded number, or can be used as a dual binary to 1-of-4 decoder.
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92 Circle 92 on reader service card

Electronics | June 23, 1969
The world now agrees on only one fundamental pulse-code modulation parameter—signal sampling rate. But differences exist for every other parameter for basic terminals with the result that many pcm systems in service around the globe cannot exchange messages. Engineers are increasingly worried about this problem, and several groups are hard at it, trying to come up with workable international compatibility standards. Unfortunately, the schedule is tight; telephone traffic among all nations is booming, and it’s probable that a commercial pcm satellite will be up and operating by 1971. The photomontage on the cover that symbolizes the difficulties involved was done by artist Jon Henry.

Despite a history of difficulties, MOS integrated circuits have been judged as reliable as bipolar devices by a recent NASA study. Certain failure mechanisms are, however, quite different. For instance, the oxide layer in an MOS assembly is an active part of the device, rather than a protective element. As a result, oxide defects and imperfections play a significant role in MOS reliability.

Manufacturers of differential amplifiers typically supply drawings of a test circuit for measuring the common-mode rejection ratio. Rarely, however, do they specify how the ratio varies with power-supply voltage, temperature, or other parameters. Moreover, there’s seldom any explanation of how the test circuit was designed, what its limitations might be, and how large an error could result. One practical way to sidestep the limitations of suppliers’ spec sheets is to use a circuit that measures an amplifier’s common-mode gain; the rejection ratio can then be calculated from this value.

Computer simulation is a key element in the systems approach required to engineer satellite earth stations successfully. For one thing, the designer must see to it that the projected facility meshes smoothly with an international communications network; this involves complying with stringent signal-to-noise ratio standards. For another, whatever the environment of the host country happens to be, the installation must perform reliably at a reasonable cost.

Coming

A new 250-Mhz oscilloscope boasts a number of advances. One is a unique cathode-ray tube in which the two vertical deflection plates are helical transmission lines. Another is production of the vertical amplifier’s active elements as monolithic transistor arrays.
PCM: A global scramble for systems compatibility

Nation-to-nation differences in such characteristics as line rates and coding could decrease the effectiveness of interconnected systems; but the imminence of pcm satellites is impelling all parties to try and thrash out differences

By William Bucci
Associate editor

Pulse-code modulation, long the telephone companies' wunderkind, is fast becoming an international problem child. Engineers around the world are increasingly worried about the inability of pcm systems in one country to communicate directly with those in another. What's more, there's not much slack in the timetable for coming up with workable standards for international compatibility. Telephone traffic among all countries is booming, and there's every likelihood a commercial pcm satellite system will be operating by 1971.

Unfortunately, compatibility goals are more easily outlined than achieved. In spite of the concern over international matchups, varying national interests lead to pcm designs that primarily satisfy internal needs. At the moment, the world agrees on only one fundamental pcm parameter—the signal sampling rate. Every system built from now on will sample analog voltages 8,000 times a second. Differences exist on every other parameter of the basic pcm terminals so that many systems in service around the globe cannot exchange messages. To change analog signals into digital form, European countries, for example, follow a different coding law than the U.S. and Japan. As things stand now, the prospects for agreement have to be rated as poor. Moreover, the English handle 24 voice channels on a single line as do the Americans and Japanese, but the Europeans bundle 30 together. And some countries code analog samples into seven binary digits, others into eight.

The recent formation of a pcm study group by the Consultative Committee for International Telegraph and Telephone (CCITT) is but the latest evidence of the urgency surrounding the compatibility problem. An element of the International Telecommunications Union (ITU)—the organization mandated by the United Nations to recommend worldwide communications standards—the CCITT has been looking at pcm for several years. A small pcm working party, part of a transmission study group, was set up six years ago, and in 1966 Richard C. Boyd, a systems engineer at Bell Labs in Holmdel, N.J., took over as chairman. Boyd now heads the new study group that evolved as a result of the present pcm turmoil; it will meet for the first time this October at ITU headquarters in Geneva.

"Our big job is to get everybody together on all the characteristics of basic pcm systems," says Boyd. "But if they just agreed, as they do about the sampling rate, on the fundamental characteristics—the companding law, load capacity, and the number of digits used for coding—our problem would be a lot simpler. Next in priority are parameters like the number of time slots and channels per frame, line rate, framing and signaling, and transmission codes. If we can't agree on these latter parameters, we could manipulate them in digital interfaces to get world compatibility. Performance wouldn't suffer, and there's no reason to think that the cost of doing so would be prohibitive."

As it happens, however, one of the fundamental characteristics—the companding law—represents the largest stumbling block. It's implemented in the pcm compandor, which consists of a compressor at the coding (transmitting) terminal and an expander at the decoding (receiving) end. Most commonly, the companding law applies to the compressor, defining part of the transfer characteristic of the input-output signal—from each sampled analog voltage to its coded pulse word. The compressor boosts higher voltage less than lower voltage.
Overseas pcm. ITT engineer tests encoder card in British 24-channel system

Companding curve. At heart of incompatibility problem are three laws. The mu equals 255 is best at low signal levels, while A law crosses over at high levels. The abscissa shows signal levels in decibels below system clipping level
samples, thus “compressing” the voltage range covered by the stronger signals. In AT&T’s D1 terminals, part of the T1 system, the compressed signals then pass through a linear coder which measures each against a “quantized” scale of many, uniformly distributed possible amplitudes. The output, a coded sequence of binary digits, designates the division on the scale that’s closest to the amplitude of each compressed sample.

Compressing and coding the samples in this way is equivalent to chopping up smaller signals into proportionally more quantizing steps than larger signals. The noise or distortion inherent in this process goes down as more, and thus smaller, quantizing steps are used. Compression keeps noise very low for soft-spoken messages but allows it to increase for loud talkers where it is less noticeable. Moreover, coding the lower voltage signals in small steps suppresses weak interference, such as crosstalk.

The amount of curvature in a companding characteristic defines how higher voltage samples are compressed. For its D1 compander, Bell settled on one known as the mu (µ) equals 100 law. The companding characteristic is expressed by:

\[ y = \log(1 + \mu x)/\log(1 + \mu) \]

where \( x \) and \( y \) are input and output signals respectively; \( x \) is the instantaneous input voltage normalized for the peak limited input voltage; \( y \) is the number of the quantizing step corresponding to the input voltage, divided by the total number of steps, both starting from the center of the range; and \( \mu \) is a constant, here 100, that specifies the degree of curvature.

Bell implemented the mu equals 100 law in its D1 compandors with diodes, at the time of development the least expensive and most reliable way of doing so. A value of 100 was the highest practically achievable with the technology of the 1950’s.

The British, from the first, pointed out the shortcomings of this law. For one thing, so far it’s only been implemented inexpensively with diodes. For another, it’s tough to make diode compandors uniform enough for the characteristics of the compressor of one to match those of an expander in another. It’s necessary to make matching adjustments after a system has been installed. Thus, it doesn’t look practical to use the D1 terminals for digital switching systems because of the impossibility of matching closely enough the characteristics of all compandors in a switching network.

Furthermore, there’s no simple relationship in mu equals 100 coders between compression and expansion characteristics and the corresponding quantizing steps. Therefore, it’s not possible to use a linear code to digitize an analog sample, then manipulate the word so that it corresponds to a compressed quantizing scale. Yet the ability to do so without converting back to analog is very desirable because, among other things, it means calls can be conferenced on a line digitally.

**Saving grace?**

When British engineers began designing pcm systems, they looked for a better companding law that could be: implemented simply and in a variety of ways with uniformity, and permit simple linear to compressed code conversion.

Their solution is known as the A law and is given by:

\[ y = Ax/(1 + \log A) \text{ if } 0 \leq v \leq V/A \]
\[ y = (1 + \log[Ax])/(1 + \log A) \text{ if } V/A \leq v \leq V \]

where \( x \) and \( y \) have the same meaning as in the mu law; \( v \) is the instantaneous input voltage; \( V \) is the maximum peak-limited input voltage; and \( A \) is a constant, 87.6, defining degree of curvature.

Adopted in Europe, the A law is implemented in pcm coders by approximating its curve with 13 connected segments. It’s simple with this law to associate quantizing steps with points on the segments. To do so, a linear coder changes a low-voltage sample into a word that matches the appropriate one of a series of small uniform quantizing steps. However, it handles a high-voltage signal differently, skipping some of the small quantizing steps. For example, a coded signal that matches, say, the 40th step will pass unchanged through the compressor. But a signal falling into the 39th or 41st will be transmitted with the same binary code as the 40th. Progressively more steps are skipped at higher voltages. The number is determined by the segment on which the quantizing step falls.

Thus, the British and their Continental colleagues were able to omit Bell’s diode compandor and, instead, use a linear encoder and the digital equivalent of the compandor.
Pcm and its payoffs

Pulse-code modulation systems transmit signals as a coded stream of digits, rather than as a continuous varying wave. Regularly spaced repeaters determine whether a pulse is present in its time interval and, if so, generate a new, clean pulse and send it along the line. The change from analog to pcm involves sampling, quantizing, and coding. Each analog signal is sampled at a rate at least twice that of its highest frequency component, producing a string of pulses whose amplitudes follow that of the analog waveform. Then each pulse is compared to a quantized scale and a coded string of equal-amplitude pulses, matching a step in the scale, is generated. In the case of Bell’s T1 terminal, the scale distinguishes between any of 128 distinct amplitude levels.

For that many amplitude levels, each pulse sample is represented by a 7-bit word. The first digit, 0 or 1, identifies the polarity of the sample; the rest pinpoint its amplitude. Each 7-bit word is time-division multiplexed with other 7-bit words, as well as framing and synchronizing bits, then transmitted to the first repeater and thence down the line. At the receiving terminal, pulses are demultiplexed into words and then converted back to analog form.

Plus factors. The advantages of pcm vis-a-vis frequency-division multiplexed systems depend on the application. Short-haul set-ups offer terminal cost savings because carrier bandpass filters aren’t required and the modulation overhead can be shared by all channels. As a matter of fact pcm continues to be the cheapest carrier system for distances of from 10 to 100 miles.

But Bell claimed the A law compression curve didn’t produce acceptable performance because its slope wasn’t as sharp near the origin as the mu equals 100 curve. This meant low-voltage signals weren’t encoded in as small steps as with the mu law. The mu equals 100 law offers, says Bell, a 2-decibel advantage over the A law for background noise and crosstalk. On the grounds that its more stringent transmission requirements demanded the extra decibels, Bell stuck with the mu equals 100 law. In the meantime, other European countries were following England’s lead while Japan went the mu equals 100 route for their pcm systems.

Recently, the Conference of European Postal and Telecommunications (CEPT) Administration adopted the A law, in either 7-bit or 8-bit form, as a standard. Among the more active CEPT countries are England, France, West Germany, Italy, Sweden, the Netherlands, Belgium, and Switzerland. Meanwhile, the Communications Satellite Corp. (Comsat) has made things hotter for AT&T, one of its board members, by proposing to the International Telecommunications Satellite Consortium (Intelsat), of which it is acting manager, that the A law be standard for the upcoming pcm bird.

Over longer hauls, the economics are still attractive, but engineers tend to emphasize the performance advantages. For example, many kinds of signals—speech, tv, and various kinds of data—can easily be coded and time-division multiplexed with pcm systems. Thus television signals can be transmitted together without intermodulation distortion. Frequency-division equipment, however, can’t handle multiplexed tv.

Then too, digital repeaters need not be ultralinear with extremely low harmonic distortion and ultraflat amplitude response characteristics; they have only to regenerate pulses—not amplify analog signals. Long-distance frequency-division systems require thousands of expensive ultralinear repeaters.

Tradeoffs. In the case of atmospheric microwave transmission, pcm uses up bandwidth but conserves power. As a result, where microwave transmitters cannot be separated by long distances from other towers, pcm minimizes interference between systems transmitting at the same frequency. Because Japan’s area is limited, forcing microwave installations to operate cheek-by-jowl, it’s been the first—and so far the only country—to develop a pcm microwave system. It also appears pcm may be the best way of getting signals through the atmosphere at millimeter wave frequencies. In theory, such a system should be able to transmit hundreds of megabits of information. Bell Laboratories expects to run field trials of atmospheric pcm systems above 11 gigahertz within the next year or two.

With satellites the question is stickier since both power and bandwidth are important. But pcm systems’ relative immunity to distortion, along with their capacity for carrying a mixture of signals looks attractive at this point.

The British Post Office contends that the A law was meant from the outset to be an international standard—one that could be implemented variously by manufacturers in different countries. Foreign officials consider the performance levels realizable with the A law perfectly adequate for Europeans.

Second-strike capability

Bell, however, came out fighting for its performance standards, as well as for international compatibility, by proposing that all countries agree on a new companding law. It then changed to this law in its second-generation D2 terminal. With an eye to such technological advances as large-scale integration and op amps, Bell decided to go to a mu equals 255 characteristic that could be approximated with 15 segments and matched simply to the quantizing steps. As a result, both the D2 coder and A law units derive the companded signals by omitting quantizing steps from a linear code.

Europe took this development quietly in stride. According to the British Post Office, a mu of 255 will be tough to specify and implement because it requires very close hardware tolerances. Moreover, Brian Edwards, who heads the digital systems de-
partment at ITT’s Standard Telecommunications Laboratories, Ltd, doubts Bell can economically implement a mu of 255 in the 8-bit D2 encoder. In the U.S. where a single outfit runs most of the long-distance network, looser manufacturing tolerances may be tolerable because they can be compensated for by the company, he says. But this doesn’t hold true for Europe where there are many manufacturers of pcm systems.

AT&T’s Boyd answers: “We agree that going to a mu of 255 instead of 100 takes more than double the precision involved in the smallest step and is beyond the present state of the art. D2 probably will achieve some of the improved noise performance that the law implies. And it won’t cost much more than the earlier mu equals 100 \(\frac{1}{2}\) terminal. But we’re looking ahead to the next generation of coders, with greatly improved precision and lower costs.”

David Thomas, head of planning at STL, questions the need for this kind of precision in Europe. “The superior performance might be important in the U.S.,” he says. “But I’m not convinced we really need such accurate reproduction at low volumes in Europe.” And the British Post Office, supported by such homebred suppliers as Marconi and STL, believe that the A law is better for a European network and that improvements promised from the mu equals 255 law are immaterial and probably not achievable in Europe.

But if the United States and Japan don’t reach an agreement with the Europeans, digital interfaces will have to be used to match up the A and mu laws. Reactions to this prospect vary. Comsat says that the resultant signal degradation would be most undesirable, if not unacceptable. Japan and Bell, on the other hand, take the attitude that distortion wouldn’t normally exceed allowable limits; the Japanese feel where it did, voice signals could always be decoded to analog. Likewise, STL’s Edwards and Thomas aren’t convinced that interfacing Mu and A law encoders with digital circuitry will lead to unacceptable distortion levels. Bell prefers such matching to decoding to analog.

Despite the difficulties to be overcome, Thomas assesses the chances for agreement on an international standard for companding as good—at least over the long term. “After all, only one group has to abandon its present position,” he says. His colleague, Edwards, isn’t as optimistic, anticipating the world will divide into two camps eventually. The consensus in Britain is that regional agreements will be made as necessary among, for example, the U.S. and Canada and the U.S. and Latin American countries, as well as within Europe. The BPO believes that if no definitive international agreement is reached, decoding to audio may prove the simplest solution.

**TV signal.** Siemens AG experimental set-up in Germany transmits pcm visual signal, which is displayed on screen.

**High capacity.** At Yokosuka, Japanese adjust pcm equipment for system that transmits 120 voice channels.
Clean pulses. Japan’s 120-channel system transmits 7.876-mbs signal, which is periodically regenerated in repeaters. Case can house 20 such devices.

Positions on the number of bits necessary to code analog signals are less partisan than on the compandor question, but they’re still diverse. And, ironically, AT&T is faced with a lack of compatibility within its own plant. It now has hundreds of thousands of pcm channels in operation—all of which carry signals coded into seven bits. But toward the end of this year, it will be introducing its 8-bit D2 coders.

Bell admits internal compatibility could pose a problem. Hopefully, when digital switching arrives it will be implemented first between long distance intertoll offices with D2 coders. But if it’s economical to install digital switching in an exchange lower in the switching hierarchy, Bell could wind up with a D1 coder in one office and a D2 in another at the end of the link. Conversion circuitry offers a way out here but is an uninviting prospect because of higher costs and the possibility of degraded performance. Alternatively, a new version of D1 could be brought out and implemented with a compatible law.

Bell is going ahead with the 8-bit D2 coder on the assumption digital switching won’t be a big deal in the U.S. for a good long while. One sure clue: At the moment it doesn’t even have such a system in development, only under study. In the meantime, Bell says it must offer high-quality pcm service on intertoll calls. Since such traffic normally would pass through several analog-digital...
**Links in the pcm chain**

The original pulse-code modulation system, Bell’s T1, is only seven years old, but already the U.S. and several other major countries are criss-crossed by pcm lines. And networks are growing at a good clip—last year AT&T and independent U.S. phone companies put over 6,000 new 24-channel pcm systems into service, a 20% increase over 1967 installations. Western Electric, AT&T’s manufacturing arm, now produces more pcm channels than analog. By December, there will be close to 500,000 two-way pcm channels—over 20,000 systems—in the Bell System. General Telephone has over a thousand systems in service and 500 more on the way.

Since Lenkurt Electric, a GT&E manufacturing unit, came out with its 9001A coder later than Bell’s D1, it was able to capitalize on technological advances. The 9001A is smaller, mounts on 19-inch rather than 23-inch racks, and interfaces directly with a switching system, thus avoiding the trunk circuits required with D1 and cutting costs. Nonetheless, Lenkurt’s pcm terminal is identical to the D1 at the carrier end so that the two work together perfectly—an object lesson in compatibility. Other U.S. firms that make or plan to make D1 type units are Vicom, Stromberg-Carlson, and Lynch Communications.

AT&T will place its first D2 coders into service this year. These units produce four independent 24-channel output streams—a total of 96 channels. These can be time multiplexed and transmitted on 6-megabit T2 lines. General Telephone has yet to announce its plans for making compatible coders.

In the meantime, Bell Labs is developing a 564-megabit system, designated T5. (T3 and T4 lines don’t exist though Bell plans eventually to offer intermediate-capacity multiplexers.) T5 is a coaxial-cable arrangement; T1 and T2 are twisted-pair designs. Bell is also investigating waveguide, as well as atmospheric millimeter-wave pcm transmission.

**Foreign affairs.** The British have some 300, 24-channel pcm systems in service in the country’s phone network; about 500 new systems are being installed annually, and 1,300 should be operating by the end of next year.

Unlike Lenkurt and Bell’s units, gear produced by Marconi for the British Post office’s system makes extensive use of integrated circuits in coders, decoders, signaling cards, and pulse generators. Standard Telecommunications Laboratories’ apparatus relies on resistor-transistor logic for a number of digital-manipulation functions, but the firm points out it would do things differently if it could start all over. The experimental time-division digital-switching exchange dubbed Empress and installed in London also makes extensive use of ic’s. The Post Office is doing experimental work to gain experience using medium-scale integration in telephony. There are four to six gates on each chip and some seven or eight chips prewired inside one pack—that is 40 or more gates in a pack. Experimental 24-channel modules shift registers are being developed for use as store to control crosspoints. While British outfits haven’t announced any plans for higher-capacity pcm systems, they are doing research in both microwave and millimeter guided-wave systems.

**Purchase orders.** France has five pcm systems in service that use 6-bit coding and transmit 36 voice signals in 37 time slots; about 100 such systems are on order and being installed. But future French systems will be of the cept 32 time slot type; two or three of these will be in operation at year’s end.

stages, Bell says it’s imperative to stick to eight bits. But when digital switching becomes widespread such precision may not be required.

The British and Japanese use a 7-bit system, while the cept countries now favor 8-bit coding. Comsat has vigorously championed a 7-bit system for Intelsat, one reason being that it permits more channels, and hence higher revenues, than 8-bit gear. Comsat also maintains that digital switching and the increase in “single-hop” calls via domestic satellites minimize analog-to-digital conversions.

General Telephone & Electronics, largest of the U.S. independents, agrees with Bell that 8-bit encoding is necessary for intertoll traffic. However, it has no plans at all for such gear because its toll needs are limited.

STL’s Thomas isn’t convinced that eight bits are necessary in European networks. “Seven’s certainly the number now, and eight may be desirable for a short time when long-distance connections are made by multiple links of short-haul pcm lines,” he says. “But eventually, say around the year 2000 when switching is generally digital and there are extensive long-line pcm links, six bits may be quite enough. So it’s arguable whether 8-bit systems should be installed now. They may be necessary in the U.S., where the network is much bigger and more complex—but not in Europe.”

However, if seven, rather than eight bits are used, Bell argues, there could be a 6-db price to pay in noise during satellite calls.

Meanwhile, France is installing prototype 30-channel pcm systems using 8-bit encoding. France was successful in getting cept to accept this as the European standard.

Japan agrees that eight bits might be needed on long-distance calls, say, for seven or so links. But its engineers point out that much of the country’s traffic is over short distances. Frequency-division multiplexed carrier systems handle the long-distance load among distant cities, so the need for 8-bit systems is limited.

The Swiss add yet another element to the picture. Their country has a growing cable network with excellent transmission quality; authorities would like to use pcm not only to carry voice but also to pipe high-fidelity music directly into private homes. It’s likely, then, the Alpine nation will
If all goes well, 100 or so will be bought annually over the next several years. At least half the circuits in these systems are monolithic IC's. During 1969, the French will begin testing two PCM microwave systems. One system will transmit two, and eventually eight, megabits of information at 2 gigahertz; the other 36 megabits at 7 Ghz.

Germany has four experimental systems under test in its commercial telephone network. One, a 60-channel system with a line rate of 3.84 megabits developed by Siemens, links exchanges in downtown Munich and Pasing, a Munich suburb. Another in Stuttgart, developed by Standard Elektrik Lorenz, transmits 24 channels. This city also has a 24-channel AEG Telefunken System. Finally a 24-channel TeKaDe-EPC system operates between Nuremberg and nearby Fuert. On order from four firms is equipment for about 50, 32-channel systems to be installed for commercial service in area networks. Delivery will start around the end of the year. Japan has more than 2,000 24-channel systems, developed by Nippon Tel and Tel; new systems are going into service—at the rate of about 1,000 a year. Discrete components are used exclusively in this equipment. Japan is now checking three versions of a 120-channel system at four locations. After completion of tests next year, these systems will be installed in many spans. One version multiplexes five 24-channel streams; another directly codes 120 voice channels; the third encodes a 60-voice-channel, frequency-multiplexed supergroup.

In two locations, four 120-channel pulse streams are modulated onto microwave carriers around the 2.1-to-2.29-GHz range. Nippon Electric equipment is used at the terminal of a 12-mile link. Fujitsu gear is installed in another span where five 24-channel pulse streams are transmitted.

Bits-number difficulties are closely related to the state of the digital-switching art in various countries. Initially, Bell developed and installed PCM to pay off in cities; at the time, however, semiconductor technology was relatively immature. Now AT&T finds itself with a very sizeable PCM plant—and no digital-switching system on the drawing boards. Now being studied, such a project couldn't make a commercial debut for at least several years.

Ironic, GTE may have a digital-switching capacity in the U.S. before its giant rival, Bell. General System exchanges, islands in the AT&T ocean, have grown to the point where they've got to be connected by tandem-switching centers. Years ago, Bell's solution was use analog switching. But advances in technology suggest to GTE at least that the digital may well prove a better solution.

Donald Ashford, a senior engineer at GTE Labs and the company's representative on the CCITT PCM study group, reports that GTE Labs expects to start work on an experimental digital-switching system by the end of this year. "One difficulty is that you've got to fit PCM switching in with the existing analog plant," he says. "You've got to get signaling tones off a PCM line, without converting back to analog. One way is to look for digital patterns and employ pattern-recognition. We're hoping that we can accomplish this with software."

Meanwhile, both Europe and Japan are racing ahead with digital switching. West Germany is beginning to develop a telephone-exchange system that will incorporate PCM switching. England—proud of the fact that the old world took digital switching requirements into account from the start—is running a service trial of its Empress PCM switching system in London. ITT is working on a different electronic version.

Japan's Nippon Telephone and Telegraph has developed an experimental digital-switching system that it's temporarily shelved because analog switching with electronic systems is still cheaper.

France looks towards 1976 when it hopes to put digital-switching equipment into commercial service. Plans for next year include testing of a system designed by the post office's Lannion Laboratory Development Center.

Loaded Question

The other fundamental property of PCM systems —load capacity, the maximum signal that can be handled without overloading—is more susceptible of international solution than other technical issues. Differentials in this parameter from country to country are at most a db; they can be compensated for by simple adjustments in the analog plant.

Europe has settled on +2 dbm0, America on +3 dbm0. But even though there's no serious difficulty, consensus is still a will-o-the-wisp. Some, for example, claim that designers of European phone systems aren't as critical of load capacity as are those in the U.S. Continental sources deny this.

While other PCM parameters aren't as crucial, there's still plenty of disagreement. "If we have to, we should be able to manipulate signals with a high degree of impunity," says AT&T's Boyd. "We hope that won't be necessary, but if it is you can bet systems designers all over the world will make good on this."

Nonetheless, the CCITT study group will try to hammer out agreements on such "minor" differences in systems characteristics as the number of time slots and channels per frame, line rate, steps in an international digital hierarchy, and methods for signaling, framing, and synchronization.

America, England, and Japan now line up on the side of 24 time slots per frame. England, however, has a slightly different bit rate. Twenty-four channels are optimum for the cables used by the Americans; originally designed to carry voice signals, they were then used for PCM to increase capacity. It's unlikely, then, that America will want to switch to the 32 time slot standard. England, however, uses a different kind of cabling and could go either way.

England's cable is similar to the European stand-
ard—a balanced-quad affair with what's advertised as superior electrical characteristics. Europe is testing this cable as justification for going to 32, instead of 24, time slots. No one quarrels with the cable's better characteristics, but there are those who believe the primary motivation in this case is commercial rather than technical.

British and European interests are potential rivals for pcm systems orders in other countries, and the 32 time slot system now gives the latter a strong selling point. In fact, some predict that England may be pressured by its pcm manufacturers into switching to the CEPT standard.

The French, who started with a 6-bit encoded system are now among the most vocal supporters of the 32 time slot CEPT standard. Telephone officials argue that it's technically superior to the 24 time slot version because 32 is a power of 2 and time-division switching devices will be bipolar.

Germany supports the CEPT system, contending that cost per channel is lower and that the system is compatible with Germany's existing carrier-frequency equipment.

But Japan takes the position that only 30 of the 32 time slots are used for voice, thereby invalidating the argument of 32 being a power of 2. The U.S. agrees. Moreover, both believe the CEPT standard represents an extravagant use of potential channel space.

Because there's little possibility that the two camps will change their minds, efforts are directed primarily at reaching agreement on second-level pcm systems, that is, those of higher capacity.

**Meeting of the lines**

One of the optimists about an agreement is Antoine Jousset, head of the French post office's pcm program and chairman of the CEPT pcm committee. “The bit rate for a secondary system could be four times the primary multiplex rate (24 time slots) of Britain, three times that of CEPT (32 time slots), and the same as that of AT&T's T2 system (96 time slots)—roughly six megabits,” he says.

CEPT countries haven't yet agreed to a secondary multiplex standard, but the nations haven't been shy about voicing opinions. For example, Italy and West Germany are pushing eight megabits while Britain and France are leaning toward six megabits.

Japan, which already has 8-megabit, 120-channel systems in operation, may prove troublesome. The Japanese designed for their own needs, producing a system that would directly encode their 60-channel frequency-multiplexed supergroups and which has the capacity to carry visual telephone signals. AT&T doesn't plan to encode supergroups but will code mastergroup signals on future high-capacity pcm systems. It is convinced six megabits is more than adequate for Picturephone signals.

Another area of difference centers on framing and signaling. Bell fills each of its 24 time slots with speech and signaling, for example, and inserts a framing pulse after the 24th time slot—the 193rd bit. England uses one of the 24 time slots for framing. The CEPT system sets two of the 32 slots aside, one for framing, the other for signaling.

Bell had originally intended using 194 bits in a D2 frame, dedicating two of these for framing. This resulted in a sampling rate of 7,959 per second, so when the rest of the world agreed to standardize on 8,000, Bell reconsidered. However, its framing technique isn't compatible with the CEPT system.

Another thorny question involves whether Europeans will accede to AT&T's recommendation to insert redundancy information in their pulse streams. This would make it possible to evaluate easily the transmission line performance by measuring the digital error rate and also permit automatic switching to standby lines in case a transmission facility fails. America, but not Europe, currently inserts such redundancy digits on its lines.

**Time standards**

International pcm networks must, of course, keep the same time. Of the several ways to get them to do so, none seems effective for all. The choices are: synchronize all oscillators to a master clock; derive the clock for every office by averaging the phases of all signals; or, omit synchronization; instead insert noninformation-carrying pulses to match pulse rates of different terminals (pulse stuffing) and remove them at the receiving terminal.

Bell expects to use each method in different parts of its network; the CT&E system will probably emphasize master-clock synchronization. England and France seem to lean toward pulse stuffing. In fact, France's Jousset hopes that this technique will be generally accepted, although he admits that it will make digital switching more difficult to implement.

The Japanese reject synchronizing "slave" clocks to a "master" clock, pointing out that even if all terminals are basically similar and the master clock is rotated from country to country, the set-up would probably not work out internationally. They favor pulse stuffing.

Other questions being debated within the CcITT group include the types of transmission line codes used. In D2, for instance, Bell throws out the code for one of the 256 quantizing steps, which would consist of all zeros, because of repeater-timing problems. But the Europeans retain this code and, instead, invert every other digit in all the codes. They argue that this is the best way of decreasing the likelihood of zeros. Bell disagrees, and it's trying to pin the question down with analysis.

As the CcITT October meeting approaches, many are pessimistic about the prospects for immediate agreement on the really important questions. But there's general optimism that eventually things will come out all right. "Countries disagreed at first about carrier-frequency system specifications," says Theodor Irmer, chairman of the pcm study group at West Germany's postal telephone administration. "But they got together eventually. We may have to wait several years with pcm, but it's got to happen. Otherwise we're going to have some really serious problems with overseas communication."
Conventional semiconductor components can be used to build a high-impedance voltmeter having superior drift characteristics and a current measuring sensitivity of 1 nanoampere or better.

Two source followers are connected to the meter across their outputs so that drift in one due to temperature changes will be canceled by a similar drift in the other. When an input is applied to the gate of $Q_1$, the current change in the transistor causes a change in $Q_3$'s base current; the change is then amplified by $Q_3$ and fed back to $Q_1$'s source, causing it to follow the original input voltage closely. Because the over-all gain is nearly unity, a directly calibrated meter can be used without modification.

The output to the meter is $\pm 1$ volt at 100 microamps. The level can be increased to 1 milliamp, but with some loss in accuracy.

The input is decoupled by a 0.1-microfarad capacitor that forms the lower part of a capacitive divider for the higher voltage ranges. The advantage of this arrangement over the resistive divider is that an extremely high impedance can be maintained over these ranges. For simplicity, only one additional voltage range is shown here. The range, set by switching to the "attenuate" position, depends on the value of capacitor C.

Current is measured by observing the voltage across a known resistor when the current flows through it. For instance, with a 1,000-megohm shunt, the meter reads 1 nanoamp full scale.
Minimizing common-mode errors in a variable-gain amplifier

By William D. Miller

Many differential amplifier circuits require adjustable gain values so that circuit sensitivity can be matched to input signal levels. No problems arise when discrete gain values are needed; the resistors can be switched into the circuit in accurately matched or pretrimmed pairs. But, problems arise when continuously adjustable gain is required.

The ideal differential circuit provides common-mode rejection if the external components are accurately matched to make \( R_{lA} \) identical to \( R_{lB} \), and \( R_{2A} \) identical to \( R_{2B} \). If these resistor pairs aren't precisely matched, the amplifier will partially respond to a common-mode input. It's not possible without using exceedingly expensive ganged potentiometers to keep \( R_{2A} \) and \( R_{2B} \) identical while they're varied over the full gain range. And poor tracking between \( R_{lA} \) and \( R_{lB} \) will introduce common-mode errors as their resistance values diverge.

The amplifier circuit shown varies gain with minimal common-mode errors by using one variable resistor rather than two. An input attenuation network consisting of fixed resistor \( R_s \) and gain-control resistor \( R_t \) raises output voltage by a factor \( (R_t + R_s)/R_s \) while maintaining equal input and feedback currents, \( I_{in} \) and \( I_t \). The smaller the value of \( R_s \), the higher must be the amplifier output to balance feedback and input current.

Circuit gain could be varied from less than unity to just about any upper limit without affecting the common-mode performance, provided \( R_s << R_{2B} \). Thus the ratio of \( R_2 \) to \( R_1 \) can be trimmed for highest common-mode rejection, then left without further adjustment where

\[
\frac{R_2}{R_1} = \frac{R_{2A}}{R_{1A}} = \frac{R_{2B}}{R_{1B}}
\]

SCR shift register can take a lot of noise

By Jerome H. Silverman
Union Carbide Corp., Greenville, S.C.

Shift registers designed for industrial needs are often used to record data on the disposition of electronic components in an automatic testing machine. The test results are shifted along with the components as they index through the machine with the contents of the registers determining the station at which the parts are ejected. But the noisy electrical environments often encountered in many factories...
can inadvertently trigger the registers.

The silicon controlled rectifier shift register shown here, however, is particularly suited to operation under these conditions. It operates solenoids and relays directly and performs well in the presence of high ripple and noise levels.

The first stage is loaded by a positive pulse applied between shift pulses, and the shift is executed when two voltage pulses occur in sequence. First, the anode supply voltage is reduced to zero for a short time period and then restored. This turns off any SCR that may have been conducting. A positive pulse is then delivered to the register line, and the line is coupled through diodes and capacitors to the SCR's gates.

Each coupling capacitor that's connected to a previously nonconducting SCR anode, charges and reverse biases its corresponding diode, thus blocking the retrigger pulse from the next SCR gate. The capacitors connected to conducting anodes are uncharged and therefore don't reverse bias their associated diodes. The retrigger pulse thus reaches these gates, firing the SCR's. In this way, the conducting SCR states are shifted through the register.

The power supply applies a full-wave rectified 110v a-c voltage to the B+ line of the shift register. Capacitor $C_1$ charges through diode $D_1$ and discharges into the B+ line through the first SCR. Its gate is connected to the capacitor through $D_2$ and $R_1$ and causes the SCR to automatically trigger every time the rectified B+ voltage drops below $C_1$'s voltage level. The capacitor need only be large enough to supply holding current to those SCR's that are on in the shift register every time the a-c output of the transformer passes through zero.

To shift information in the register, a shift pulse is applied that turns on $Q_1$ for the duration of at least one half-cycle of the a-c line voltage. This removes the gate drive to the first SCR and thus erases the B+ voltage. $D_2$ prevents the SCR from receiving excessive reverse gate bias.

The shift pulse also turns on $Q_2$, charging $C_2$. When the shift pulse drops to zero, the SCR is restored to normal operation. The reappearance of the B+ voltage and the absence of the shift pulse turns the second SCR on, discharging $C_2$ into the retrigger line. The second SCR then turns off when $C_2$ has been discharged. The transfer cycle is completed and the shift register is ready to accept more information.
How reliable are MOS IC's?  
As good as bipolars, says NASA

Although failure mechanisms differ for MOS because oxide is a functional part of the device, tests indicate failure rates running at 0.016% per 1,000 hours

By Leon C. Hamiter Jr.
National Aeronautics and Space Administration, Huntsville, Ala.

Partial holes. Burned-out portions occur at “partial” holes, where oxide is thinner because of contamination or irregularities on the silicon surface. Here, the oxide ruptured at less than rated voltage.
An oxide layer is as much a part of a bipolar integrated circuit as it is of a metal oxide semiconductor IC. The difference is that the oxide in an MOS circuit performs a dual function: protects the semiconductor material and participates in the operation of the circuit. It's this difference that gives the physics of failure of an MOS circuit a different character. Such oxide-dependent failure modes as threshold voltage variations and gate shorts are unique to MOS IC's.

In addition, contamination and certain process parameters are far more critical with MOS. And the dimensions and alignment of masks are more critical, too, because of the much smaller size of transistors and interconnections. (See "Defects in MOS IC's," p. 108.)

The National Aeronautics and Space Administration in Huntsville, Ala., has studied the reliability of MOS IC's and has found that they have become stable and manufacturable products thanks to refinements in growing, etching, regrowing insulating layers on semiconductor substrates, and rigid process controls.

Thousands of MOS IC's from a single manufacturer were tested, for example, at 25°C operating life, 85°C operating life, 125°C reverse bias, 125°C storage, and 150°C storage. Some 4,339,000 circuit hours were accumulated in this group of tests alone, with only three failures—a failure rate of 0.095% per 1,000 hours at maximum stress. If it's assumed that the acceleration factor is eight, these tests are equivalent to 26.4 million operational hours and a failure rate of 0.016% per 1,000 hours at 60% confidence. (Although the stress in an average application is only about 30% of device rating, the NASA tests were conducted at maximum rated temperature and voltage. Some reliability engineers feel that this extra stress accelerates failures by a factor of five, others say it's 20. Therefore, the factor of eight is a conservative estimate of acceleration factor.)

This test experience is comparable to NASA's experience with operational systems using MOS IC's. The IMP-D and IMP-F satellites, for example, accumulated 19 million MOS circuit hours with two failures for a failure rate of 0.016% per 1,000 hours at 60% confidence. The failures occurred after one year of operation, and indications are that the MOS devices were not the cause of failure. In an information-handling system, 2.5 million MOS circuit hours were accumulated with four failures for a failure rate of 0.016% per 1,000 hours. Significantly, all failures occurred during the first 150 hours of operation, and none of the units were screened previously.

It's now possible to draw these general conclusions about MOS IC reliability:

- MOS and bipolar IC's of equal complexity offer approximately the same failure rates. Variations of failure rates between the two are more a function of application, screening and quality control than technology.
- A complex MOS circuit offers a lower total failure rate than discrete parts or less complex IC's that must be assembled on printed-circuit boards and interconnected to perform the equivalent function. Therefore, increasing the complexity of MOS circuits—to a point—can improve over-all system reliability.
- To obtain high-reliability MOS circuits (and bipolar, too) requires strict quality control, high workmanship standards, careful handling and application, and effective screening and inspection criteria.
- Within their application capability, large-scale-integrated MOS circuits offer tremendous reliability potential, limited primarily by yield and packages.

The NASA study covered the most common kind of MOS circuit—the p-channel, enhancement-mode device. However, it's safe to assume that these conclusions also apply to n-channel depletion-mode and complementary IC's. The IC's in the NASA tests were thick oxides in which the silicon-oxide layer is typically 15,000 angstroms thick except for

**Structure.** Basic MOS transistor design provides for overlap of gate metal on the diffused p regions. This assures proper registration. The thinner oxide under the overlap, however, is susceptible to breakdown.
### Causes of Failure in MOS ICs

<table>
<thead>
<tr>
<th>Cause of Failure</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxide</td>
<td>20%</td>
</tr>
<tr>
<td>Handling and overstress</td>
<td>20%</td>
</tr>
<tr>
<td>Metalization and particle</td>
<td>12%</td>
</tr>
<tr>
<td>Bond and connection</td>
<td>10%</td>
</tr>
<tr>
<td>Package</td>
<td>10%</td>
</tr>
<tr>
<td>Photolithographic and diffusion</td>
<td>8%</td>
</tr>
<tr>
<td>Chip mechanical</td>
<td>5%</td>
</tr>
<tr>
<td>Chip mount</td>
<td>3%</td>
</tr>
<tr>
<td>Others</td>
<td>12%</td>
</tr>
</tbody>
</table>

The major causes of MOS IC failure found by NASA—and their percentage of occurrence in failed circuits—are in these categories:

- **Oxide defects**, 20%—Flaws in the insulating layer between the silicon and the metal interconnection pattern. Gross defects in this dielectric, or inadvertent removal of it, prior to metalization cause nonfunctional shorted devices. Pinholes are another kind of oxide defect; these are small localized regions in the oxide with low dielectric strength. Such regions have reduced resistance to electrical overstress and can easily become a leakage path or a complete short circuit. Causes of pinholes are dust particles, minute mask flaws, and contamination. Pinholes are scattered at random over the chip. Sites in inactive areas and not under the gate or metalization are of no consequence since they cannot contribute to device failure.

- **Handling and overstress**, 20%—Poor handling causes broken or badly twisted packages and leads. Electrical overstress—from static charges on personnel and equipment, inserting the wrong leads in the test socket, and transient voltages—can destroy the gate oxide.

- **Metalization defects and particles**, 12%—These defects include scratches, smears, insufficient thickness, and insufficient clearance between metal paths. Insufficient thickness can cause excessive current density while insufficient clearance can enable particles to cause a short circuit. Serious cracks have been observed in metalization over oxide cuts and steps [Electronics, April 26, p. 40]. Although these cracks have only appeared in bipolar ICs, they could also occur in MOS circuits. Both conducting and nonconducting particles are found in many ICs. Metal particles big enough to short out two metalization paths are of primary concern. Such particles include gold wire, aluminum slivers, fragments of silicon, and gold flakes.

- **Bonds and connections**, 10%—Failures in this area are usually broken wires and separation of the wire from the chip (which appear as open circuits), and sagging and misrouted wires (which appear as shorts).

- **Package**, 10%—These failures are usually leaks in the seal, lead fatigue, external surface contamination, and marking and plating deterioration.

- **Photolithographic and diffusion defects**, 8%—These include faulty alignment between one or more of the successive masks, and defects in the mask itself. Typical mask defects are poor definition, variations of intensity, dark spots in clear areas of the mask, and clear spots in areas that could not transmit light. Such defects result in improper oxide removal or improper diffusion.

- **Chip mechanical defects**, 5%—These include cracks, chips, and fractures. Cracks are unintentionally induced during the scribing operation that separates the chips from the wafer. Every force, bending moment, or torque applied to the chip from that point on could result in a failure. Even after the chip has been packaged, sufficient force can be transmitted by the package itself, and even by the circuit board that it's mounted on, to break the chip.

- **Chip mount**, 3%—These include improper placement in the package cavity, orientation, and clearance, which result in the chip shorting to the package and overstressing the wires.

- **Others**, 12%—These include a variety of causes, most of which are still undetermined. In some cases the IC is so badly damaged that it's impossible to pinpoint the original cause.
Especially critical. Conducting particles are critical in all IC's, but especially in MOS. In bipolar circuits, the maximum permissible particle size is 0.5 mil, but even particles of this size could cause trouble in an MOS circuit in which the space between metalized paths is 0.3 mil or less. (Above, the largest burned spot—a particle that has short-circuited two metal paths—is 2.8 mils long.) A possible solution is coating the entire chip with glass after metalization.

the gate area, where it's only 2,000 A, comparable to the oxide in thin MOS circuits.

The MOS structure on page 107 indicates the causes of device degradation and failure. A negative voltage applied between gate and drain establishes an electrostatic field that inverts the n-material under the gate metal to a p-channel between source and drain. The minimum voltage necessary to produce this channel is the threshold voltage, V_T. The high input impedance characteristic of MOS is obtained by the use of an oxide layer between the gate and the substrate.

The metal gate extends beyond the gate into the p-regions to insure that the field-effect channel occupies the entire gate region. (If the gate metal mask is misaligned enough that the p-n junction is not covered, the conducting channel in the gate region would terminate before it reaches a p-region and the device could not function.) This region of gate metal overlap is the weakest part of the MOS structure, because it imposes high electrical stresses on the oxide.

One failure mode, for example, is rupture of the input-gate insulator by stray voltages. The effect of oxide rupture ranges from degradation of the gate breakdown voltage to complete short-circuiting of the gate. A low-energy transient can produce a silicon-aluminum compound that tends to reduce the breakdown voltage; higher transients, or higher-than-average operating voltages, can completely short the device.

MOS devices are usually rated at 10 to 50 volts, and if they are carelessly subjected to higher voltages—from an ungrounded soldering iron, for instance—the input gate oxide can easily be ruptured.

Another cause of gate rupture is man. By just walking across a nylon-carpeted floor, a technician can build up a static charge of sufficient voltage and energy (up to 5,000 volts on a typical capacitance of 200 picofarads) to destroy the gate oxide.

Gate-oxide rupture usually occurs between the gate metal and the underlying diffused region, rather than between gate and body of the device, since the diffused region has a higher conductivity than the channel region.

The gate-oxide rupture failure mode can be minimized by incorporating an input-protection circuit in the chip—a diode and resistor network, for example. Precautions against static charge build-up on personnel will help, too, of course.

Another major source of failure are defects in the oxide, chiefly pinholes; even with the recent improvements in oxide technology, pinholes still occur. Depending on the mask and etch sequence, the gate oxide under the gate metal overlap can contain a boundary between the SiO_2 thermally grown on n-type silicon and that grown on p-type silicon. This boundary arises from the difference in growth rates for oxide over n- and p-type sections. There is a greater chance for imperfections such as nonuniformity and inhomogeneity at this boundary, and these can start pinholes. A similar boundary occurs between old and new oxide—when oxide

Static stress. The large dark spot is where a rupture occurred, melting away part of the gate metal. This failure was caused by static charge on a test operator; actually the gate self-healed twice before the third jolt produced a permanent short between gate and substrate. Solution: proper handling and a protective zener-diode network on the chip. Electrical symptoms are a 1,000-to-2,000-ohm linear resistance on the gate lead and a soft reverse-diode breakdown of from 5 to 7 volts.
is regrown in an etched-out pit, for example—since
the growth rate of an oxide film already in place
is different from that of a fresh film.

Such boundary defects in the oxide come in a
spectrum of sizes—from a size large enough to
cause device failure at first test to smaller defects
that grow under stress to cause a failure after
prolonged testing or use.

Contamination is also a critical consideration at
these intra-oxide boundaries. Distribution of con-
tamination in SiO₂ grown over n silicon is different
from that over p silicon. The contamination con-
tent in that boundary or at the p-n junction
beneath the oxide can also lead to crystal-lattice
structures that cannot survive prolonged stress in
an electric field.

From another standpoint, oxide contamination
affects reliability because it affects the fabrication
process. Contaminated SiO₂ tends to etch faster
than the purer SiO₂, therefore the oxide layers
may be thinner than the time-of-etch calculations pre-
dict. This leads to a lower breakdown voltage than
the device is designed for.

To obtain a low threshold voltage, the gate oxide
is kept to minimum thickness, typically 1,000 to
2,000 Å. This is much less than for bipolar circuits.
Defects and contamination contribute far more to
irregularities in the oxide thickness and variations
in its insulating properties. And the severity of
these irregularities can be compounded by etching.

SiO₂ reacts with aluminum—the common inter-
connection metal—in the temperature range of 400°
to 500°C. The aluminum tends, at these high
temperatures, to be absorbed into the silicon dioxide
and the conductive pattern can actually disappear.
Circuits are not tested or operated in this tempera-
ture range, of course, but MOS devices are some-
times processed in this range and the reaction
could be initiated there. And even within the rated
operating temperature range, leakage currents
through small defects in the oxide can produce
local heating that could raise the temperature
enough for the Al-SiO₂ reaction to proceed at a
rapid rate, resulting in rupture of the oxide film.

This effect is serious because it’s an exponential
reaction; the more aluminum that’s absorbed, the
greater the leakage current. The increased leakage
sends the temperature climbing and the leakage
increases until it constitutes a short circuit—actually
an oxide rupture.

Aluminum migration can occur in bipolar IC’s,
too, but it’s far more serious in MOS circuits be-
cause of the critical function of the gate oxide.

How can all these sources of failure be detected
in finished IC’s? Threshold voltage and leakage
current are the two most dependable and conven-
tent parameters for monitoring or predicting device
reliability. Changes in these parameters can be
detected after only a few hours of operation, and
units that exhibit the changes nearly always fall.
Certainly, life-test data indicates burn-in is essen-
tial to eliminate operating failures.

At the chip level, the reliability problems are
about the same for both MOS and bipolar circuits.
The problems with the die mounting and bonding
also are not significantly different. However, there
is some difference in package problems. These re-
result from the new and unusual packages, with
many more leads, required for the complex MOS
microcircuits. Additional leads require more bonds
per package, additional area to be sealed with
less distance between leads, and smaller cross-
sectional area per lead. These requirements tend
to make the package more fragile.

Other MOS IC package failures are common to
the entire field of semiconductor devices: post-
processing surface contamination, contamination
migration during die attachment, and gas leaks in
the final package are among the most common.
And after the device has been successfully pack-
aged, it is still subject to failures during handling.

The tests and screens listed in the table
above were selected by NASA as the most effec-
tive for detecting and eliminating potential fail-
ures in MOS IC’s. These screens should cost about
the same per MOS package as for a bipolar
package. However, since most MOS microcircuits
have a higher functional density per package, the
screening cost per system of equal complexity
should be less for MOS than for bipolar.

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**Recommended screening sequence for MOS IC’s**

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Die inspection</td>
<td>200X minimum magnification</td>
</tr>
<tr>
<td>Precap inspection</td>
<td>40X minimum magnification</td>
</tr>
<tr>
<td>Temperature storage</td>
<td>Maximum temperature rating</td>
</tr>
<tr>
<td>Temperature cycle</td>
<td>10 cycles, −65° to +125° C</td>
</tr>
<tr>
<td>Constant acceleration</td>
<td>20,000 G</td>
</tr>
<tr>
<td>Electrical tests</td>
<td>Read and record critical parameters</td>
</tr>
<tr>
<td></td>
<td>at 25° C</td>
</tr>
<tr>
<td>Temperature and bias</td>
<td>Maximum temp. with circuit</td>
</tr>
<tr>
<td></td>
<td>back-biased for 24 hours</td>
</tr>
<tr>
<td>Electrical tests</td>
<td>Read and record go/no/go at 25° C</td>
</tr>
<tr>
<td>Burn in</td>
<td>Maximum temperature for 240 hours</td>
</tr>
<tr>
<td>Electrical Tests</td>
<td>Read and record critical parameters</td>
</tr>
<tr>
<td></td>
<td>Reject devices which exhibit</td>
</tr>
<tr>
<td></td>
<td>parameter drift greater than:</td>
</tr>
<tr>
<td></td>
<td>1. Logic level ±10%</td>
</tr>
<tr>
<td></td>
<td>2. Leakage current</td>
</tr>
<tr>
<td></td>
<td>(a) low logic levels +10</td>
</tr>
<tr>
<td></td>
<td>times initial</td>
</tr>
<tr>
<td></td>
<td>(b) High logic levels +20%</td>
</tr>
<tr>
<td>Hermetic seal</td>
<td>Fine and gross</td>
</tr>
<tr>
<td>Radiographic inspection</td>
<td></td>
</tr>
</tbody>
</table>

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*Electronics | June 23, 1969*
July
Conference on Nuclear & Space Radiation Effects
July 7-11
Pennsylvania State University

Engineering in Medicine & Biology & International Federation for Medical & Biological Engineering Conference
July 20-25
Palmer House, Chicago

August
Western Electronic Show & Convention (Wescon)
August 19-22
Cow Palace & San Francisco Hilton Hotel, San Francisco

September
Broadcasting Symposium
September 18-20
Mayflower Hotel, Washington

International Telemetering Conference & Exhibition
September 15-17
Sheraton Park Hotel, Washington

At Wescon, Electronics brings you a free-wheeling dialogue between vendors and users on circuit/system interface—Aug. 19
Fall Joint Computer Conference
November 18-20

Does a good conference have to be dull? The FJCC program committee doesn't think so. It's arranging a prize—in addition to the usual one for best paper—for the best presentation and will hold seminars around the U.S. to aid authors. At the conference, videotapes will be made for later viewing by judges. The prize will be awarded next year—perhaps at the Spring Joint Computer Conference. Although something similar was attempted at this year's SJCC in May, videotapes are a definite escalation. The theme of the conference is "Threshold of the 70's:" papers will describe how the revolutionary concepts of the past 10 years will be implemented and extended during the next 10.

For more information: Eugene Crabbe, TRW Systems, Building R3, Room 2070, 1 Space Park, Redondo Beach, Calif. 90278

Conference on Magnetism and Magnetic Materials
November 18-21

The program committee has asked for papers on basic topics relating to magnetism—experimental and theoretical work, new magnetic materials, and peripheral areas in which magnetics play a major role. And basic or not, there's much of interest to be reported. Interdisciplinary papers will be welcomed—for example, on the applications of magnetics in medicine, geology, or even archeology. New magnetic evidence was recently reported that supports the theory of continental drift; the site of an ancient city was found by measuring minute anomalies in the earth's magnetic field.

For more information: J.D. Blades, Franklin Institute Research Laboratories, Philadelphia, Pa. 19103

National Electronics Conference
December 8-10

For early Christmas shoppers, there will be a product exhibit. In addition, a broad range of subjects in communications technology, IC designs, electronic switching systems, computer applications, instrumentation, and consumer electronics will be discussed at the technical sessions.

For more information: National Electronics Conference, Oak Brook Exec. Plaza #2, 1121 W. 22 St., Oak Brook, Ill. 60521
Conferences: July-December

**October**

- Joint Conference on Mathematical & Computer Aids to Design
  October 26-30
  Disneyland Hotel, Anaheim

- Electronic & Aerospace Systems Convention (Eascon)
  October 27-29
  Sheraton Park Hotel, Washington

- Instrument Society of America Conference & Exhibit
  October 27-30
  Astrohall, Houston

- International Electron Devices Meeting
  October 29-31
  Sheraton Park Hotel, Washington

**November**

- Northeast Electronics Research & Engineering Meeting (Nerem)
  November 5-7
  Sheraton Boston Hotel, Boston

- Fall Joint Computer Conference
  November 18-20
  Convention Center, Las Vegas

- Conference on Magnetism and Magnetic Materials
  November 18-21
  Benjamin Franklin Hotel, Philadelphia

**December**

- National Electronic Conference
  December 8-10
  Conrad Hilton Hotel, Chicago

- International Symposium on Circuit Theory
  December 8-10
  Mark Hopkins Hotel, San Francisco
Conference on Nuclear & Space Radiation Effects
July 7-11
This specialized meeting deals with hot stuff—radiation exposure. It will warm up to such subjects as displacement effects produced by neutrons, gamma rays, charged particles, and surface effects.
For more information: E.A. Burke, Air Force Cambridge Research Laboratory, Hanscom Field, Bedford, Mass.

Western Electronic Show & Convention (Wescon)
August 19-22
It's the turn of Baghdad by the Bay to play host as Wescon, which alternates annually between Los Angeles and San Francisco, heads north. There will be 625 company exhibits, 100 papers in 23 sessions, and a session sponsored by Electronics magazine on the circuit/systems interface problem. With IC's due to hog the spotlight, the peninsula will buzz with talk of spider and beam-lead technology, the potential of MOS, and the design of high-power circuits. Add to that computer-aided design, time sharing, and university tv networks—not to mention a session on the problems of starting a business — and you have a typically eclectic Wescon.
For more information: Wescon Office, 3600 Wilshire Boulevard, Los Angeles, Calif. 90005

Joint Conference on Mathematical & Computer Aids to Design
October 26-30
A new stop on the circuit, this conference was created by three scientific and engineering societies. In addition to contributed papers, the program committee plans a series on invited papers on such topics as relevant mathematics and numerical analysis; computer science — graphics, man-machine interaction, and formula manipulation; large-scale systems—urban and utility; and special topics in design — holo-graphy, optics, high-energy physics, and aerodynamics.
For more information: J.F. Traub, Bell Telephone Laboratories, Mountain Avenue, Murray Hill, N.J.

Electronic & Aerospace Systems Convention (Eascon)
October 27-29
You'd expect the military and space to get most of the attention, and you won't be disappointed. But the conference is also going to look at the role of technology in the problems of our time. There will be papers on earth resources exploration by satellite and aircraft, aircraft navigation and landing systems, pattern recognition, urban problems and aerospace technology, terrestrial and satellite communication and navigation systems, coding and signal processing, and lunar exploration.
For more information: Atalla, Hewlett-Associates, 1500 Page Mill Road, Palo Alto, Calif.

Calendar on request

Northeast Electric Research & Engineering Meeting (Nerem)
November 5-7
A big one for the Northeast, the Nerem will prob ably cover almost every aspect of electronics, from computer-aided design, computer research and development, solid state electronics, and integrated circuits to radar, system design, energy conversion, and many others.
Better safe operating area.*
Rugged reliability.*
Lower lead inductance.*

<table>
<thead>
<tr>
<th>Type #</th>
<th>$V_{CC}$</th>
<th>$P_{out}$ (W) @ f (MHz)</th>
<th>$G_{PE}$ (dB) (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2N5589</td>
<td></td>
<td>3.0 @ 175</td>
<td>8.2</td>
</tr>
<tr>
<td>2N5590</td>
<td>13.6V</td>
<td>10.0 @ 175</td>
<td>5.2</td>
</tr>
<tr>
<td>2N5591</td>
<td></td>
<td>25.0 @ 175</td>
<td>4.4</td>
</tr>
<tr>
<td>2N5635</td>
<td></td>
<td>2.5 @ 400</td>
<td>6.2</td>
</tr>
<tr>
<td>2N5636</td>
<td>28V</td>
<td>7.5 @ 400</td>
<td>5.7</td>
</tr>
<tr>
<td>2N5637</td>
<td></td>
<td>20.0 @ 400</td>
<td>4.6</td>
</tr>
<tr>
<td>2N5641</td>
<td></td>
<td>7.0 @ 175</td>
<td>8.4</td>
</tr>
<tr>
<td>2N5642</td>
<td>28V</td>
<td>20.0 @ 175</td>
<td>8.2</td>
</tr>
<tr>
<td>2N5643</td>
<td></td>
<td>40.0 @ 175</td>
<td>7.6</td>
</tr>
</tbody>
</table>

-balanced emitter transistors in Ceramic Stripline cases.

The broad range of output power at VHF/UHF frequencies for both 12V and 28V designs qualifies these devices for a large variety of AM/FM commercial, industrial, and military applications. Prices are lower, too, as much as 30% less than previous BET transistors in 100-up quantities.

The same concern for versatility and breadth of line shown in these new RF power introductions is also evident in Motorola's complete line of RF transistors, including a full range of small signal low noise and oscillator devices for an equally wide variety of applications.

Detailed new data sheets for the nine types listed here are available for prompt response to your inquiry. Information on any Motorola RF transistor is available from your Motorola distributor or sales office.

That's Motorola's 2N5641 RF Power Transistor.
And the 2N5641 is just one of nine new RF power types that offer the combined benefits of BET‡

‡Trademark of Motorola Inc.

-where the priceless ingredient is care! -

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Silicon RF Transistors

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Electronics | June 23, 1969
Common-mode rejection ratio:
what the spec sheet doesn’t say

Some critical assumptions, that aren’t always true,
lurk behind test circuits recommended by amplifier makers

By Frederick Gans
IC Metrics Inc., Oceanport, N.J.

"The common-mode rejection ratio is so many decibels; here's a test circuit if you want to check it out yourself." This seems to be what makers of differential amplifiers are saying on their spec sheets. Rarely does a maker tell how the ratio varies with power-supply voltage, temperature or other parameters. And rarely does he explain how he designed his test circuit, tell what its limitations are, and show how large an error the use of a typical recommended circuit can cause.

For his test circuit, the amplifier maker derives the equation for calculating rejection ratio by assuming that a certain relationship exists between circuit and amplifier resistances. But this relationship doesn't necessarily exist, so using it to calculate an amplifier's rejection ratio usually gives an inaccurate result. What's worse, the user has no way of calculating or measuring how inaccurate it is.

A better way to find the common-mode rejection ratio is to measure the common-mode gain and divide it into the differential gain.

Ideally, a differential amplifier responds only to the difference between the voltages at its input terminals

$$e_o = (e_1 - e_2) A_d$$

where $e_1$, $e_2$ are the input voltages, $e_o$ the output voltage, and $A_d$ the differential voltage gain.

But to some degree, all differential amplifiers are responsive also to the magnitude of the inputs. So in real life

$$e_o = (e_1 - e_2) A_d + \left( \frac{e_1 + e_2}{2} \right) A_c$$

Note that the second term on the right defines the error. The voltage $(e_1 + e_2)/2$ is the common-mode voltage, and $A_c$ is the common-mode gain. The ratio of $A_d$ to $A_c$ is the common-mode rejection ratio, $CM_{rr}$.

The circuit to the right is typical of those recommended by differential-amplifier makers for measuring $CM_{rr}$. According to this amplifier's spec sheet, a differential amplifier's $CM_{rr}$ is

$$CM_{rr} = \frac{R_t e_s}{R_o e_o}$$

where $e_s$ is the input to the test circuit, $e_o$ is the output, and $R_t$ and $R_o$ are resistances in the test circuit, as shown in the figure.

But using this relationship can lead to serious errors. How does the maker get this relationship? His first step is to assume that the input impedances at the amplifier’s inverting and noninverting terminals are equal, normally a valid assumption. Then he writes $e_1$ and $e_2$ in terms of $e_s$ and $e_o$.

$$e_1 = K_1 e_s - K_2 e_o$$

$$e_2 = K_3 e_s$$

where $K_1$, $K_2$, and $K_3$ are impedance-dependent terms, defined on page 118. Using these two equations and the equation for $e_s$ in terms of $A_d$ and $A_c$ he draws a signal flow diagram, and uses it to derive the test circuit’s transfer function.

To here, there has been only one approximation, equal input impedances. Now he makes some more. $A_d$ is usually 100,000 times larger than $A_c$ so the term $\frac{1}{2} A_c$ in the transfer function can go. And $A_d$ is always higher than 1,000 so when $K_2$ is equal to or greater than 0.1, dropping the 1 from the denominator of the transfer function introduces an error.
The maker's way. To measure common-mode rejection ratio, CMrr, one amplifier manufacturer recommends using the circuit on the left along with the equation under it. This relation comes from first writing three independent equations; two are network equations and the third a characteristic equation of the amplifier. (K1, K2, and K3 are the coefficients whose values are given in the panel, A_c is the amplifier's common-mode gain, and A_d is its differential gain.) From these equations a signal flow diagram is drawn out of which comes the circuit's transfer function. When certain assumptions, not always valid, are made, the transfer function is reduced to the equation for CMrr.

no greater than 1%. After these two approximations are made the transfer function is

\[ \frac{e_o}{e_s} = \frac{(K_1 - K_3)A_d + \frac{1}{2}(K_1 + K_3)A_c}{1 + (A_d + \frac{1}{2}A_c)K_2} \]

which is still a very accurate representation.

To finally get the equation

\[ CM_{rr} = \frac{R_f e_s}{R_s e_o} \]

the maker assumes that

\[ K_1 = K_3 \quad \text{and} \quad \frac{K_2}{K_3} = \frac{R_f}{R_s} \]

Here's where trouble comes in. Making the second approximation won't introduce much error but what is the effect of assuming \( K_1 \) and \( K_3 \) are equal?

Let's examine the approximation more closely. Instead of dropping \( (K_1 - K_3) \), use the relationship

\[ K_1 + K_3 = 2K_3 \]

which also says that \( K_1 \) equals \( K_3 \), but allows the carrying along of the difference term. Then

\[ \frac{e_o}{e_s} = \frac{R_f}{R_s} \left[ \left( K_1 \frac{K_3}{K_3} - 1 \right) + \frac{A_c}{A_d} \right] \]
The coefficients

\[
K_1 = \left( \frac{R_s + (R_t + Z_o) Z_i}{R_s + (R_t + Z_o) Z_i} \right) \frac{(R_t + Z_o) Z_i}{R_t + Z_o + Z_i}
\]

\[
K_2 = \left( \frac{R_t Z_i}{R_t + Z_i} \right) \frac{R_s Z_i}{R_s + Z_i}
\]

\[
K_3 = \left( \frac{R_t Z_i}{R_t + Z_i} \right) \frac{R_s R_t Z_i}{R_s + Z_i}
\]

where \(Z_i\) and \(Z_o\) are the amplifier's input and output impedances, and \(R_t\) and \(R_s\) are resistances in the test circuit.

\[
\frac{R_s e_o}{R_t e_s} = \left( \frac{K_1}{K_3} - 1 \right) + \frac{1}{CM_{rr}}
\]

So to find out how valid is the assumption that \(K_1\) is exactly equal to \(K_2\), evaluate

\[
\left( \frac{K_1}{K_3} - 1 \right)
\]

and compare it with \(A_c/A_3\).

If the test circuit has 1% resistors, the most that each of the sets of matched resistors—the \(R_t\)'s and the \(R_s\)'s—can be mismatched is by 2%. So, from the definitions of \(K_1\) and \(K_3\) in the panel, the result of a 2% mismatch is

\[
K_1 = \frac{(R_t + Z_o) Z_i}{1.02 R_s (R_t + Z_o + Z_i) + (R_t + Z_o) Z_i}
\]

\[
K_3 = \frac{1.02 R_t Z_i}{R_s (1.02 R_t + Z_i) + 1.02 R_t Z_1}
\]

where \(Z_i\) and \(Z_o\) are the amplifier's input and output impedances.

To further simplify things, choose \(R_t\) and \(R_s\) so that \(R_t = Z_i/10\) and \(R_s = Z_i/100\).

Then

\[
K_1 = \left[ \frac{0.1 (Z_i)}{Z_o} + 1 \right] \left( \frac{0.11302}{0.11122} \frac{Z_i}{Z_o} + 1.0102 \right)
\]

If \(Z_o\) is assumed to be 0, then \((Z_i/Z_o)\) approaches infinity. Therefore

\[
\lim_{(Z_i/Z_o) \to \infty} \frac{K_1}{K_3} = \left( \frac{0.1}{0.11122} \frac{0.11302}{0.102} \right)
\]

\[
= 0.996262
\]

So

\[
\left( \frac{K_1}{K_3} - 1 \right) = -37.3 \times 10^{-4}
\]

A typical spec-sheet value of \(CM_{rr}\) is 80 decibels, or \(10^4\). So when the resistance mismatch of the test circuit is 2%, and when \(Z_o\) is 0, then

\[
(K_1/K_3) - 1 = -37.3 \times 10^{-4}
\]

Now

\[
\frac{1}{CM_{rr}} = 10^{-4}
\]

So in this example, the term,

\[
\left( \frac{K_1}{K_3} - 1 \right)
\]

which is dropped to obtain the simplified expression for \(e_o\) is 37.3 times larger than \(A_c/A_3\), the term that's kept in the equation.

Equating K's

So only when \(K_1\) equals \(K_2\) does the test circuit measure \(CM_{rr}\) accurately. But the user has no way of knowing how close in value \(K_1\) and \(K_3\) are.

Trying to equate these two K's by measuring \(e_1\) and \(e_o\), and then adjusting one of the \(R_s\)'s to make those voltages equal is futile since \((e_1 - e_2)\) is in the low-microvolt or nanovolt region.

Another way could be to make adjustments in the circuit and observe the output. When \(K_1\) equals \(K_3\), \(e_o\) has some specific value. Unfortunately, it's impossible to determine what this value is.

This can be seen by letting

\[
e_o = \sin \omega t
\]

in the equation

\[
\frac{R_s e_o}{R_t e_s} = \left( \frac{K_1}{K_3} - 1 \right) + \frac{1}{CM_{rr}}
\]

then

\[
\frac{R_s}{R_t} e_o = \left( \frac{K_1}{K_3} - 1 \right) \sin \omega t + \frac{1}{CM_{rr}} \sin \omega t
\]

The second term on the right side is in phase with \(e_o\) and the first term is either in phase or 180° out, depending on whether \(K_1\) is larger than \(K_3\).

When \(K_1\) is larger, the magnitude of \(e_o\) is some large value. As \(K_1\) decreases, \(e_o\)'s magnitude decreases. When \(K_1\) equals \(K_3\), \(e_o\)'s magnitude is still
Measuring $A_c$

**FLOATING-BIAS SUPPLY**

```
<table>
<thead>
<tr>
<th>COARSE CONTROL</th>
<th>FINE CONTROL</th>
</tr>
</thead>
<tbody>
<tr>
<td>47</td>
<td>100</td>
</tr>
<tr>
<td>500</td>
<td></td>
</tr>
</tbody>
</table>
```

How to measure common-mode voltage gain, $A_c$

$$A_c = \frac{E_{o1} - E_{o2}}{\Delta V}$$

1. Set $V$ to 0, and use the controls of the bias supply to set $E_c$ to 0.
2. Set $V$ to the negative limit of the amplifier's common-mode input range, and measure the output, $E_{o}$.
3. Set $V$ to the positive limit of the common mode input range, and measure the output $E_{op}$.
4. $\Delta V$ is the difference between the positive and negative limits of the common-mode input range.
5. Calculate $A_c$.

There are several popular ways to measure $A_d$, but ways to measure $A_c$ aren't that well known. Here's one good approach.

The definition of $A_c$ is

$$A_c = \frac{e_o}{e_c}$$

where $e_c$ is a voltage applied simultaneously to the amplifier's input terminals.

The simplest way to simultaneously apply a voltage to the input terminals is to tie the input terminals together and connect them directly to a d-c supply. However, shorting the inputs together like this isn't the most accurate solution because the offset voltage at the inputs multiplied by $A_d$ may drive the d-c output off the linear region of the amplifier's input-output curve. Instead of being shorted directly, the inputs should be shorted through a floating bias supply of low impedance, such as the one shown in the panel above, along with the steps for measuring $A_c$.

This figure shows only the amplifier's input and output connections. Not in the figure are the power supply, bypass capacitors, and frequency-compensation networks that must be connected to the amplifier, as specified by its manufacturer. ■

greater than zero. As $K_1$ continues to decrease, $e_o$'s magnitude hits zero and then starts to increase. But the user has no way of separating the two sine waves that make up $e_o$, so he has no way of telling when the coefficient of the first term on the right side is zero.

Also complicating things is the presence of stray capacitance in the test circuit and in the amplifier. When $K_1$, $K_2$, and $K_3$ have reactive components, the term

$$\left( \frac{K_1}{K_2} - 1 \right) \sin \omega t$$

is phase shifted relative to

$$\frac{1}{C_{Mrr}} \sin \omega t.$$

The result of this shifting is that $e_o$'s magnitude may not even be a very low value when $K_1$ equals $K_3$.

Get the gain

The best way to measure an amplifier's common-mode rejection ratio is to find its common-mode gain first, and then divide $A_c$ into the differential gain, $A_d$. 
Listening in. Complex interfaces characterize a satellite communications earth station like this Sylvania-designed installation in Thailand. Implementation requires a well-integrated team of systems engineers.

Systems engineering

Computer simulation plays key role in design of satellite earth stations

Systems approach offers solution to complex politico-technical interface problems in ground terminals of global communications network

By Lee B. Zahalka

If you're going to build a complex system in the face of inhibiting constraints, do it with systems engineering. Few engineers know this lesson better than the designer of satellite ground stations, who has had to contend with tough transmitter-receiver problems that are tied to stiff international standards regulating the compatibility of earth terminals with the global communications system.

Working as a systems engineer, the designer undertakes the total and continuous planning of his station, and relies heavily on computer simulation techniques while using tradeoff and cost effectiveness methods.

Technologically, ground station design has its complexities. Each station must be designed to withstand extreme local temperatures, winds, and humidity; and each must be worked out in the light of such atmospheric factors as attenuation.

However, the major challenge comes from the fact that each station is a participant and a contributor in a world-wide network shared and operated by a host of countries. The trick is therefore to fit the complicated technology into the context of multinational needs as embodied in the interface requirements between the satellite and earth stations. These requirements have been set down by the Interim Communications Satellite Committee (ICSC). Only an orderly, systematic approach—
**Intelsat 3 transmission parameters**

<table>
<thead>
<tr>
<th>Carrier capacity No. channels</th>
<th>24</th>
<th>60</th>
<th>132</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom baseband frequency khz</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Top baseband frequency khz</td>
<td>108</td>
<td>252</td>
<td>552</td>
</tr>
<tr>
<td>Zero dbm test-tone deviation khz</td>
<td>250</td>
<td>410</td>
<td>630</td>
</tr>
<tr>
<td>Multichannel rms deviation</td>
<td>420</td>
<td>830</td>
<td>1,490</td>
</tr>
<tr>
<td>Occupied bandwidth Mhz</td>
<td>4.0</td>
<td>8.0</td>
<td>14.4</td>
</tr>
<tr>
<td>Carrier-to-noise dbw/K</td>
<td>-154.8</td>
<td>-151.3</td>
<td>-148.5</td>
</tr>
<tr>
<td>temp. at operating point</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Television transmission parameters**

<table>
<thead>
<tr>
<th>Satellite bandwidth allocation, Mhz</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiver bandwidth, Mhz</td>
<td>25</td>
</tr>
<tr>
<td>G/T total at operating point, dbw/K</td>
<td>-142</td>
</tr>
<tr>
<td>American</td>
<td></td>
</tr>
<tr>
<td>Foreign</td>
<td></td>
</tr>
<tr>
<td>Television standard (lines/frames per sec)</td>
<td>525/60</td>
</tr>
<tr>
<td>Maximum video bandwidth, Mhz</td>
<td>4.2</td>
</tr>
<tr>
<td>Peak to peak deviation, Mhz (15 khz test signal)</td>
<td>9.4</td>
</tr>
</tbody>
</table>

**Transmitting power for operational satellites**

**Intelsat 2**
- Per voice channel
  - 68 dbw
- Television video
  - 90-95 dbw

**Intelsat 3**
- Per voice channel
  - 61 dbw
- Television video
  - 86 dbw

systems engineering—can deal effectively with the demands of such a technical-political entity.

The specification, which the designer gets from the contracting country, is normally generated by the Communications Satellite Corp. (Comsat), which acts as the ICSC’s manager. Spelled out in the specification are the functional requirements of the station based on the country’s communications needs and ICSC’s inter-face standards. The designer’s job is then to translate this order into an equipment specification.

As the global civilian network now stands, the International Telecommunications Consortium (Intelsat) owns and operates the satellites. There are now six Intelsat satellites in synchronous equatorial orbits working with 20 ground stations. Another 50 ground stations are either under construction or being planned. Of the Intelsat 3, latest of the satellite series, there are two aloft, one over the Atlantic Ocean and the other over the Pacific. Launching of a third one scheduled the end of May for a position over the Pacific Ocean is to be followed by moving the earlier Pacific-Ocean satellite to a position over the Indian Ocean. The Intelsat 3 series has a 1,200 two-way voice channel capacity, five times that of the Intelsat 2 series.

Whether owned privately or by the contracting country, the earth stations must comply with ICSC rules on compatibility. These are contained in ICSC document 37-38 E, “Performance Characteristics of Earth Stations,” and deal primarily with signal-to-noise performance as advised by the International Radio Consultative Committee (CCIR). Certain requirements must be met before an earth station can be admitted to the global system: for example, transmitting power and receiving sensitivity are dictated by the ICSC.

Transmission requirements, specified in terms of effective isotropic radiated power for satellites now in operation, are listed in the tables adjacent. The power ranges indicated for television accommodate both monochrome and high quality color transmission.

Receiving sensitivity is specified in terms of the ratio of antenna gain to noise temperature \( G/T \) in decibels per degree Kelvin. The minimum requirement is \( G/T = 40.7 + 20 \log F/4 \) \( \text{db/K} \) where \( F \) is a frequency between 3.7 and 4.2 gigahertz, the limits of the bandwidth allocated for satellite receiving use, at antenna elevation angles of 50°.

For Intelsat 3, other major transmission parameters including television data are listed in the adjacent tables.

The components of a typical earth station are shown in the block diagram shown above. The high-efficiency antenna is typically a 30-meter Cassegrain dish driven by a servo for automatic pointing and tracking. Also located at the antenna...
**System program.** Three basic routines form the computer model, used to determine the performance of a proposed earth station or satellite, by exercising the inputs shown under various environmental conditions. Up-link, down-link, or the system's characteristics can be analyzed as desired.

facility is the cryogenic preamplifier, which provides a receiving temperature of about 20°K and a corresponding noise figure of 0.3 db. The preamplifier has a 500 megahertz instantaneous bandwidth. The remaining equipment in the facility is a high-power amplifier that provides transmission output at the kilowatt level.

In the control facility, the transmission equipment makes the required frequency conversions and provides the necessary gain for signals to and from the modem, a frequency modulation unit similar to those used in microwave relays. The multiplex unit accepts baseband signals from one or a number of terrestrial networks and formats them for transmission on a frequency division basis.

The station's tracking receiver is a conventional phase-locked monopulse unit. Equipment for the station's control functions is located centrally.

**Global switchboarding**

While it is well within the state of the art, earth station design is not as simple as it might at first appear. The multiple destination nature of global communications places it in sharp contrast with conventional microwave relay systems. Multiple signal carriers are required for disseminating many different messages to different places.

To transmit information to the satellite, each station has a distinct carrier frequency within the allocated 5.925 Ghz to 6.425 Ghz band. Then the satellite receives signals in this range and retransmits them at a carrier between 3.7 Ghz and 4.2 Ghz, shifting the carrier downward by 2.225 Ghz.

A typical earth station is equipped to transmit carriers for television video, television programs, voice messages, and data traffic. The receiving equipment must accommodate not only the tv video and program carriers but also the transmitted carriers for each country in the network. This may require from eight to twelve receivers and demodulators in addition to the tv equipment.

As the requirements for routing hundreds of two-voice channels begin to unfold, the designer begins to see the formidable switching task before him. A large part of his efforts must be devoted to integrating the diverse equipment available into a smoothly functioning system.

**Path to optimization**

As in other systems, the computer plays a major role in the design stage, permitting detailed investigation of problems that affect system performance, and leading to optimization. Parameters of models representing the station are fed to the computer and optimized for a simulated solution, thus forecasting how the actual system will operate.

Beforehand optimization is important because it takes into account many performance measurements that simply cannot be adjusted after the system is built.

Earth-station design problems can be broken down for computer analysis. The system's performance is determined by the available signal levels and by the effects of distortion due to thermal noise and nonlinearities of amplitude and phase. Generally, the factors of greatest interest are the up-link and down-link signals, and the distortion parameters at the satellite input and the earth station. These factors are all subject to identical computer techniques. The complete communications link can be simulated by iteration.

The computer flow process at Sylvania is subdivided into three basic routines: antenna, interference and f-m link as shown. Each one has many subroutines but only generalized input-output parameters are considered here, to identify the information flow. The appropriate input parameters are selected depending on whether up-link or down-link computations are desired. The system's characteristics are analyzed by looping the outputs for the up-link conditions back through the route.

To show how the antenna's gain, temperature,
Subsystem program. Antenna subsystem routine operates on input phase and amplitude data obtained from source feed patterns and produces design information that permits the system engineer to optimize on the basis of best gain-temperature ratio.

**Antenna G/T calculation for 97-ft. reflector at 90° elevation angle**

<table>
<thead>
<tr>
<th>Feed data</th>
<th>Strut data</th>
<th>Gain calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>4.0 GHz</td>
<td>Maximum directive gain.................. 61.86 db</td>
</tr>
<tr>
<td>Subreflector angle</td>
<td>19°</td>
<td>Spillover efficiency.................... -0.57 db</td>
</tr>
<tr>
<td>Type</td>
<td>Polyrod</td>
<td>Spar plane wave blockage eff........... -0.03 db</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spar spherical wave blockage eff....... -0.12 db</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rear spillover eff...................... -0.01 db</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Subreflector blockage eff.............. -0.11 db</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Phase eff................................ -0.02 db</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Surface tolerance eff................... -0.19 db</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cross-polarization eff.................. -0.09 db</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aperature eff........................... -0.09 db</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Net directive gain...................... 60.60 db</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VSWR eff................................ -0.03 db</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resistive eff........................... -0.15 db</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Net gain at reference flange........... 60.42 db</td>
</tr>
</tbody>
</table>

Temperature calculations:
- Main beam: 4.20°K
- Spillover-subreflector: 1.05°K
- Blocking-strut, plane: 0.06°K
- Blocking-strut, spherical: 1.48°K
- Spillover-main dish: 0.41°K
- Blocking-subreflector: 0.14°K
- Phase center: 0.02°K
- Surface tolerance: 0.24°K
- Cross-polarization: 0.11°K
- Total: 7.75°K
- Noise temperature at flange: 19.71°K
- Receiver noise temperature: 16.00°K
- System noise temperature: 35.71°K
- System G/T at 90° elevation angle = 44.89 db

and G/T are derived, consider the flow diagram above. The antenna routine is associated with seven main programs:
- Feed efficiency
- Shaping
- Strut blockage
- Scattering
- Brightness temperature
- Antenna efficiency
- System G/T

Each program can provide discrete outputs so that any design element in the chain can be optimized: for example, the feed efficiency program provides information on pattern integration of the measured phase and amplitude characteristics.

The main inputs to the antenna routine are the measured source feed phase and amplitude data. These are processed by the shaping program whose output yields the reflector geometry needed to provide the desired illumination function across the
Field pattern deviation

To determine the system's temperature in a satellite communications earth station, the deviation from the design ideal of the antenna's energy distribution pattern must be accounted for in the model. Listed here are the major factors affecting the antenna field pattern which are built into Sylvania's energy distribution model.

- **Subreflector blockage.** Energy intercepted by the antenna subreflector is scattered back into the main reflector and concentrated into a solid angle near the main beam. The average sky brightness included in the solid angle is essentially in the direction of the main beam.

- **Phase errors.** Nonspherical wave fronts or reflector surface imperfections cause a slight but perceptible broadening of the antenna's main beam. The resulting radiation pattern can be resolved into an unperturbed main beam with slightly reduced amplitude, and into a superimposed pattern produced by the removed energy and concentrated in a region near the main beam. The average sky brightness that must be accounted for is again in the direction of the main beam.

- **Subreflector spillover.** Some of the energy radiating from the source feed misses the subreflector and spills out over the sides. The distribution of this spillover energy is derived from the measured feed patterns, weighted by the prevailing brightness temperature. This calculation neglects the small fraction of energy diffracted by the subreflector in the main lobe regions.

- **Diffraction losses.** Diffraction of some of the energy reflected from the subreflector surface spills over to the rear of the main reflector. The model assumes that this waste energy is contained within a region bounded by the edge of the main reflector and a plane perpendicular to the antenna beam axis. The energy density within this volume is assumed to be uniform (see sketch).

- **Subreflector support blockage.** Two additional effects are introduced by the presence of the subreflector support struts. In the transmitting mode, part of the energy contained in the spherical wavefront radiating from the virtual feed is intercepted by the struts before reaching the main reflector, producing a "shadowing" effect. The spherical wave component is scattered back into the dish by reflection. If the strut is circular in cross section, the reflected energy behaves as though radiated from a circular source whose circumference runs through the focal point in the plane normal to the strut.

The resulting far-field pattern is that of a defocused circular source with a maximum intensity following a conic pattern determined by the specific antenna geometry.

Plane wave components reflected from the main reflector are also intercepted by the struts. These too are scattered off the support in a pattern with maximum intensity following a conical geometry, as shown in the sketch.

These energy distributions, suitably weighted by the temperature model, are used to calculate the antenna temperature, and when combined with the dissipative losses, receiver temperature, and various other contributions, produce the system temperature.

main reflector, suitably compensated for phase errors. The illumination function may be selected on the basis of various criteria—maximum gain, minimum temperature, or maximum G/T—by iterating the steps in the program.

The source feed pattern and sub-reflector data are then fed to the scattering program, which provides the virtual feed pattern, consisting of the radiation characteristics of an equivalent radiator at the focal point of the main reflector. The virtual feed radiation pattern and the nominal phase data from the shaping program are inputted to the antenna efficiency program, an integration routine producing subreflector spillover, diffraction, illumination, and cross-polarization efficiencies. These factors, used to determine antenna gain, are combined with the output of the strut blockage program and data from other routines including wave blockage efficiencies, measurement of voltage standing-wave ratio, and dissipative losses. The combination of all these factors is finally fed to the system G/T program from which antenna gain and
temperature are obtained. The temperature, incidentally, can also be calculated from the angular density distribution of the radiation pattern, which is provided with each efficiency factor.

**Simplified model**

The key to the system G/T model program is the energy distribution model. While it is a relatively easy job to calculate the energy removed from the main beam of a radiating aperture by the presence of the imperfect subreflector surface and its support struts, it is a formidable task to determine the precise distribution of the scattered energy over 4π steradians with the proper polarization. Accordingly, a simplified model has been established and validated by field tests to expedite calculations. Intermediate solutions permit tradeoff studies to be made on individual design elements without exercising all the antenna subsystem routines each time.

Output format for the system G/T program is shown in the tabulation on page 123. First, all input elements such as antenna geometry, support strut geometry, type of source feed, frequency, elevation angle, and receiver are identified. Next efficiency factors that degrade the maximum directive gain for the antenna under study are listed with the temperature contribution. The specific data in this example is for a 90° elevation angle.

The computer output provides useful insight into how various design parameters interact. For example, comparing the main beam temperature contribution of 4.2°K with that of the sky brightness at zenith of 5.5°K shows that 76.3% of the total available sky noise is intercepted by the main beam. The total antenna temperature, calculated to be 7.75°K at the aperture, shows that spillover is responsible for an increase in temperature of 2.25°K over that of an ideal antenna, or an overall efficiency of 71% at the aperture.

The fact that different aperture efficiencies can be derived, depending on whether gain of temperature is being considered, clearly shows the danger of under-optimization. Any antenna can be optimized with respect to gain and still have poor temperature characteristics, and vice versa.

**Sensitivity coefficients**

The G/T program finds its major applications in sensitivity studies for the various antenna design elements. This is accomplished by establishing what are called sensitivity coefficients for specific operating points, antenna geometries, and elevation angles. Analyses of these are very useful in determining the effectiveness and priorities of design improvements.

As an example, assume that a particular antenna has the following coefficients at an elevation angle of 0.5°.

- Dissipation loss 5 db
- Spillover loss 1.8 db
- Diffraction loss 1.8 db
- Strut blockage loss 2.4 db
- All others 1 db

These figures represent changes in the gain-tem-
Money talks. System optimization diagram shows relationships between performance, schedule, operational factors and cost. Ultimate test of system engineer's judgment in making these tradeoffs is whether or not his efforts paid off in a contract award.

<table>
<thead>
<tr>
<th>RELATIVE IMPORTANCE FACTORS</th>
<th>RELATIVE COST FACTORS</th>
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<tr>
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<td>RELIABILITY</td>
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<tr>
<td>MAINTENANCE</td>
<td>COST-IMPORTANCE TRADE OFF</td>
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</tbody>
</table>

Temperature ratio achieved by corresponding changes in the tabulated parameters. An improvement of 0.1 db in dissipative loss, for example, improve the G/T by 0.5 db. From the table it can be seen that the best performance payoff can be achieved by improving dissipative loss, strut blockage, spill-over, and diffraction in that order, while little improvement can be derived from refining other parameters.

**Receiver location**

The high-sensitivity coefficient of strut blockage offers an excellent tradeoff opportunity. Traditionally, the subreflector supports have always been considered part of the mechanical design rather than part of the radio-frequency geometry. However, the G/T program for various strut angles shows a significant effect on antenna gain. The plot seen on page 125 illustrates the loss in gain due to spherical and plane wave components. A region clearly exists where spherical wave losses decrease much more rapidly than plane wave losses increase, indicating that struts placed at large angles relative to the antenna r-f axis are desirable. While it is difficult to pinpoint the condition for minimum loss on the total blockage curve, the plot indicates that strut angles of 45° or more will keep the loss to within 0.1 db of the minimum loss case. The minimum loss takes place when the struts are extended to the rim of the main reflector—a design that is difficult to achieve mechanically in large earth-station antennas.

Still another design tradeoff is required in the location of the cryogenic receiver. Because receivers of this type require periodic maintenance, they must be readily accessible. The ideal location for the receiver is behind the main reflector. The antenna's r-f geometry is normally determined by matching the radiation characteristics of the source feed with the appropriate subreflector diameter and feed location. A standard rule of thumb is to have the subreflector's diameter about 10% that of the main dish. In practice, the source feed usually gets placed well in front of the main reflector. The designer then has the choice of connecting the source feed to the cryogenic receiver by a length of transmission line or he can move the receiver closer to the source feed, which is impractical from a maintenance standpoint. However, if he fixes the receiver behind the main dish, the designer obtains an additional engineering tradeoff.

Since earth-station contracts are subject to heavy competition, the penalty for over-design is severe. The diagram shown above represents a traditional system optimization flow. It is also structured to reflect cost considerations. The usual systems criteria—performance, schedule, reliability, and maintenance—are weighted by relative importance factors and systems tradeoffs. Cost is still the major consideration in design modification. Initial cost is determined by the performance specs and development scheduling, while operational cost is determined almost entirely by reliability and maintenance considerations. The final tradeoff, cost effectiveness, is subject to the all-important test: can it produce a contract award? ☒
All three logic diagrams fail to show you what's really important about our new DCL arrays. Things like increased system performance, Logic flexibility, can count savings. And look what else they don't show...1. 8239/8232 Digital Multiplexer: three-to-one can count reduction; address-to-output time, 22 ns typically. 2. 8266 Digital Multiplexer: three-to-one can count reduction; address-to-output time—18 ns typical—provides conditional complement function. 3. 8241/8242 Digital Comparator: four-to-one can count reduction; high speed TPD = 10 ns typical—8241; TPD = 18 ns typical—8242; 8242 expandable for word comparison up to 100 bits in length.

One final goof: the diagrams take up so much space, we can't show you 11 other MSI's available right now, today, from Signetics. So stop reading this magazine upside down, drop us a line, and we'll rush you all the specs!

**Answer:**

![Image of logic diagrams](image-url)
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<table>
<thead>
<tr>
<th>From</th>
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<th>Max. Error</th>
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<td>Receiver</td>
<td>26/11.8</td>
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<td>AY080A-36-A1</td>
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<td>Resolver</td>
<td>26/11.8</td>
<td>7'</td>
<td></td>
</tr>
</tbody>
</table>

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The display above is the same 72 V Zener diode test previously discussed except the display offset and magnifier are used to improve resolution and accuracy. The centerline value is now 70 V but the horizontal deflection factor is 1 V/div. The Zener voltage can now be resolved as 72.6 V within 2%, a X10 increase in resolution and improvement from 3% in absolute accuracy.

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Brash newcomer’s plans for low-priced microprocessor systems shake up suppliers; but what looked like long-shot bets on MOS-LSI technology could be close to a payoff

By James Brinton
Associate editor

Thirty-nine dollars isn’t much to pay for the use of a computer; in fact it’s little enough to make a lot of people suspicious. But that’s the minimum monthly rental Viatron Computer Systems Inc.—a firm that has yet to celebrate its second birthday—announced last fall for its microprogramed System 21 machines. The prospect of bargain-basement pricing policies, along with the company’s decision to build its desk-top data-management equipment with giant MOS arrays to keep costs down, has set rumor-mongers’ tongues to wagging.

Among the juicier items now making the rounds: There’s the possibility of a fiasco like the one that occurred when Victor Comprometer’s highly touted electronic calculator failed to get to market because Philco-Ford couldn’t come up with the MOS devices [Electronics, March 6, 1967, p. 231]... Viatron won’t be able to afford, or find, the MOS it needs... The rental figures are a come-on and will rise soon after the first units are delivered... The company’s revenues from rentals will be too low to pay overhead... The prototype machines road-showed at several recent industry get-togethers, notably the Spring Joint Computer Conference, are those Viatron plans to produce—but for rental well above the $39 level.

Viatron’s president and board chairman, Edward M. Bennett is undismayed by such reports. “MOS and mechanical parts development for our microprocessors is either on or ahead of schedule,” he asserts. “We’ll make our announced late-1969 deliveries [Electronics, Sept. 30, 1968, p. 48 and April 28, p. 33], and expect to have about 100 machines operating before the first of the year. By mid-1970 monthly production will have reached 5,000 to 6,000 machines monthly. And by 1972, we plan to have delivered more digital machines than have previously been installed by all computer makers.”

Laurence C. Drew, Viatron’s manager of development engineering, says: “Some people have been misled by the large number of development contracts. We have 40 to 50 going now and will soon have nearly 70 large-scale integration development programs at various companies. Certain parties believed that we were trying to rescue a bad design or that our machines would use an impossibly large number of circuits. In fact, neither guess is correct; these contracts cover parts for machines other than the System 21 components already announced—peripherals and related gear. In addition, there’s some parallel development work on critical circuits which will compete for the same applications.” Bennett adds that costs to date are in line with predictions; it might even be possible, after volume production begins, to lower rental costs slightly, he says.

Countdown. But a question still arises as to exactly how many chips go into a System 21 processor. Using the $39 machines as an example, Bennett and Drew quote a figure of 40 large chips. They believe that while this is a lot of LSI, it’s “not the impossibly large number that’s been suggested.”

“Out of that 40, about 30 circuit types are different; 21 are individually unique random-control logic units,” says Drew. “Nine are read-only memories, but only the metalization patterns differ among four basic layouts.”

Development of these circuits is under way at eight semiconductor houses. Says Drew: “Work on processor MOS is centered at American Microelectronics; display control logic is being developed at Texas Instruments, General Instrument, and Ragan Semiconductor; main memory MOS is in the works at TI, GI, Ragan, Motorola, and...
Autonetics; the latter is also developing much of the control logic for the keyboard and tape subassemblies.

Among the first scheduled peripherals are the so-called typing robot, which converts an IBM Selectric typewriter into a printout device, and a card reader/punch to automate keypunched input and output. MOS for both these units is being developed at Fairchild Semiconductor, and Hughes Aircraft is doing parallel work for the typing robot.

Many of the prototype MOS-LSI circuits have already been delivered and all should be in hand by the end of July, says Drew. At that time he figures on putting together the first two microprocessor systems; they probably won't be identical.

A penny saved . . .

Viatron, as a matter of policy, revises its designs whenever savings look possible. This process has already begun on the System 21's MOS components. "There are three separate MOS lines now, and there will be more. The 40-chip machine might be called a model-one type," Drew says. "But models two and three are being developed; Autonetics already has delivered some of the chips for model two, beating some of the model-one MOS into our lab." Mod one might never be delivered: If the price is right, the company will probably jump immediately to the second design.

"Some of the model-two designs were suggested by semiconductor manufacturers; they said they could do a job more cheaply or on smaller chips," notes Drew. "But many, if not most, are coming out of our own MOS design group. We've found that while the computer-aided design techniques used by our suppliers are fast, they waste chip area. We pay for LSI on the basis of real estate. Thus, as we get each new design from our developers we begin to sweat down the size and up the packing density. We've been able to cut chip areas greatly; and often we've put two designs on a single chip by doing our own composites. Both moves cut costs."

Viatron can afford to continue product improvement as long as its machines are in the field. "With our (projected) volume, engineering

Who needs it

Viatron's System 21 is a set of electronic data processing wares—processors, displays, keyboards, and the like—that can be assembled as desktop microprocessors, interconnected networks, or "intelligent" terminals for large computer input-output applications [Electronics, Oct. 14, 1968, p. 193]. The processors are preprogramed, storing "microinstructions" in read-only memories holding up to 1,024, 12-bit words. Several basic instruction sets handle business operations as diverse as payroll entry and executive information retrieval.

Since the software is hardwired into the computer, the usual costly covey of programmers and systems analysts aren't needed to get a System 21 lash-up operating. In addition, the machines are designed to eliminate business waste. For example, firms today may have clerks rewriting reports from third parties, forwarding them to keypunch operators, who in turn punch cards, which become computer fodder. "We want to do away with error-adding extra steps in data management," says Joseph Spiegel, Viatron's operations vice president. "The man originating or using the data should have the edp gear."

Viatron calls this, "distributed data processing." It would amount to real-time inventory control as, say, a stockroom clerk punches out an order on his System 21 console or an executive checks next year's sales predictions at his desk by punching a short code. Such applications, among many others, have never been economical before.
costs are only $3 to $4 per machine," says Bennett. He expects 20-year lifetimes, "based on one or two trips to the maintenance depot each year." It would be during these trips that redesigned—and probably less costly—circuit boards would be installed.

"By the end of that 20 year period, we aim to make the MOS something you will have to hunt for; we plan to squeeze LSI onto some pretty small chips," he says. Tactic. This sort of interchangeability makes it possible for us to take advantage of each new drop in MOS prices, or of each breakthrough in any related technology almost as soon as it appears, according to Bennett. "It's one reason we plan only to rent our machines. By retaining the right to change boards we can force down our parts and maintenance costs and, hopefully, boost reliability. This last will lower depot inventories and ease cash flow."

This doesn't mean that parts costs won't be low to start with—they must be to reach $39. As a result, Viatron's design engineers are continually aiming for the lowest components and production costs consistent with specifications. According to Joseph Spiegel, operations vice president, they're sometimes very aggressive about it. Drew offers a case in point; his MOS development efforts are slated to be a major source of the needed savings. He's doing things with—and to—the semiconductor industry that have never been tried before and not everybody appreciates his activities. Nonetheless, he says, only three firms have refused to do development with Viatron: RCA (because its complementary MOS capacity was needed for defense work), National Semiconductor (because it had only one MOS designer on board when approached and wanted him to concentrate on standard products), and Signetics (which, Drew says, didn't believe it could deliver what Viatron wanted and said so).

There are, however, other versions to some of these stories. One has it that RCA refused to work with Viatron out of pique—Drew was once among the company's best MOS engineers. National is said to have been taken aback when Drew announced that he wanted to watch
every single wafer probe—a yarn
Drew more or less denies and Na-
tional won't confirm. Negotiations
with Philco-Ford, an outfit with an
MOS reputation, never really got off
the ground. Company sources say
that they didn't like the way Via-
tron's contract was written and
elected not to bid. Drew claims he
wasn't particularly eager to do busi-
dness anyway, one reason being
that Philco-Ford was out of step
With our in-house resources, total
visibility of each vendor's design
won't confirm. Negotiations and
quality high and prices low.
wasn't particularly eager to do in their lines than they are."

As each new circuit is developed,
Viatron will make a set of masks
which it can run through its own
line, affording a back-up capability.
However, there's no idea that this
set-up will ever supply more than
10% of the company's needs.
"Once I've got this escape hatch,
I'll make masks adapted to the
processes of each supplier," says
Drew. "We own the art and masks
developed, so a company won't
necessarily be turning out the cir-
cuit it designed. We'll make deci-
sions based on production rather
than engineering ability. Whoever
does the work will have masks
tailored to their process—and with
a contract that says so. This is the
only way we could honestly ask
companies to guarantee the MOS
they build for us; we'd be fools to
expect one firm to work with an-
other's masks."

Safety in numbers. This ploy
may lay to rest one criticism to the
effect that Viatron's highly com-
plex MOS increased the danger of
being dependent upon a single
source and possibly left in the
lurch. Multisourcing, as it hap-
pens, is a keystone in the com-
pany's procurement policies. "To do
business with us, a supplier knows
it either has to have its own second
source or be able to tell us where
to find one." As a result, outfits
like American Microelectronics are
going so far as to form new sub-
sidiaries to back up their own pro-
duction. "Second-sourcing is par-
ticularly necessary for MOS," says
Bennett. "But it's being applied
across the board."

Noting the high current cost of
risk capital, Bennett says that once
Viatron is rolling, it will take a leaf
from the auto makers' operations
manual, bankrolling some of its
subcontractors. A start may al-
ready have been made along these
lines as Viatron develops captive
capacities to make motors, power
supplies, keyboards, and related
equipment. It's probable these op-
erations will be spun off quickly—
either as separate companies or
subsidiaries.

After volume production begins,
Drew plans on buying LSI at $5
or less per packaged circuit. He's
depending on the leverage created
by monthly output of 5,000 to
6,000 processors. This works out to
about 2.5 million chips a year—not
counting what's used in peripheral
equipment and other products.
Drew figures to be characterizing,
specifying, and negotiating for LSI
from now through early Septem-
ber. "By then I'll be able to turn
on the spigots and let the circuits
run. This will give us three months
to get deliveries, and the process
lines should be waiting. I don't
have any doubt that we'll be get-
ing quantity production well be-
fore the end of the year," he says.

Timetable. Five system 21's are
to be made from prototype com-
ponents in October, 45 more in
November, and 50 or so in Decem-
ber; the latter will use production
MOS. In January the first units to
be assembled under subcontract
should be ready, and by mid-1970,
monthly production should level at
5,000 to 6,000 machines, with Via-
tron building 1,000 itself.
A traditional problem for low-cost computer makers is peripheral equipment. Obviously, if a user has to rent gear costing several times the rate for the basic machine, the computer begins to look like a poor bargain. Viatron also has had its problems in this area. Spiro tells of tape deck makers unable to meet Viatron's desired price—about $1,000 for an item typically listing for almost $4,000. "This part of the data processing industry goes first class, builds in frills, and sells relatively few machines a year," he says. "We bargained with several companies, and couldn't make enough headway. Finally, we developed our own IBM-compatible deck, which we'll produce for a lot less than $1,000 each. Apparently, peripheral equipment makers are incapable of judging the cost leverage that high-volume production yields." Viatron's unit borrows freely from audio-deck design, using read-back checking, as well as some proprietary features to offset mechanical deficiencies.

The tape deck also represents some striking examples of Viatron's drive to cut costs. The motors, to be made by the company, cost only about $4 each, against about $50 for the nearest commercial equivalent. The motor was designed in less than three weeks by Richard Seeger, manager of machine design. Likewise, the system 21's keyboard has been subject to price paring. Originally, Honeywell's Microswitch division was the supplier. But Viatron found it could build its own photoelectric keyboards at a fraction of Honeywell's price. Even the plastic buttons and knobs used on the keyboard and control panel were scrutinized. Matthew F. Thompson, vice president for manufacturing operations, says he found keyboard buttons priced from 5 cents to 17 cents each. "But we figured out that the manufacturers' unit costs were less than a penny," he says. "Even bargaining hard, we were only able to get cost down to about 2.7 cents each. So, we're going to mold our own, having found we can sell to ourselves for about 2 cents."

Case study. Viatron's typing robot fits over the keyboard of an IBM Selectric and converts it to a
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Here's how the Model 4200 stacks up against several competitors:

**BROADER FREQUENCY RANGE:** The Model 4200 outranges most of the others, including more expensive units.

**MORE OUTPUT POWER:** The Model 4200 has from 2.5 to 50 times the power of the other units.

**BEST WAVEFORM PURITY:** The Model 4200 is unexcelled.

**BEST BUY:** The $350 price speaks for itself.

See for yourself. Write for data. Then contact your Krohn-Hite Representative for a no-holds-barred demonstration. The Model 4200 is a lot of oscillator for $350.

*Patent applied for.

---

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*Patent applied for.

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**Automating output**

"Even with each part coming in at the lowest possible price, production costs could prove ruinous," says Bennett. "As a result, we decided to automate everywhere we could." This may have been the big reason for hiring Thompson to run things. He formerly worked at Litton on production of the Monroe Epic calculator on which about 84% of manufacturing operations were automated. Thompson figures 80% is about right for Viatron. A greater level would involve tradeoffs that raise costs of the end product, he believes.

"From the moment a circuit board schematic is ready, we begin thinking along with the design engineer," says Thompson. "Manufacturing and design hold hands right down through to production with the result that the circuit boards are designed with axial components parallel, rather than at angles to one another. Parallel component mounting may sound insignificant but a minimum number of flow-solder masks are required. Moreover, with skewed components, the insertion machine must stop to rotate the workpiece, then rotate it back to its original position. Viatron's boards are all designed so the inserter can stitch along like a sewing machine without pausing."
Components are tape-fed into the insertion machines, but prior to this, those containing resistors, diodes, and capacitors are fed into a sorter which not only checks the tolerance or polarity of each device but also retapes them into the insertion sequence. The idea is to inject quality control early in the manufacturing cycle, eliminating costly testing at the end.

**Fail safe.** Critics claim Viatron can’t keep field engineers on the job for the rentals it plans to charge, and Bennett agrees. But then the company never planned to use them in the first place. “If a section of our machine fails, we replace it using stock subassemblies from a nearby depot. Some maintenance may be carried out there, say, replacing one circuit board with another. But repairs will be handled here in Burlington.”

Bennet figures that the MOS-LSI chips are going to be too valuable to allow the unskilled to work with them. Thus, the depots will have simple specialized test gear to help get major subassemblies back in operation and out of inventory quickly to speed cash flow. The Burlington facilities will use automated fault-locating apparatus especially designed by the company to deal with LSI.

Spiegel figures that only 7% of monthly rentals will be needed to cover servicing and all associated overhead. Wilford J. Olson, manager of quality assurance, is devising much of the custom test gear. He’s already developed a device which may “say it all.” This prototype paragon is a multiconductor cable tester which identifies the conductor being probed. It is designed to spot shorts and assure that the right wire gets attached to the right contact. Just what’s inside the machine is proprietary, but the number of the conductor is shown when probed; the readout is red when there’s a short. No special training is needed to use the test system. There’s another aspect to the tester. In theory it makes color coding unnecessary. Thompson says that color coding always is useful, but maybe—just maybe—the company might be tempted—especially if it were able to cut costs by standardizing on a single hue.

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**MAXIMUM RATINGS**

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Space electronics

Proposed national space station will put electronics to the test

Three preliminary design and planning bids are in for this vast undertaking, which will depend heavily on ultrareliable, long-lived components and systems

By Paul A. Dickson

Among the projects the National Aeronautics and Space Administration would especially like to run off as an encore for next month's planned lunar landing is a national space station. A lot of work has already been done with this goal in mind, and earlier this month three bids for design and planning studies were submitted to the space agency. Officials stress that the venture is not simply an upgraded Apollo Applications Program; it is, they say, an effort to strike out in new directions, advancing the state of the art in a number of technologies. In particular, however, electronics and aerospace concerns would be prime beneficiaries should the space station be approved in whole or part.

When NASA was set up over a decade ago, five criteria were established for all new programs: gaining national preeminence in space; enhancing the country's security; increasing scientific knowledge; advancing technology; and achieving economic benefit. Charles W. Mathews, deputy associate administrator for manned space flight and head of NASA's space station task force, says of the proposed venture: "No other program we've ever attempted so broadly satisfies these objectives."

Mathews' assessment of the project as "a renaissance man's space program" may be overstated, but there's no gainsaying the fact that the undertaking is sizable and offers industry a lot of room to grow. The basic station would be launched in 1975 and would house a dozen men. It would be designed to have an operating life of 10 years. During the first half of the decade, it would grow as new modules were flown to it in reusable spacecraft; eventually there'd be room enough for a crew of 50 or more. Top officials at the Office of Manned Space Flight, say the original station would be the first building block around which a larger base in space for the 1980's would evolve.

NASA sees the station as an orbiting version of an earth-based scientific R&D firm, which also does a little specialized manufacturing. Unique features of orbit—for example, weightlessness, vacuum, and earth and celestial vantage—offer scientists and engineers a wide variety of research and applications possibilities. While certain mundane benefits would accrue, there would also be a grander purpose—the station would provide the needed experience to make the U.S. a truly spacefaring nation committed to interplanetary travel.

The project would be costly. Estimates for R&D alone run between $4 billion and $15 billion, with more needed to keep the station aloft for a decade or longer. Since Russia is reportedly planning space platforms as well, the decade-long space race would be kept vibrantly alive. In short, the concept promises a new adventure with all and more of Apollo's grandeur and achievement.

Two to go. The big question now, however, is whether or not there's going to be an okay from the Administration and Congress. It is a massive commitment and, thus far, NASA stands alone. There are, however, signs that the project is getting serious consideration in the right places. Last month, the House Committee on Science and Astronautics unexpectedly authorized an extra $66 million on top of an original request for $9 million to do studies of the station and shuttles. The Presidential task

Habitat. Prospective contractors are already doing preliminary designs for NASA's proposed space station; this model was prepared for Grumman by a consulting architectural firm.
... NASA wants to rely heavily on LSI in systems for the space station ...

group on space is taking a hard look at the station before it makes recommendations for the next decade to the President on Sept. 1. NASA Administrator Thomas Paine and Air Force Secretary Robert C. Seamans Jr. are working on the report, and both are strong advocates of the station.

Though the all-important question remains unresolved, the space agency is moving quickly through the early stages of the program. Unlike Apollo, the program is slated to go through the same phased planning reserved for unmanned programs. Preliminary first-phase analysis has been completed and the definition and design phases have begun. Actual development work can start in fiscal 1971, which begins July 1, 1970.

Two of the three groups submitting bids will be selected shortly to perform 11-month studies under cost-plus-fixed-fee contracts. One of the awards will be managed by the Marshall Space Flight Center in Huntsville, Ala. And the other by the Manned Spacecraft Center in Houston. One of the winners will be selected to carry out phase D development, including fabrication, testing, and initial mission operations. Though the amount of money involved in the initial work will not be great, the contractor on the scene should have the inside track in future competitions.

Among the three competing teams, Grumman heads one which includes Lockheed for logistics, TRW for mission operations and the General Dynamics' Convair division for experiments. A second is led by McDonnell Douglas and includes Martin for experiments and IBM for information handling. North American Rockwell captains the third group which includes General Electric for experiments.

Meanwhile, other important studies are already under way. The Air Force's Mitre Corp. is checking information management for the station and Martin has been commissioned to find ways of reducing launch costs. General Dynamics, Lockheed, McDonnell Douglas, and North American Rockwell are finishing up parallel studies of the proposed reusable launch vehicles. Boeing has finished one study on launch operations and is working on another, as well as a check of earth-orbital emergency entry systems. Marshall will soon contract for a study or studies of the module concept for the station.

At this early stage, NASA has involved most of its other centers in the program. Special groups at headquarters are using the agency's top manned space experts to look at the shuttle and the station. Last week, these units sent recommendations in these two areas to the President's space task group. The shuttle group is working under the direction of associate director George E. Mueller and the station group is working under Mathews, with astronaut Frank Borman acting as space station field director.

Early foot

According to Mathews, the reason that NASA is moving quickly is simply that a lot must be done to get the program off the ground. The space station makes use of new hardware and pushes into new areas of technology. Mathews points out that a variety of disciplines ranging from nuclear power through metallurgy will be pushed. Electronics, he notes, will be an all-important element, since a lot of work must be done in the areas of microelectronics and component reliability.

"We want to rely heavily on large-scale integration in the station and we want the electronics to be reliable," says Mathews. "We don't want to cascade redundancy upon redundancy to get it either." He anticipates tighter specifications and state-of-the-art improvements as the two major factors which will help achieve this goal. He also expects a shift in the way systems are integrated in the station: "With LSI, it should be possible for each black box to be more capable and independent. In Apollo, the tendency was to run all the data through general-purpose computers and make subsystems interdepend-

ent. In the case of the station, we expect to accomplish checkout fault-isolation at the black-box level."

Several factors led NASA in this direction: the size and modular complexity of the station; the potential capability of LSI; the need to be able to plug in new systems for old ones; and persistent problems with simple electrical wiring connections.

By the book. The work statement prepared by NASA for contractors says this: "The space station will use modular concepts in subsystem design and in the placement of subsystems throughout the station. Subsystem modularity will enhance man's ability to maintain, repair, and replace critical elements in orbit. Subsystems will be located to insure compatible grouping; the redundancy needed for safety and reliability considerations; and the capacity to update, repair, and/or replace major subsystems as new technology becomes available and is required ..." In plainer English, the station will be a test bed for long-lived subsystems with maximum reliability.

John E. Condon, head of reliability and quality assurance for NASA's Office of Industry Affairs, says that one of the major concerns of his office these days is greater electronics reliability. (This operation, however, is not project oriented, and the greater reliability goals for the 1970's could apply as much to the 11-year-long unmanned missions as to the proposed manned space station.) By the start of next year, at the latest, the Industry Affairs Office will release a set of reliability documents on microelectronics. Condon says that the specifications will become immediately effective and will impose a maximum of controls, inspections, and check points. "Though it will not be used for all systems, we will be moving into the most rigid area, which is assembly line certification," he says.

"For important space systems we will actually certify production right from the original cultivation of the chip," Condon points out that such stringency stems from a realization of microelectronics' importance for NASA in its programs in the post-Apollo period.

Condon shares Mathews' con-
cern about such apparently "simple" difficulties as soldering, electrical connectors, batteries, and wiring. He says: "I doubt we'll ever see the day when there'll be an end of the mundane problems. We're going to have to pay meticulous attention to these things as we get into systems with longer lifetimes."

**Supplying demand**

Prospective space station contractors are also aware of the challenges in the electronics field. Edward F. Gray, assistant to the president in charge of space programs at Grumman, points out that the amount of data generated by the space station will be tremendous, dwarfing even the high rates produced during Apollo missions. He figures that designing the right data-handling set-up will be one of the biggest problems in developing the system. "The Apollo program has a tremendous number of people tied up just monitoring data describing the status of the spacecraft," he says. "Status information will have to be handled in the station itself—by far fewer people—so that the bulk of the data results from the experimental activity."

Reinforcing Gray's point, another source on a competing team says, "NASA has consistently underplayed the data-handling problems in its unmanned space programs. The Goddard Space Flight Center has reams of experimental data taken from spacecraft that no one has even had a chance to look at. On the space station we must make certain the data is rapidly converted, sorted, and used."

Ian Dodds, North American Rockwell's space station program manager, says that the primary thrust in pushing the state of the art will center on the technology of long-lived subsystems involving in-flight maintenance at the black-box level. "Every component is going to have to be operationally tested over a very long time," he says. "You can't afford to have personnel spending time going up to do maintenance work." Dodds notes state of the art advances will also be required in information-management systems, including improved computer interaction with on-board displays to insure that only significant

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\[\ldots\] the station will give NASA a chance to check sensors \ldots\]

data is transmitted to the ground for evaluation.

**Payoff.** In the coming months the two winners of study contracts will use NASA's work statement as their technological bible in defining the station. Among other things, there's a lengthy list of electronics projects. A sampling of communications challenges includes the following:

- A dedicated satellite-relay system, consisting of three spacecraft at asynchronous altitudes, would become an integral part of the station set-up.
- A television and multichannel voice system would allow investigators aboard the station to consult with colleagues on the ground on a real-time basis.
- Internal communications will provide the basis for the station's data management system. A single coaxial cable will be used to transfer video, digital, voice, and teletype information among all elements of the station, affording flexibility, as well as the means for expansion.

Beyond supplying hardware and support services for the station and its vehicles, there will be other advantages for the electronics industry if the project is approved. Grumman's Gray, for example, points out that the venture would allow the NASA/industry Apollo R&D staff to stay together. In addition, the station will furnish continuing outlets for electronic instrumentation to conduct experiments in eight research areas—biomedicine, astronomy, earth applications, space biology, space physics, engineering operations, materials processing, and advanced technology.

In earth applications, for example, NASA anticipates that the original instrument package will include a metric camera for ground mapping, a system for multispectral photography, two vertical-profile radiometers, and two or three infrared and microwave imagers for sensing surface features. Mathews says, "The station can give us the chance to test sensors for unmanned earth resources satellites. Everything will move more"
quickly. The sensors could be flown to the station and tested as soon as they're available. Later, after they've proven out, the unmanned operational satellite could be deployed by one of the reusable craft.” He suggests that such integration of manned and unmanned programs will be a commonplace way of operating with the development of the station and its accompanying shuttles.

**Possibilities.** Finally, the station offers some unique prospects for manufacturing and advanced technology. For example, material processing methods which could be developed in the zero-gravity environment of the station include the cultivation of large crystals with vastly reduced dislocations, achieving the discovery of new alloys, and the exploration of new means of casting metals.

While there is genuine skepticism within NASA as to whether such processes would prove economically attractive due to transportation costs, consideration is being given to offering small quantities of new materials from the station. Says Mathews: “Even if the transportation costs were as much as $50 to $100 a pound, there may very well be a benefit in getting them, at least for experimentation, on earth. I would think that the electronics industry would be very interested in having some new alloys to experiment with or some absolutely perfect crystals.”

Clearly, NASA and the electronics community have a lot to gain from the acceptance and final realization of the space station. One factor which can make or break the plan will be how the Congress assesses public reaction. However, the planners at the agency feel that the practical nature of the venture will be a big selling help. As for preconditioning to the idea, Mathews says, “If you saw the movie ‘2001,’ you have an inkling of how exciting this program is. I think that the space station was the most interesting part of the picture to most people.” Recently, NASA Administrator Thomas Paine admitted that he had gone to see the film five times and was still intrigued by it. If the station eventually gets into orbit, producer Stanley Kubrick probably will rate credit for an assist.

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- Q at 10 pf & 100 MHz: >2,000
- Insulation Res. at 25°C: 10^10 meg.
- Temp. Coeff. of Cap. (-55°C to +125°C): 0 ±20 PPM/°C
- Test Voltage: 500 VDC

**ACTUAL SIZES**

- Panel Mount w/Turret Terminal: VAM 010
- Panel Mount w/Lug Terminal: VAM 010M
- Printed Circuit: VAM 010W

*VAM 010 also available as VAM 010H with 4-40 threaded stud replacing turret terminal.*

Write for catalog VAM-67-B.

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Design with New Dual-Gate MOSFET and Forget About Transient Voltages

RCA's new 40673 permits you to take full advantage of the superior high-frequency performance characteristics of dual-gate MOSFETs without concern for transient breakdown problems. Back-to-back diodes—Transient Trappers—diffused within the same silicon pellet as the MOS Field-Effect Transistor, guard each gate against:

• Static discharge during handling operations without the need for external shorting mechanisms
• In-circuit transients

Typical characteristics of the RCA-40673 are:

• Power Gain (MAG) = 20 dB @ 200 MHz
• Noise Figure (NF) = 3.5 dB @ 200 MHz
• Superior Cross-Modulation Characteristics
• Wide Dynamic Range Without Diode Current Loading
• Reduced Spurious Response
• Extremely Low Feedback Capacitance = 0.02 pF
• Simplified AGC Circuitry

Recommended for RF Amplifier applications up to 400 MHz, RCA-40673 MOSFETs may also be used as RF Amplifiers, Mixers and IF Amplifiers in:

• TV Receivers
• FM Radios
• Aircraft and Marine Vehicular Receivers
• CATV and MATV Equipments
• Telemetry and Multiplex Equipments

For more detailed information, circle Reader Response No. 225.

5 Transistor IC Array
In DIP—CA3046, 98¢ (1000 Units)

For design flexibility and big economy in all types of signal processing systems, from DC to 120 MHz, investigate RCA-CA3046 Linear Integrated Circuit Array. In this five-transistor monolithic array, transistor pairs are $V_{th}$ matched to within ± 5 mV, with a 2 µA Input Offset Current at $I_{c}$ of 1 mA. Noise Figure is 3.2 dB (typ.) at 1 kHz. Use this array as five discrete transistors in conventional circuits, or as differential pairs in your custom circuit configurations.

This array is also available in dual-in-line ceramic package at $1.50 (1000 units) for use over the full military temperature range. Circle Reader Response No. 226 for full information, including pertinent Applications Notes and a copy of "Design Ideas for RCA Linear Arrays."

MSI Adds New Cost Effectiveness To COS/MOS Technology

The new RCA-CD4006D, 18-stage COMplementary Symmetry MOS Static Shift Register, with over 200 MOS transistors, provides the unique performance advantages of COS/MOS circuits with real-world economics. The CD4006D @ $17.25 (1000 units) provides military-temperature range operation at less than $1.00 per flip-flop. Design features are:

• -55° to +125°C operation
• 100 nanowatts quiescent dissipation (typ.)
• 18 stages in 4 and/or 5 bit sections
• Static to 2 MHz shift rate
• Single phase clock
• Single 6- to 15-volt power supply
• 4-volt noise margin (10-volt logic)

CD4006D in ceramic dual-in-line package is $25.00 (1-99 units). Effective July 1, 1969, CD4006 in ceramic flat pack is $26.50 (1-99 units). For technical information, circle Reader Response No. 227.
Sock It to These Triacs—at 10 A and 15 A (RMS)

More and more users are finding more and more uses for RCA Triacs. Join them with these additions to the growing RCA line of Thyristors:

10-ampere types 2N5567, 2N5568 (press-fit) and 2N5569, 2N5570 (stud types) handle 10 A (RMS) at $T_c$ of $+85^\circ C$ and conduction angle of 360°.

Repetitive peak off-state voltages are rated at 200 V for 2N5567 and 2N5579, and 400 V for types 2N5568 and 2N5570. Gate characteristics are controlled in all four firing modes.

15-ampere types 2N5571, 2N5572, 2N5573 and 2N5574 have 15 A (RMS) on-state current rating at the same repetitive peak off-state voltage ratings and $T_c$ as their 10 A "brothers."

Check RCA for the widest line of Thyristors—from low-signal units to heavy-duty industrial-type devices. And Circle Reader Response Number 228 for details on the complete line.

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Full second breakdown protection up to 100 W and 150 V—plus safe area rated up to 300 V! That's a power level, performance and reliability no other high-voltage silicon transistor can match.

To you, this means better performing, more reliable performance for high-voltage regulators, series regulators, high-speed inverters for off-the-line operation, switching bridge amplifiers for servo motor controls, and ultrasonic power amplifiers.

Choose between the 2N5240 with $V_{ces}$ of 350 V or the 2N5239 with a 250 V rating. Both have an $I_C$ (max.) of 0.5 A and $P_o$ (max.) of 100 W. Both are in TO-3 packages.

For more information, circle Reader Response No. 229.

For price and availability information on all solid-state devices, see your local RCA Representative or your RCA Distributor. For specific technical data, write RCA Electronic Components, Commercial Engineering, Section No. QM6-3, Harrison, N. J. 07029.

Class C Power for 470 MHz Mobile Communications

Here's a driver-amplifier combination for your mobile two-way radio designs (and anywhere else you can use a 6-W plus output at 470 MHz). Drive with the RCA developmental type TA7408. Use the RCA-TA7409 for the final. Both units are epitaxial silicon n-p-n planar transistors. And both types feature RCA's overlay emitter electrode construction in a hermetically-sealed ceramic-metal package with electrically-isolated mounting stud.

The TA7408 and TA7409 have low-inductance, radial leads which make them particularly suited for strip-line circuits, as well as for lumped-constant designs. Both types operate from a 12-V supply.

Key ratings and electrical characteristics include (for both types): $V_{CEO} = 36 V$; $V_{CEO} = 14 V$; $V_{CES} = 36 V$; and $V_{CEO} = 3.5 V$. Driver unit TA7408 has 0.5 A $I_C$ and $P_o$ rating of 5.7 W. The TA7409 has $I_C$ of 1.5 A and $P_o$ of 10.7 W. The driver offers 7 dB gain at 470 MHz, to take the TA7409 up to its full-rated 6 W minimum output.

Circle Reader Response Number 230 for details.
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156 Circle 156 on reader service card Electronics | June 23, 1969
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Circle 157 on reader service card
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You get quick, accurate, full-scale calibration and automatic zero. It also provides 100% over-range with an overrange digit reading to 1999 (4000 count option to 3999), BCD outputs, remote encoding, print command and an accuracy of ± 1 digit.

Innovative? Yes. Practical? Definitely. At only $245. (quan. of 1-24 units)

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A new, wideband, high speed tuning technique for coaxial magnetrons.

Gyro-tuning employs a ring gear which drives a set of rotating dielectric paddles within the magnetron coaxial cavity. A high speed synchronous motor drives the entire mechanism, which is external to the tube vacuum envelope. This arrangement provides a high degree of frequency tuning and reliability for coaxial magnetrons used in airborne search, navigation, terrain following and missile seeker radar applications. The complete tuner assembly is compact and adds only 1/2 pound to the basic magnetron weight.

Gyro-tuning presently achieves tuning rates of 400 Hz at frequency excursions of 250 MHz at Ku-band. It features low tuning drive power and a simple, directly driven, high voltage electrical generator readout technique to reduce local oscillator tracking problems.

Gyro-tuning is reliable. The rotary tuner mechanism provides long operating life and meets relatively stringent shock and vibration specifications. Operation outside the vacuum enhances tube life.

Gyro-tuned magnetrons are now being delivered at the 35 kilowatt level at Ku-band and 70 kilowatt level at X-band. Tubes are in development at other power levels.

For information on Gyro-tuning and other rapid tuning techniques now available or under development, contact: Electron Tube Division, 960 Industrial Road, San Carlos, California 94070. Telephone: (415) 591-8411.
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Now consider this: the Surfanalyzer 360 may also be used with the Clevite Surfanalyzer 1200 for linear as well as rotary measurement. And when you add one of Clevite's high performance strip chart Brush Recorders for complete surface analysis on round or flat parts, you'll see why the Surfanalyzer's in a class by itself. Basic system linearity is 1% with extremely high frequency response. Both recorders feature a patented, pressurized inking system that gives you high-contrast, non-smudging traces at all writing speeds. If you really want to see something new in surface analysis and measurement of geometric relationships, phone or write: Clevite Corporation, Gaging & Control Division, 4601 N. Arden Drive, El Monte, California 91731.

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Key to the success of lunar missions: the precise connections, disconnections or reconnections of the Apollo spacecraft modules. And one of the most critical of these connections in the whole NASA mission is when the Command and Service Modules reconnect with the Lunar Module.

All this takes good connections in another sense, too — good electrical connections to the millions of parts in the whole Apollo/Saturn vehicle. And that's where we come in, with a host of ultra-reliable connectors in every stage.

To name a few of the 18 types we supplied: Circulars (CV, RX, KPD, 5015), Rectangulars (D Subminiature, DPK, Double Density D), KPT Hermetic, Micro-D™ connectors and five different umbilical connectors.

The moral? When it comes to a unique combination of versatility and reliability, come to ITT Cannon. Whatever the connector application, you'll be on solid ground. For further information, write ITT Cannon, 3208 Humboldt St., Los Angeles, Calif. 90031. A division of International Telephone and Telegraph Corp.
A great selection of types to meet a wide range of applications

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3/4 • 20 UNEF · 2A THD

Illustrated are a few of the pickups designed and stocked by Airpax. Types include units for operating temperatures to 800°F and outputs to 600 volts peak-to-peak. If your problem is Positioning, Counting, Synchronizing, Slippage Control or just straight Tachometry, Airpax has the pickup and accessory modules, including Digital Readout units, to provide a complete system. Data on operating principles, curves, and characteristics is available on request.

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1/4 • 40 NS 2A THD

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(Shown Actual Size)
Rms measuring time cut to 300 msec

Five-digit voltmeter uses curve-fitting network to compute true rms values; instrument also measures resistances down to 10 ohms, d-c voltage and voltage ratios

By Owen Doyle
Associate editor

High speed. The 5500 computes a true-rms reading electronically, so it’s almost 10 times as fast as a dvm that measures rms with thermocouples. And distortion can’t fool this meter like it can an integrating dvm.

Take your time or take your chances. This is the usual choice for an engineer measuring the rms value of an a-c signal. If he has time, he uses a digital voltmeter built with a thermal converter; this type of dvm measures rms regardless of the shape of the meter’s input, but takes 2 or 3 seconds to do it. If he’s in a hurry, he reaches for a dvm that uses an integrating converter. This type is fine as long as its input is a perfect sine wave; but if 60-hertz pickup or other noise distorts the input, the meter’s reading, is, at best, inaccurate.

Now Dana Laboratories Inc. is offering a third choice: a dvm built with what the company calls a computing converter. There are no thermocouples in it, but this converter, according to Dana, allows its new dvm to measure rms as accurately as “true-rms” meters measure. And since the Dana meter calculates electronically, it’s as fast as an integrating dvm—a reading every 300 milliseconds.

The rms-reading dvm is just one version of the 5500/135, a five-digit meter Dana will introduce at Wescon.

The term “true-rms” and similar adjectives refer to dvm’s built with thermal converters. The standard rms volt is defined in terms of energy dissipated in a standard resistor, so a true-rms dvm runs its input through a thermocouple, measures the energy dissipated, and then computes and displays the input’s rms value.

An integrating dvm, on the other hand, measures the average value of its input and multiplies the average by 1.1 to get rms. This technique is fast; and it works as long as the input is really a sine wave. But input distortion small enough to be undetectable on an oscilloscope can throw an integrating meter’s reading off by as much as 5%.

Doesn’t matter. But a little distortion doesn’t bother Dana’s meter because it doesn’t take the wave shape for granted. This meter first finds the absolute value of its input by running it through
Bunker-Ramo's Defense Systems Division has demonstrated its capability to convert operational requirements into advanced electronic equipment.

Here are significant examples:

- The BR-90, combines electronic and photographic displays with stored-program control.
- BR-700, low-cost solution to source-data automation and local data management.
- UNAMACE, a computer-controlled system that automatically prepares orthographic maps from aerial photographs.
- New techniques which provide faster data acquisition systems using high-speed cyclic analog-to-digital converters.
- New techniques leading toward low power, low cost MOS microelectronic digital equipment.

If your project requires either special-purpose product design or large-scale systems engineering — or both — contact Bunker-Ramo.
a rectifier. A curve-fitting network then squares the rectified wave, and finally the squared signal is averaged to produce the input's rms value.

According to Dana, its meter can match the true-rms meters in accuracy when the signal being measured is a sine wave subjected to "commonly experienced distortion", such as 60-hertz pickup, harmonic distortion and low-level rfi.

And the Dana meter handles square and sawtooth waves. Says Barton Weitz, Dana's product marketing manager: "If a square wave is fed to an averaging converter, a thermal converter, and a computing converter, the rms reading of the averaging converter would be off by 11%, of the thermal converter between 0.05% and 0.1%, and of our computing converter off 0.1%.”

There are cases where the Dana meter can't compete. Since a true-rms meter respond to energy changes, it alone among dvm's can handle weirdly shaped waves.

Other members. Dana's rms-reading meter is part of a family. The basic 5500/135 measures d-c voltages and ratios, and costs $2,995. Everything in the meter, except the power supply, is on printed-circuit boards. So a user of the 5500 who wants to measure a-c and resistance just gets a few more p-c boards from Dana, and plugs them into the 5500's mother board.

The rms board with the computing converter on it costs $745; a board that holds an averaging converter costs $545; and a board containing a resistance-measuring network costs $445. So, for example, the price of a 5500 that measures d-c, rms, and resistance is ($2,995 + $745 + $445) $4,185.

The instrument has five d-c voltage ranges—100 and 1,000 millivolts, and 10, 100 and 1,000 volts. When set to a millivolt scale, the 5500 resolves 1 µvolt, has a temperature coefficient of ±0.001% per °C, and an accuracy of ±0.005% of the reading ±0.002% (1,000 mv) or ±0.01% (100 mv) of full scale.

The noise rejection is 40 db from 59 hz to 300 hz, and 70 db for higher frequencies; and the common-mode rejection is 140 db for d-c and 120 db for 60 hz. The input resistance is 10 megohms.

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The 5500’s ratio ranges are 1, 10, and 100. The numerator can roam between −1,000 and +1,000 volts, and the denominator between 20 and 110 volts.

Down and up. Accuracy goes down as the input’s frequency goes up; for the three higher voltage ranges the accuracy is between ±0.00% of the reading ±0.09% of full scale and ±0.9% of the reading ±0.1% of full scale. At the 1-volt range, the accuracy is ±0.18% of the reading ±0.02% of full scale for inputs under 10 khz, and ±0.3% of the reading ±0.05% of full scale for higher frequencies.

The 5500 has seven resistance ranges, from 10 ohms to 10,000 kilohms. Accuracy usually goes down as the range goes up. At the 10-ohm setting it’s ±0.02% of the reading ±0.02% of full scale and at 10,000 kilohms it’s ±0.1% of the reading ±0.001% of full scale.

The 5500 and all its p-c boards will be ready in production quantities by Sept. 1; delivery time is 45 days.

Dana Laboratories, Inc., 2401 Campus Drive, Irvine, Calif. 92664 [338]

Noise rejection is 80 decibels for signals over 59 hertz, and the common mode rejection is 140 db for d-c and 120 db for 60 hz.

At the 10-volt range, the input resistance is 10,000 megohms; and at the 100-volt and 1,000-volt ranges it’s 10 megohms.

When set to a millivolt scale, the 5500 resolves 1 µvolt, has a temperature coefficient of ±0.001% per °C, and an accuracy of ±0.005% of the reading ±0.002% (1,000 mv) or ±0.01% (100 mv) of full scale.

The noise rejection is 40 db from 59 hz to 300 hz, and 70 db for higher frequencies; and the common-mode rejection is 140 db for d-c and 120 db for 60 hz. The input resistance is 10 megohms.

The 5500’s ratio ranges are 1, 10, and 100. The numerator can roam between −1,000 and +1,000 volts, and the denominator between 20 and 110 volts.

In the ratio mode, the 5500 has an accuracy of 0.004% of the reading ±0.001% of full scale, and a noise rejection of 80 db.

For measuring a-c, the 5500 has ranges of 1 volt and 10, 100, and 1,000 volts. It resolves 10 µvolts, and has a frequency range of 50 hz to 100 kilohertz; a more expensive model goes down to 10 hz.

The 5500 has seven resistance ranges, from 10 ohms to 10,000 kilohms. Accuracy usually goes down as the range goes up. At the 10-ohm setting it’s ±0.02% of the reading ±0.02% of full scale and at 10,000 kilohms it’s ±0.1% of the reading ±0.001% of full scale.

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At the 10-volt range, the input resistance is 10,000 megohms; and at the 100-volt and 1,000-volt ranges it’s 10 megohms.

When set to a millivolt scale, the 5500 resolves 1 µvolt, has a temperature coefficient of ±0.001% per °C, and an accuracy of ±0.005% of the reading ±0.002% (1,000 mv) or ±0.01% (100 mv) of full scale.

The noise rejection is 40 db from 59 hz to 300 hz, and 70 db for higher frequencies; and the common-mode rejection is 140 db for d-c and 120 db for 60 hz. The input resistance is 10 megohms.

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For measuring a-c, the 5500 has ranges of 1 volt and 10, 100, and 1,000 volts. It resolves 10 µvolts, and has a frequency range of 50 hz to 100 kilohertz; a more expensive model goes down to 10 hz.

Down and up. Accuracy goes down as the input’s frequency goes up; for the three higher voltage ranges the accuracy is between ±0.00% of the reading ±0.09% of full scale and ±0.9% of the reading ±0.1% of full scale. At the 1-volt range, the accuracy is ±0.18% of the reading ±0.02% of full scale for inputs under 10 khz, and ±0.3% of the reading ±0.05% of full scale for higher frequencies.

The 5500 has seven resistance ranges, from 10 ohms to 10,000 kilohms. Accuracy usually goes down as the range goes up. At the 10-ohm setting it’s ±0.02% of the reading ±0.02% of full scale and at 10,000 kilohms it’s ±0.1% of the reading ±0.001% of full scale.

The 5500 and all its p-c boards will be ready in production quantities by Sept. 1; delivery time is 45 days.

Dana Laboratories, Inc., 2401 Campus Drive, Irvine, Calif. 92664 [338]
Where do you get yours?

Prospecting was once the only source for gold. Not so today! The most modern production techniques, the latest refining methods and the best equipped research laboratories make Williams your one best source for all precious metals and their alloys. Available in ultra-high purity sputtering discs, preforms, foil, ribbon, tape, wire, sheet and other forms. Write for our 1969 catalog and for information on our "Instant Engineering" kit.

WILLIAMS PRECIOUS METALS DIVISION OF WILLIAMS GOLD REFINING CO., INC., 2978 MAIN STREET, BUFFALO, NEW YORK 14214

Circle 168 on reader service card
New components

Digital coupler gives 100,000-megohm isolation

Built with thick-film hybrid circuitry, device fits 14-lead dual in-line sockets; it can withstand 500-volt noise spikes and doesn’t require a power supply

Coupling digital systems, particularly in electrically noisy environments, is often a difficult task. Usually, designers run into trouble with so-called ground loops or other grounding problems; shielding leaves isolation to be desired, especially where high-speed, sensitive logic is used.

Traditional approaches include elaborate filtering and potentially costly but noise-immune high-voltage logic. But a new company, Hybrid Electronics Inc., has taken a different approach with what it calls a digital isolator.

The isolator provides input/output isolation of about $10^{11}$ ohms—100,000 megohms—and only 2 pico-farads of input-output capacitance.

According to Richard H. Wagner, the company’s applications manager, the isolator withstands 500-volt noise levels. Sized and pinned to fit 14-lead, dual in-line package sockets, the isolator is built with thick-film hybrid circuitry. It is notable for its small size and short parts list—made possible says Wagner, by hybrids. “It uses two transistors, two diodes and a few capacitors,” he points out, “and the largest com-
Selective. Coupler rejects noise components in linking digital systems.

ponent of the assembly is a quarter-inch transformer.”

The isolator consists of a single-transistor Hartley r-f oscillator that is coupled to a half-wave rectifier through a toroidal transformer. Capacitive filtering at the rectifier output removes the signal’s a-c components—including any noise—but passes d-c to an output transistor in the circuit.

Digital route. The isolator doesn’t need a power supply; its r-f oscillator runs on the digital input, turning on and off in response to logical “0’s” and “1’s”. The rectifier output turns the output transistor on and off in response to the digital input—but minus its noise component.

“The isolator allows digital operation of equipment that floats at potentials above or below that of ground,” says Wagner. This includes such complex gear as programable power supplies or test equipment, industrial-process controllers and other logic circuits, sample and hold networks, or silicon controlled rectifier switches. “In all cases, the isolator provides about 500 volts common-mode noise rejection,” he adds, “and at bit rates as high as 500 kilobits.”

Another application for the isolator is as a replacement of driver/receiver pairs often used when signals must be sent over long cables.

Prototype quantities of the digital isolator are available from stock, and are rated for the industrial temperature range of 0° to 70°C. Volume production will begin in five to seven weeks. The isolator is priced at $25.25 each for one to nine units, $22.76 in lots of 10 to 99, and $19.85 in lots of 100-499.

Hybrid Electronics Inc., 7 DeAngelo Dr., Bedford, Mass. 01730 [349]
PRECISION SWITCHES — Five new types of precision switches are now available that will be of special interest to those users looking for savings in space and cost, along with long life and high performance characteristics. Design simplifications and unique constructions are such as to assure the switch buyer of large control capacities, the greatly reduced sizes notwithstanding.

TOGGLE SWITCHES; SLIDE, TUMBLER, & ROCKER SWITCHES — Six new patents explain the high performance, long life, and unique construction of four types of heavy-, medium- and light-duty toggle switches. High quality slide, tumbler, and rocker switches are also available in a variety of shapes and colors.
CTS cermet resistor networks

...with

NEW 16-lead
dual-in-line
package

Add more circuitry...up to 16-lead
dual-in-line packages...with these new
CTS space-saver cermet resistor net-
works. Specifically designed to simplify
automatic insertion and reduce your as-
sembly costs. Easy to hand mount, too.

Series 760 DIP Resistor Networks provide
...14 or 16 lead packages...up to 15 re-
sistors per module with an infinite number
of circuit combinations...excellent envi-
ronmental characteristics...5 lbs. pull
strength on leads...and are available with
or without active devices...lead spacing,
.125".

Check CTS low prices and fast delivery
schedule...2 weeks for prototypes; 4-6
weeks for production quantities. See the
prices listed below!

More flexibility...CTS packages can be
delivered without organic cover coat. You
trim for circuit balance in your plant.

Ask your CTS sales engineer for data. Or
write CTS of Berne, Inc., Berne, Indiana,
46711. Phone: (219) 589-3111.

<table>
<thead>
<tr>
<th>Series 750</th>
<th>Series 760</th>
</tr>
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<tbody>
<tr>
<td><strong>Quantity</strong></td>
<td><strong>4-pin 3 resistors</strong></td>
</tr>
<tr>
<td>10,000 piece price</td>
<td>14.4¢ ea. (4.8¢/ resistor)</td>
</tr>
<tr>
<td>1,000 piece price</td>
<td>28.8¢ ea.</td>
</tr>
</tbody>
</table>

Prices shown are ±2.5% tolerance, ±250 ppm/°C from 50 ohms through 1 megohm standard TC. (Also based on circuits with all resistors screened simultaneously on one side of the substrate.)

Microelectronic Circuitry
Selector Switches
Trimmers
Potentiometers
Crystals, Oscillators, and Filters
Loudspeakers

CTS CORPORATION
Elkhart, Indiana

172 Circle 172 on reader service card
Electronics | June 23, 1969
New components

**Cooling dual in-lines with dissipator/clip**

Conduction base fits on circuit board; retainer assures IC contact pressure

**Excessive** heat is a common cause of failure in integrated circuits. In dual in-line packages, steadily increasing power requirements of from 1 to 5 watts have made efficient heat dissipation mandatory.

International Electronic Research Corp. has introduced a heat dissipator/retainer that it says is the first specifically designed to control heat levels in dual in-line IC packages having up to 14 leads.

The assembly consists of a conduction base that fits between the circuit board and the package case, providing thermal contact with the bottom of the case, and a retainer clip that inserts over the IC to provide proper contact pressure. An optional heat sink/dissipator can be placed between the circuit board and conduction base for additional reduction.

In a typical application, with the General Electric PA 237 linear amplifier, a temperature reduction of 16° at a dissipation level of 700 milliwatts has been attained, using only the retainer clip and conduction base. By adding the staggered-fingered heat sink/dissipator, a temperature reduction of 25° can be attained.

**Sockets or solder.** The retainer clip and conduction base can be used to retain dual in-line packages either when sockets are used in the assembly, or when IC’s are soldered directly onto the circuit board.

Pricing of the conduction base is 7.4 cents in quantities of 100 and 5 cents in quantities of 10,000; for the retainer clip, 25 cents in quantities of 100 and 15 cents in quantities of 10,000; and for the sink/dissipator, 20 cents each for 100 and 11 cents for 10,000.

International Electronic Research Corp., Burbank, Calif. 91502 [350]

**WE’VE JUST MADE THE INDUSTRY’S BROADEST LINE OF TEFOLON® TAPES A LITTLE BROADER**

By about a thousandth of an inch.

That’s the thickness of the Teflon film used in our new HM225 Temp-R-Tape®. With its silicone polymer pressure sensitive adhesive it makes out to only .00225”.

Along with the super-slipperiness of Teflon, HM225 has low elongation, high strength, easy no-curl handling, outstanding electrical properties and a −100 to +500 F operating range.

You can’t buy a thinner Teflon tape that offers this combination of unique qualities.

CHR has a tape of Teflon to match just about any design requirement you may come up with. And with the other new high modulus tapes (see box) CHR has the broadest line in the industry.

CHR has a tape of Teflon to match just about any design requirement you may come up with. And with the other new high modulus tapes (see box) CHR has the broadest line in the industry.

NEW CHR TEMP-R- TAPE OF TEFOLON

Four HM series tapes are available with silicone polymer pressure sensitive adhesive: HM225—2¾ mils, HM350—3½ mils, HM650—6½ mils and HM352—3½ mils with the Teflon surface treated to promote adhesion of varnishes.

For the widest selection of tapes of Teflon in the industry see your nearest CHR distributor for technical assistance and prompt delivery. Look in the Yellow Pages under “Tapes Industrial” or in major industrial directories and microfilm catalogs under CHR. Or write for details and sample. The Connecticut Hard Rubber Company, New Haven, Connecticut 06509.

CHR

Subsidiary of U.S. Polymetric, Inc.

Circle 173 on reader service card

Electronics | June 23, 1969
When you're stuck with more wire than space...

Get around the problem, neatly, with Brand-Rex ribbon cables.

These slim space-savers bend into tight corners... hug contours around obstacles... keep wiring out of the way. They make high density interconnections easier to handle.

Brand-Rex gives you a wide choice of vinyl-insulated ribbon constructions (singles, pairs, shielded wires, coaxials)... with 2 to 100 conductors... to meet a variety of commercial and military requirements. Conductors can vary in type, size and color (striped wires also) within a given cable. They separate and strip easily, terminate in standard devices.

Write for the facts on Brand-Rex ribbon cable. And ask about any custom design you have in mind. Brand-Rex Division, American Enka Corporation, Willimantic, Conn. 06226.

Connect for tomorrow.
BRAND-REX
New instruments

British pair checks radiation levels

Gamma monitor measures dose rates over a nine-decade range; six-decade counter helps keep track of isotope activity

One looks for trouble and the other looks for answers. Both are used for looking at radiation. They're a pair of instruments developed by Labgear Ltd., a member of Britain's Pye of Cambridge Group.

The gamma monitor measures gamma-radiation dose rates over a nine-decade range, from 1 milliroentgen/hour to 10⁶ roentgens-hour. It's for installations with nuclear power plants or other source of radioactivity, and can be used either in routine tests or in checks for radiation leakage.

The decade/counter D4151/B is a six-decade pulse counter which works with a detector to measure radiation from isotopes. And isotopes are usually an experimental tool for engineers or scientists and a diagnostic tool for physicians and medical research workers.

The gamma monitor comprises an indicator, a power supply, and three detectors, each with a particular gamma sensitivity—1 mR/hr to 10⁹ R/hr, 10 mR/hr to 10⁶ R/hr, and 1 R/hr to 10⁶ R/hr.

A detector can be installed as far away as 100 feet from the monitor. The detector contains an ionization chamber, an electrometer pentode,
Hamilton has added a new plant—just to produce precision, Photoformed® parts!

This new facility is equipped with the most modern photo-etching machinery on the market. The new equipment will produce precision parts in large quantities to the highest standard of dimensional accuracy.

Now, you can get from the Precision Metals Division, finished parts to the same degree of precision as world wide metal users have come to expect in Hamilton's strip and foil.

Hamilton offers the advantages of a completely integrated facility controlling every step from melt to finished strip or foil—and now to finished parts. This means that you get the same adherence to metallurgical standards and dimensional accuracy that has become the hallmark of Hamilton.

For the complete story on the capabilities of Precision Metals Division and what it can do for you, write for your copy of the Precision Metals catalog. It's yours for the asking—write today!

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PRECISION METALS DIVISION

Show... The counter's display has four registers and two glow tubes.

... and tell. The monitor warns if radiation is over a limit.

Price of the monitor is $1,670 and of the counter $152.

Labgear Ltd., St. Andrews Rd. Cambridge, England. [369]
New from ZELTEX!
A four-quadrant modular multiplier that requires no external amplifiers for

LOW COST MULTIPLIER

1000 Chalomar Road, Concord, Calif. 94520/ (415) 686-6660
Circle 177 on reader service card

* In quantity.
Making Testers?

It's just one way to use Elgin's Integrid® Cards and power supplies to solve a design problem.

The custom test equipment pictured above demonstrates another use for these Elgin off-the-shelf products when you are faced with a job requiring reliable, low cost components. Elgin's 5V power supplies in each tester feature exclusive over-voltage and over-current protection. They are available in three basic sizes with output currents of 4, 8 or 16 amps, at low cost with GUARANTEED PROMPT DELIVERY—on the way to you within 48 hours after receiving your order.

Inside each tester are 12 circuits assembled on our Integrid Card elements (dual-in-line's above). Integrid Cards are available in multiple patterns, permitting modular use of precisely the type and number of boards required.

The PC Assemblies being checked in the test equipment were made by us, including the printed circuit boards manufactured at our new PC board plant. Circle the reader Service Card for our new Integrid Card and Power Supplies folders.

New instruments

Checking fluidics the easy way

Rugged and inexpensive, pressure transducer plugs right into oscilloscope

Checking out a fluidics network, with all the tubing involved, can make an electrical engineer uncomfortable. What he wants is a feeling of being at home, not of working with plumbing. And few instruments give the engineer that "at home" feeling more than an oscilloscope. Now, Simmonds Precision Products Inc. offers a device that allows an engineer to check fluidic networks with his scope.

The tester converts fluid pressure changes into electrical signals, and it does this fast enough to produce meaningful waveforms on a scope.

Pressure-prone. The fluidic tester responds to pressure that changes at a rate as fast as 100 kilohertz.

Strain-gage transducers do this too, but they cost as much as $1,000. Simmonds’ tester costs $219. With a built-in power supply, the price is $294.

Also, the tester is easy to use. Unlike strain gages, which have four leads and thus require special plug-ins for scopes, the new unit has only two leads. And these leads are plugged directly into the scope’s vertical-deflection terminals. The input from the fluidic network being checked comes to
The ultimate in complete wire wrapped panels... from one source

Augat and Raytheon Now Combine their Capabilities
To Provide New Economies and Faster Turn Around Time.

An alliance of leaders.
Augat, long recognized for its innovations in
IC packaging panels and the quality of its products.
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Together, we're now producing packaged panels unmatched
in reliability, flexibility and fast turn around time.
Let us wrap up your IC and interconnection requirements efficiently and economically.
Contact: Augat Inc., 33 Perry Ave., Attleboro, Mass. 02703, (617) 222-2202.
quadrature hybrid couplers

Our line of 3 db Quadrature Couplers features an equal power split with a 90° phase differential between output ports.

There are 5 models in our current line. All use standard 3mm miniature coaxial connectors.

- D-5924-L 1-2 28 1.20
- D-5924-S 2-4 28 1.20
- D-5924-C 4-8 20 1.25
- D-5924-X 8-12 18 1.30

Max. Deviation from mean output on all models = ±0.5db. Typical mean coupling = 3 ± 0.2.

LDV also makes connectors, terminators, filters, attenuators, and Radite.

... pressure-sensitive transistor is key...

the tester through a hose, whose inner diameter is either 5/32 or 3/8 inch.

About the size of a package of cigarettes, the device is rugged. "You can drop it or throw it around, and it will still work," says Dino Zampini, a Simmonds engineering manager.

Making the tester rugged was Simmonds' biggest problem. The device's sensor is a Pitran, a pressure-sensitive transistor made by Stow Laboratories Inc. [Electronics, Jan. 23, 1967, p. 163]. "We broke quite a few of the sensors before we learned how to handle them," says Zampini.

To protect the transistor, Simmonds engineers pack it into a nylon capsule, and then put the capsule in a shock mount.

Line or lab. Zampini feels that the tester has a place both in the laboratory and on the production line. Potential customers, he says, are makers of fluidic networks and of equipment that uses fluids.

According to Zampini, the first testers were made for Pitney-Bowes Inc. which used them to check out some of its commercial products.

Simmonds believes it can capture a small segment of the pressure-transducer market with its new device. The tester has neither the range nor the linearity of some strain gages already on the market. But it does run off a couple of flashlight batteries, so it can be carried around the lab or up and down the production line.

There are three versions of the device, with ranges of 0.25 pound per square inch, and 2 and 5 pounds/square inch respectively. Linearity of all versions is 1%.

A full-range change of pressure causes a 2-volt change in output. And the output range can be set anywhere between 0 and 7 volts.

The tester responds to pressure changing as fast as 100 kilohertz, and reacts to pulses with rise times as fast as 30 microseconds.

The device's temperature coefficient is 200 microvolts per degree C. An optional model has a coefficient of 3 µV/°C.

Simmonds Precision Products Inc., Bellows Falls, Vermont [370]
Not everyone needs our 5700

Sure it’s the most accurate DVM there is — 0.0025% . And the most stable — 0.0065% for a year. But if you don’t really need a DVM that’s good enough to calibrate other DVMs, don’t buy it. Buy one of our 32 others instead.

We make them for labs and production lines, for use on the bench and in systems, militarized models, four digit DVMs and five, from $1150 to over $8000. (Actually, with our unique plug-in modules, you can create some 300 different configurations. For every imaginable application. To fit every budget.)

And no matter which of our other 32 you buy, you’ll have a DVM made with the same meticulous care as our 5700. With many of the same circuits. By the same people. To give you the confidence you’ve come to expect from Dana.

Which one suits you best? Ask for the decision maker, our free brochure.

Dana Laboratories, Inc., 2401 Campus Drive, Irvine, California 92664.
We tossed out the space wasters.

Now you can reduce the size and weight of a connector without losing a circuit.

Our Astro/348®, MIL-C81511 connector design replaced them with a contact retention system integral to the dielectric. And an interesting thing happened. Originally developed as a high-density subminiature, Astro/348 turned out to be a better miniature and standard design, too. It packs more contacts into less space than retention devices with metal clips permit.

This simplification created other advantages, too. For example, Astro/348 connectors cost less per circuit than other present-day connectors. We expect Astro/348 to become the standard connector family for the next decade.

We’d like to demonstrate how the Astro/348 is smaller in size, bigger in performance. Call or write Bob Meade for an appointment. Amphenol Connector Division, 2801 S. 25th Ave., Broadview, Ill. 60153. (312) 261-2000.
New subassemblies

**High power r-f amplifier operates at 100°C**

Designed to provide a building block for sub-kilowatt power addition, module delivers 50 watts c-w with 10-db power gain in 6 cubic inches.

A family of power modules can be used individually or in combination to provide sub-kilowatt power additions over the frequency range of 100-to-150 megahertz.

Developed by Microwave Power Devices Inc. as replacements for power tubes, the modules have a calculated mean time between failure of 15,000 hours. They are designed to function reliably at a chassis temperature of 100°C, and they provide a 50-ohm interface. The modules are gain- and phase-locked to within 0.5 decibel and 15° of an average unit, and can be easily combined—using commercially available couplers—to produce up to 500 watts.

The first units of the new series put out 50 watts in a volume of less than 6 cubic inches, although the transistors are capable of delivering more than 100 watts continuous-wave. For reliability purposes at the high operating temperature, the power amplifiers use only half the power capability of their transistors. And, says the company, as the transistor manufacturers increase the power output of their devices, 100-watt modules should become available.

---

**Regulated d-c supply PM728** is designed to provide power for digital IC applications. Output is adjustable from 4.8 to 6.3 v d-c at 3 amps. Line and load regulation is ±0.05% each and ripple and noise is less than 1 mv rms. Prices range from $124.90 (1-3) to $84.20 (100 or more). Computer Products, 2709 N. Dixie Highway, Ft. Lauderdale, Fla. [381]

**Analog-to-digital converter ADX** is based on the companion differential input multiplexer, provides random or sequential access to as many as 512 analog channels at a rate of 20,000 conversions per second for a 14 bit binary data word. Input Impedance is 500 kilohms and system accuracy better than 0.05%, Dynalex Inc., 885 Front St., Burbank, Calif. [385]

**Wideband d-c operational amplifier** 3260/25 has a guaranteed slew rate of 500 v/sec and settles to 1% of final value in 100 nsec. Rated output is ±10 v, ±30 ma. Open-loop gain is 80 db minimum. Unity gain bandwidth is 20 Mhz minimum. Voltage drift is ±25 µv/°C maximum. Burr-Brown Research Corp., Int'l Airport Industrial Park, Tucson. [386]

**D-c milliamp to frequency converter model DF-101** features three selectable input current ranges, 1 to 5 ma, 4 to 20 ma, and 10 to 50 ma, to provide direct compatibility with pressure transducers, differential pressure transducers, and certain flow meters. Linearity is ±0.025%. Anadex Instruments Inc., 7833 Haskell Ave., Van Nuys, Calif. [387]

**Power supply module HV-01-35** has multiple outputs of ±12,000 v, ±400 v and ±100 v available simultaneously. An internal voltage regulator allows operation of the supply from unfiltered d-c voltages between 35 and 50 v. Ripple is less than 0.2%. Temperature range is 0 to 50°C. Price is $149.50. Sierra Systems Inc., 2255 Old Middlefield Way, Mountain View, Calif. [388]
We'll ship them immediately—toroids and oscillators* right out of stock—at far below competitive prices.

At Allen Electronics Division, we manufacture these, and other components, in quantity for the world's finest electronic organs. So we constantly maintain a complete stock of high quality frequency sources, and over 150 sizes of toroids. We'll send you the few you need to start your idea; the many you'll need to produce it.

All Allen components are made under the most rigid quality controls, including thorough inspection and testing, at one of the most modern and efficient plants in the country.

Send for complete information on the "Prototypes". Then, when you have an application that requires quality components immediately, at no-penalty prices, you'll know where to get them. Pronto.

* Allow several extra days for packaging.

Type C Oscillator
Range: 15 Hz to 10 kHz
Use: Designed for applications having moderate requirements for stability in respect to temperature and frequency drift.

Toroids
Over 150 sizes available from stock include Permalloy, Ferrite and Powdered iron types. Some no-center-tap. Inductance tolerance ± 2%.

Building block. Typical module uses both power dividers and combiners to deliver 50 watts into 50 ohms with 5 watts of r-f drive.

Rugged. Power amplifier operates at high chassis temperature.

PT6672 transistors. Two ferrite balun transformers, $T_1$ and $T_4$, provide the 180° phase shift necessary to split the input power and combine the output power. Capacitors $C_1$ through $C_4$ set the center frequency, and the series inductance-resistance-capacitance networks in the base of each transistor act as parasitic suppressors.

The tunable capacitors in each of these networks is used to minimize any spurious responses.

To meet specifications, the modules must be adequately secured to a heat sink capable of keeping chassis temperature no higher than 100°C at the highest ambient operating temperature.

Prices of the modules depend on the bandwidth and power output requirements. Unit price for the 150-50-50-5 is $1,900. A low-temperature version is also available at a reduced price. Delivery varies from stock to six weeks.

Specifications (model 150-50-50-5)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Center frequency</td>
<td>150 Mhz</td>
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<tr>
<td>1-db bandwidth</td>
<td>50 Mhz</td>
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<tr>
<td>Power gain</td>
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<td>Efficiency (includes r-f drive power)</td>
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<td>Harmonics</td>
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<tr>
<td>Size</td>
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<tr>
<td>Shock</td>
<td>50g</td>
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<tr>
<td>Impedance</td>
<td>± 15° reference to an average unit</td>
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<tr>
<td>Phase tracking</td>
<td>± 0.5 db reference to an average unit</td>
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<tr>
<td>Gain tracking</td>
<td>± 0.5 db reference to an average unit</td>
</tr>
<tr>
<td>Environment</td>
<td>Chassis temperature up to 100°C with less than 0.5 db decrease in power output</td>
</tr>
<tr>
<td>Connector type</td>
<td>OSM Standard</td>
</tr>
</tbody>
</table>

Microwave Power Devices Inc., 226R Merrick Road, Lynbrook, N.Y. 11563 [389]
THE PARELCO R10 RELAY
2 times more pull force

Optimum distribution between magnetic core and pole piece cross sections and coil volume, and a low reluctance armature bearing produces a force-displacement product of 140 gm/mm at .050". The result is higher contact pressure and greater overtravel. Sensitivities to 20 mw/pole.

Contacts: From 2 to 8 Form C. 6 types from heavy duty 10A silver cadmium oxide to bifurcated cross bar gold — platinum — silver for dry circuits.

Coils: From 3 to 115 vdc. UL listed.

THE PARELCO R40 SLIMLINE® .43" max. thickness

Lowest profile industrial relay available. Higher switching density: .18 cu. inches/Form C. Easy pcb board layout. Lower cost, wider switching range (dry circuit to 10A) than dry reed packages. 5 mounting options.

Contacts: 2 and 4 Form C. 5 types from heavy duty 10A silver cadmium oxide to bifurcated cross bar gold — platinum — silver alloy for dry circuits.

Coils: From 3 to 115 vdc.

THE PARELCO R12 VARIABLE TIME DELAY RELAY
1/3rd the size You're now using!

All the R10 features plus a superior delay circuit using silicon transistors throughout. No false operations. Critical timing capacitor meets MIL-specs. Measures only 7.35 x 1.187 x 1.375 (2 pole) or 1.380 (4 pole). Delay range from .1 to 120 seconds — special to 300 seconds. High resolution, 15 turn pot. The only 4 Form C time delay currently available. Three mounting choices.

Contacts: 6 types from dry circuit to 10 amps.

Coils: 12, 24 and 48 vdc.

OTHER STANDARD MODELS

R11 guarded, low capacitance relay for instrumentation.

Quick Delivery — 110 standard models always in stock. Prototypes in 3 days — production quantities in 3 weeks!

PARELCO, INC.
26181 Avenida Aeropuerto
San Juan Capistrano, California 92675
Phone (714) 493-4507  TWX (810) 596-1412  See EEM Section 4506

Electronics | June 23, 1969  Circle 185 on reader service card 185
They said it couldn’t be done!

**CONTROL METER RELAY**
with 50% savings and high performance

WELL, THEY WERE WRONG! After a year of customer use in the field, our customers report that our units are consistently providing high accuracy and high reliability — and they must be right because they are re-ordering and pocketing cost savings of up to 50%. Why not join our increasing list of satisfied customers now?

Beede’s Non-Contacting Control Meter Relay was initially designed to offer a wide choice of design options for the greatest application versatility. For instance:

- 8 or more choices of power supply
- 4 choices of fail-safe configuration
- 10 or more choices of output mode
- 9 choices of alarm lights and reset switches
- Many special features such as tamper-proof units, fixed set point
  er stops, etc.
- Pyrometers and resistance thermometers

Write for complete literature today!

**NEW SUBASSEMBLIES**

**Transmitters accurate to 0.1%**

Instruments for control include auxiliary alarms, adjustable set points

All standard thermocouples are accepted by a line of process-control transmitters from Deltron Inc. Each of the 15 models can produce a regulated current output proportional—within a 0.1% accuracy—to a thermocouple or millivolt signal.

Output ratings include the three most widely used process current ranges: 1 to 5 milliamps at 0 to 24 volts, 4 to 20 milliamps at 0 to 24 volts, and 10 to 50 milliamps at 0 to 12 volts. Input suppression is adjustable from 5 to 50 millivolts for full-scale output.

The transmitters can be supplied with single and dual auxiliary alarms that produce a contact operation when the input reaches a preset value. The set point is adjustable from 0 to 100% of input range, and in dual alarms both set point adjustments are independent. Adjustable dead band is provided on each alarm.

All of the components in the 15 models of the new line are solid state. The models provide for front-connected field wiring. Deltron says that the transmitters are immune to line fluctuations, that the 0.1% accuracy is independent of load changes, and that calibration will hold for one year. Additional features include thermocouple break protection and little temperature drift.

Three models accept type J thermocouple inputs, three are designed for type K, three for type R, three for type T, and three accept millivolt signals. Thus the line covers the range of inputs used in process control.

The basic price is $150 each; with single alarm, $200; with dual alarm, $240. Delivery time is four to six weeks.

Deltron Inc., Control Division, Wissahickon Ave., North Wales, Pa. [390]
Get up to 1000 units of 2N3773 and 2N3054 transistors in less than two weeks. Now from Westinghouse.

What's more, we'll also give you fast service on larger orders. However many it takes to fill your total requirements.

Our 2N3773, 2, 1 (TO3) is a family of 30-amp diffused transistors for high power switching and amplifying applications. They offer a wide selection of voltage and gain.

Our 2N3054 (TO66) is a 4-amp device used to drive our 2N3773, or as the output stage in low-to-medium power applications.

For complete data — and a large ready supply — of any and all of these transistors, contact your local Westinghouse Sales Office or Westinghouse Semiconductor Division, Youngwood, Pa. 15697.

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

Circle 187 on reader service card
Meet the MICRO SWITCH Quality Assurance Department

Left to right: vice president, design engineer, computer programmer, punch press operator, and shipping clerk.

Not present for picture: All the other employees of MICRO SWITCH.

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HONEYWELL INTERNATIONAL Sales and service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.
New microwave

Yig-tuned Gunn oscillators sweep X band

Two companies market solid state replacements for bwo’s; reliability, size provide edge in generator applications

Backward-wave oscillators haven’t yet had to take a back seat to solid state replacements, but the time may be fast approaching.

A yig-tuned Gunn Effect oscillator has been developed as a product by Varian Associates, and the company bills it as a replacement for a bwo (Electronics, Sept. 30, 1968, p. 44). The oscillator sweeps electronically from 8 to 12.4 gigahertz, thus covering all of X band. Minimum power output is 10 milliwatts, and the device can put out up to 40 milliwatts.

Another San Francisco-area company, Physical Electronics Laboratories, has put a yig-tuned Gunn oscillator on the market. Designated the OX-100, it also provides a minimum of 10 milliwatts swept power output over 8 to 12.4 Ghz. Maximum power deviation is 6 db over the full band, and tuning linearity is 0.1 %. The OX-100 is the first of a family being developed to cover the 4-18 Ghz range.

Swept frequency module model CX-12 generates 0.1 to 5 Ghz continuous sweep or any portion of it in one band, with an external unlevelled swept source delivering 10 to 50 mw from 7 to 12 Ghz. The CX-13 generates 4 Ghz continuous sweep or any portion of it in two bands, one extending from 0.1 to 4.1 and one from 4.1 to 8.1 Ghz. Space Kom Inc., Box 235, Goleta, Calif. [4011]

Miniature coaxial directional couplers series CB are 6, 10, 20 and 30 db devices that cover full octave ranges from 2 to 12.4 Ghz, offering flat coupling, high directivity, and low vswr. Maximum insertion loss is 0.2 db; power rating, 100 w average, 3 kw peak; directivity, to 25 db; maximum vswr, 1.30, coupling accuracy, ±0.1 db. Microlab/FXR, 10 Microlab Rd., Livingston, N.J. [4022]

Transistorized amplifier model WAI-225-400-20 has a gain of 33 db with a power output of 20 w. Harmonic response is typically −20 db below rated power output with an over-all amplifier efficiency of 40%. Reliability analysis indicates a mean time before failure figure in excess of 15,000 hours. Microwave Power Devices Inc., 556 Peninsula Blvd., Hempstead, N.Y. 11550. [4034]

Hybrid thin film r-f amplifiers series 4A are suited for use in severe environments. Frequency range is 500 to 4,500 Mhz; bandwidth, 25 Mhz to several octaves; noise figure, 3 to 12 db; gain, 25 db; power output, to +30 dbm; input/output impedance, 50 ohms; and temperature range, −54° to +71° C. Estimated mtbf exceeds 250,000 hours. Locus Inc., Box 740, State College, Pa. [4044]
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FH-301

FH-302

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The line consists of three (3) basic models: FH-300 Flip Chip, FH-301 with wire leads, and FH-302 with PC lead strip. Typical characteristics of the FH-300-040 are:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Resistance, $R_i$</td>
<td>40 - 80Ω</td>
</tr>
<tr>
<td>Output Resistance, $R_o$</td>
<td>1.4Ω</td>
</tr>
<tr>
<td>Nominal Control Current, $I_n$</td>
<td>15 mA</td>
</tr>
<tr>
<td>Product Sensitivity, $y_p$</td>
<td>1.4 V/A • kg</td>
</tr>
<tr>
<td>Magnetic Sensitivity, $y_m$</td>
<td>20 mV/KG</td>
</tr>
<tr>
<td>Temperature Coefficient, $y_t$</td>
<td>-0.08%/°C</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>-55°C to +100°C</td>
</tr>
</tbody>
</table>

Detailed Specifications on All Thin Film Hall Generators are available on request.

Send for SAMPLE EVALUATION KIT! Contains one each of three thin film HALL-PAKS® with a detail application booklet — $6.50 plus 50¢ handling charge.

*10,000 units or more

Announcing

the newest shape in receiving antennae

Challenger. Varian's Gunn oscillator is shown in front of a bwo. The Gunn unit's tuning element is a yig sphere—in center of the cross-section drawing.

products, says that Varian's price would go down to a thousand dollars or so for large orders. "Ultimately," he adds, "the Gunn oscillator will be cheaper than the bwo." Physical Electronics Laboratories' unit, temperature-compensated and built for military use, sells for $3,000.

Constable of Varian stresses that in addition to being smaller and lighter than a bwo, a Gunn unit is less noisy and more reliable. "Bwo's have to be replaced once a year," he says. "There's nothing to fail in the Gunn oscillator but the diode; we have run tests on 16 units, and the results can be expressed as a 25,000-hour mean time between failures, with a 90 per cent confidence level."

Varian and EEL are the first companies to announce Gunn oscillators for X and K bands—though the Hewlett-Packard Co., which could use such a unit in its sweep generators, is expected to market a product soon, and Watkins-Johnson Co. will have a solid-state oscillator at X band within two months. Watkins-Johnson makes the multi-octave source,
a yig-tuned harmonic generator, that went into the 1 to 12.4-GHz sweep generator introduced three months ago by the Narda Microwave Corp. [Electronics, March 31, p. 147].

**Outgrowth.** The Varian unit, dubbed the VSX-9070, is the outgrowth of an experimental device built last year by Mashiro Omori and Gene F. Day of the company’s central research labs. That unit weighed 1.8 pounds and measured 10 cubic inches; Varian hoped to cut each of those figures in half before announcing a product. Omori now says that Varian did get the oscillator down to 5 cubic inches and under a pound—but the required magnetic shielding brought the measurements right back up again.

Varian succeeded in shrinking the magnet gap, in which the Gunn diode, the yig sphere, and the microwave circuitry must lie, from 200 mils to 90 mils. Tuning power is thus cut to a specified 6 watts, but Omori says it is actually about 3.5 watts. He used microstrip for the circuits, and a packaged Varian diode for the source. Originally, the magnet was a solid core; but Omori found that fast tuning caused eddy currents that heated up the metal, so he switched to a laminated core.

In transferring to production status, Omori says, the principal problem has been teaching operators to align the yig sphere.

The circuitry in PEL’s oscillator is also microstrip, in a coaxial configuration. The magnet gap is 100 mils—but the gap on the C-band unit will be 50 mils. The PEL oscillator, which uses a Gunn diode made by Varian, requires a tuning power of about 7 watts. It measures 31 cubic inches and weighs 3.5 pounds. Delivery time is one month.

**Specifications (Varian model VSX-9070)**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuning current, max</td>
<td>1.0 amp</td>
</tr>
<tr>
<td>Tuning voltage, max</td>
<td>6 v d-c</td>
</tr>
<tr>
<td>Bias voltage range, max</td>
<td>9-12 v d-c</td>
</tr>
<tr>
<td>Bias current, max</td>
<td>600 ma</td>
</tr>
<tr>
<td>Hysteresis swept either direction, max</td>
<td>50 MHz</td>
</tr>
<tr>
<td>Power variation over band, max db</td>
<td>6 db</td>
</tr>
<tr>
<td>Size</td>
<td>10 cu. inch</td>
</tr>
<tr>
<td>Weight</td>
<td>2 lb</td>
</tr>
<tr>
<td>Availability</td>
<td>75 days</td>
</tr>
</tbody>
</table>

**Varian Associates, 611 Hansen Way, Palo Alto, Calif. 94303 [409]**

**Physical Electronics Laboratories, O'Brien Drive, Menlo Park, Calif. [410]**

---

**Solitron Devices, Inc.**

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\[ t_R @ 2.0 \text{ A} = 10 \text{ n sec Max} \]

\[ I_C \text{ Max} = 5.0 \text{ A} \]

Solitron’s new SDT6100 Series of 5.0 Amp fast switching power transistors have total switching time typically less than 60 nanoseconds and rise time less than 10 nanoseconds. They are designed to function in place of many parallel high speed, low current units.

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We brought out our 3½-digit compact DPM just last March. It's the one that plugs into a panel slot only seven inches square, and pulls out for servicing or replacement. If you need the accuracy of 3½ digits, Model 1290 is still your best buy. But if you can settle for a digit less, you can have our new Model 1260 at less than half the price. Don't be fooled by the price tag; though . . . there's nothing "cheap" about this 2½-digit version. Housed in the very same plug-in case and fully compatible with its more sophisticated brother, Weston Model 1260 offers 0.5% ±1 digit accuracy—with far greater resolution capability than mechanical movements provide. Full scale reading is 199, with 25% over and under-range capability, remote command signal and Weston's usual high rejection characteristics. In addition to the convenience of front panel pluggability and circularly polarized viewing, we've included front panel calibration as a built-in bonus feature on the 1260.

Write to the originators of the DPM. WESTON INSTRUMENTS DIVISION, Weston Instruments, Inc., Newark, N.J. 07174. a Schlumberger company.

Prices for Models 1290 and 1260 based on quantities of 25.
*U.S. Pat. 3,051,939 and patents pending.
MOS read-write memory goes to market

First standard building block is 128-bit random-access device; 900-nanosecond unit to compete with the cores for 500-1,000 word storage jobs.

It's still a matter of speculation in the metal oxide semiconductor business as to what size memories will shake out as standard building blocks. There seems to be a good deal of backing for 256 bits, but no one is delivering standard 256-bit MOS memories. Electronic Arrays Inc., has settled on a 128-bit device organized as 64 words, each 2 bits long; and this appears to be the first off-the-shelf MOS random-access read-write memory available.

By introducing the EA 1400 this month, Electronic Arrays appears to have stolen the March from American Micro-systems Inc., which is expected to have a standard 128-bit MOS random-access memory available from stock early next month. The EA 1400 is now available from distributors and off the shelf at the firm's headquarters.

The device has 978 MOS FET's forming 128 storage flip-flops, and also includes address decoding from six input lines, plus output buffers, all on the chip. It has a specified read or write time of 900 nanoseconds. EA officials expect it to be used in larger arrays in...
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which customers are looking for 500 to 1,000 words of memory. “We believe we’ll be competitive with cores in smaller memories,” says Earl Gregory, vice president and director of marketing. “And while there’s been a lot of talk about 256-bit memories, 32 bits is about the most complex device being delivered. We decided that 128 bits makes for a reasonably functional device that is truly manufacturable in quantity,” he adds, “and we’ve seen some interest in the smaller bit lengths.”

Some dynamic cells are refreshed by addressing each bit location individually. In the EA device, a strobe pulse on only one of the six input lines restores data. The line powers each cell in the array. According to EA engineers, even memories with no refresh capability usually require 2 to 3 milliwatts per bit to operate, compared with about 1 mw for the 1400. In a standby condition, the strobe can be operated at intervals of 0.1 microsecond, using only microwatts.

Discriminates. A chip-select feature on the EA 1400’s output enables selection of the next device, in a group of such arrays, that will be activated. This coupling of the outputs to activate another array on the read or write cycle is needed if a number of the devices are combined to build a 500- or 1,000-word memory.

Another feature EA officials cite as important is the 1400’s separate input and output lines. Some memories use a common bus, necessitating somewhat complicated gating to switch from reading to writing. This isn’t necessary with separate input and output lines.

As with all standard products introduced by the firm to date, the EA 1400 operates on a drain supply level of 12 to 14 volts; the gate voltage is —24 to —28. The output logic level for a “zero” condition is 0 volt minimum and —1.0 volt maximum; for a logical “one”, the levels are —10 volts minimum and —14 volts maximum.

Data read rate, data write rate, and strobe repetition rate are all 1 megahertz. The EA 1400 is housed in a 16-pin dual in-line ceramic package. It sells for $35.60 each in quantities of 100.

Electronic Arrays Inc., 501 Ellis St., Mountain View, Calif. 94040 [444]
A SOLUTION TO A COMPLEX WIRING PROBLEM.

Untangle the electrical wiring maze now! The Deutsch-developed Integrated Termination System (ITS) introduces simplicity and organization into your system and eliminates virtually every source of possible trouble in high-performance electrical interconnection for man-rated vehicles.

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All ITS components are in production and readily available for almost every interconnection assignment. Let us tell you more. Call your local Deutschman or write for our ITS Data File.

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IRC's new precision wirewound trimmer in dual-in-line package simplifies PC board layout. Pin spacing is the same as the popular TO-116 size integrated circuit. It is fully compatible with high-speed automatic inserting equipment.

The sealed, moisture-resistant units meet the environmental requirements of MIL-R-27208. Maximum height is only .200 inches. 1 watt @ 40°C. 10Ω to 20K. ±10% tolerance. TC is ±50ppm/°C.

Pin spacing of these ⅛" square trimmers matches the ¼" square unit. Only .062" larger on each side they can cut your cost almost in half and give you three times the power rating of the ¼" and 40% better resolution.

Two types are available—precision wirewound and infinite resolution Metal Glaze. Both are fully sealed and impervious to common industrial solvents because of a silicone rubber shaft seal and epoxy bonding at all seams.

For data and prices, see your IRC Industrial Distributor or write IRC St. Petersburg Division of TRW INC., 2801 72nd Street, North, St. Petersburg, Florida 33733
New Books

A hot subject

Infrared System Engineering
Richard D. Hudson, Jr.
John Wiley & Sons Inc., 642 pp., $19.75

For nearly two decades following Pearl Harbor the vast body of infrared engineering knowledge was locked up in military secrecy. Then, in the late fifties, declassified i-r literature began trickling into the public domain. As more material became known, Hughes Aircraft scientist R. D. Hudson prepared to realize a long-held ambition—to write a practical, lucid text on infrared technology.

His book is probably the last word in the field to date. Its relevance to the equipment designer can be traced to the author's extensive industrial experience with infrared, his appreciation for systems engineering, and the organization of the book, which rests on the principle of a simple block diagram. All i-r systems, according to the author, consist of eight elements: a target (or radiation source), the attenuating atmosphere, an optical receiver, an optical modulator, a detector cooling mechanism, a signal processor to handle the detector's output, and a display.

The author then proceeds to examine the elements chapter by chapter, each one revealing a distinct technology. Natural and man-made sources of i-r radiation (in the spectral portion from 0.75 to 1,000 microns) are investigated as are atmospheric effects on i-r transmission. Optics and the use of rotating reticles as optical modulators are reviewed followed by a chapter on noise and three chapters on detectors, their characteristics, performance, and limitations. At no point does the author dwell on fancy derivations; only equations pertinent to an understanding of the physical and engineering concepts are given.

After a discussion on cooling techniques, signal processing, and displays, the author pulls together the different technologies for a systems analysis, replete with tradeoff studies and advice on the

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Circle 197 on reader service card
The ideal flight recorder according to a recent survey of users:

Would be rugged (for overall airborne operation), yet lightweight (less than 25 lbs.)

Must operate on very low power (say, 40 watts)

Would have a stop/start speed of less than 200 milliseconds

Should function as a digital "computer memory," with a read or write capability of 100,000 bits per second and a guaranteed bit error rate of less than $1 \times 10^{-7}$

Must provide a lot of storage (how about 140 million bits?) in a small package (around 600 cubic inches)

The ideal flight recorder according to Leach:

Thanks to a patented new technique called HDDR* (High Density Digital Recording), our new MTR-8600 is a spec-for-spec match of the recorder-by-consensus (above). And more. And, it's available now in a more conventional package from Leach Corporation, Controls Division, Department A, 717 Coney Ave., Azusa, California 91702 (213) 334-8211.

The MTR-8600
New Books

best systems performance.

If the reader wonders at this point about the dearth of examples, he will find them all contained in the next chapter on the development of an i-r search system for commercial jet transports.

On the applications of i-r techniques, Hudson devotes five chapters to military, industrial, medical, and scientific applications. However, instead of presenting the usual how-to-do-it examples, he annotates some 1,400 references of i-r literature from books, periodicals, declassified government sources, and especially from patent disclosures. Each reference summarizes the content, hardware, and results of the engineering work described. In a later appendix, he directs the reader to unpublished and classified sources.

The book also makes for interesting reading, particularly the introductory chapter where Hudson traces infrared history from its discovery in 1800 by Sir William Herschel, through the Lichtsprecher, an i-r communication system used by the Germans in the African desert during major tank battles, down to the Government clam-up on i-r information in the post-war years. Hudson estimates the 1968 market figure of i-r devices to be $350 million annually, 75% of which go into military applications.

Recently published

Electron Optics, B. Paszkowski, American Elsevier Publishing Co., 305 pp., $13.00

A graduate level text, this book also presents many practical design curves for electronic lenses and deflecting systems. Subject coverage also includes field distributions and defects of electron-optical imaging.

Bessel Functions with Some Physical Applications, C.J. Trantcr, Hart Publishing Co., 149 pp., $10.00

An up-to-date treatment of applications of Bessel functions, the book also includes many exercises at the end of each chapter. Aimed at mathematicians, it could also be of use to engineers with strong mathematical backgrounds.
Plotting the dielectric constant of a TEFLON resin against frequency, or temperature, or what-not makes a pretty dull-looking graph.

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But once established, it remains a fixed design constant. This is particularly important to designers of RF cable who require the highest propagation velocity and a constant impedance — and to designers of microwave transmission lines.

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A straight line parallel to the X axis is about all you get when you plot the dielectric constant of a Du Pont TEFLON fluorocarbon resin — over a wide frequency range — and over a wide temperature range. The same stubborn constancy applies also to the other excellent electrical characteristics of TEFLON: a dissipation factor of only 0.0002 and a high dielectric strength (500 volts/mil).

The dielectric constant is in the lowest range of any solid material; between 2.0 and 2.1, depending on the exact TEFLON resin used and its processing.
Technical Abstracts

Too close for comfort

A proposed low cost proximity warning device for aircraft
L.C. Drew, W.R.L. Thomas, A.G. Atward
C. Park and H. King
RCA
Burlington, Mass.

There's been a lot of talk about proximity warning indicators that set off an alarm when two aircraft fly too close but no one seems to do much with them. Cost has been the big problem: the indicators must be cheap enough so the owner of the smallest aircraft could afford to buy one.

RCA's Defense Electronic Products group, the latest organization to do some talking, proposes a system that detects the visible and near infrared radiation emitted by the xenon strobe lights currently being installed atop aircraft. These pulses last about a millisecond. The system includes silicon detectors, focusing lenses, the signal processing circuitry necessary to discriminate an actual signal from the strong visible and i-r radiation coming from the daylight sky, and a display panel in the cockpit. And, when produced in quantity, it will be low cost. However, no price is yet available.

Calculations show that the range of the system could be as much as six miles in clear daylight conditions, about three miles when conditions are hazy. Flights tests of a device using a single silicon detector have confirmed these ranges.

The system will use 24 silicon detectors, arranged in an immobile circle around the bottom of the xenon strobe. With molded plastic lenses the system views the horizon over a 360° angle, and through an elevation of 15° without scanning.

Pairs of adjacent detectors, each having an area of about one square centimeter, will be connected to a common preamplifier so as to provide 12 horizontal sectors. Each lens will be less than 6 inches in diameter.

An amplitude discriminator in the system sorts the signals received from an intruding aircraft by the detectors. Amplitude is also
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- Make medical check-ups a family routine.

Set a good example. Follow the rules yourself and guard your heart, too.
Technical Abstracts

an indication of range, and the detectors themselves indicate the direction of the signal. Following this initial sorting, the signal passes through a pulse width filter that rejects pulses whose widths are greater than 1.5 milliseconds. This effectively eliminates the back-ground radiation.

After it is filtered, the pulse is stretched to approximately 11 milliseconds to light indicator bulbs on the cockpit display. This display, which consists of three concentric circles of bulbs, also indicates the direction of an intruding aircraft. A bell could also ring to alert the pilot. It's up to the pilot, then, to look for the intruder and decide on the evasive action to take to avoid a collision.

Large scale integrated circuitry, made with metal oxide semiconductor (MOS) technology could be used to bring costs down. This would also reduce the power requirements.

A self-test feature, using an infrared emitting gallium arsenide diode giving millisecond flashes every second could also be included. The output from this diode goes into the lens assembly and is distributed simultaneously to all the detector elements. This lights all of the indicator bulbs on the pilot's display panel at the same time. The test can be made to trigger the audible alarm as well.

Presented at the National Aerospace Electronics Conference (Naecon), Dayton, Ohio, May 19-21.

Bridge building

Crossovers for interconnections on substrates
H. Basseches and A. Pfahnl
Bell Telephone Laboratories Inc.
Allentown, Pa.

Some hybrid integrated circuits have so many elements that it's impossible to interconnect all of them in one plane. Designers then are forced to cross thin film conductors over each other. They do so either by separating the conductors with a dielectric such as silicon dioxide or glass, or by stitch type structure, consisting of electro-bonding gold wires. Now a third type, electroplated pillars and beams, offers

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Standard 20W model
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SHF Band
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4-port model, 4GHz

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203
Mechanical and electrical advantages that make it compatible with both tantalum thin film and beam lead ICs.

Preparation of the beam crossover structures—originally developed by Martin Lepselter of Bell Labs—includes photolithographic techniques that make batch processing possible.

The substrate is first cleaned, titanium and gold are evaporated and plated onto it, and the bottom conductor pattern is delineated by etching. Next, the pillars that raise the top conductor, thereby preventing shorts, are formed in three steps. First, by evaporation a sandwich of titanium-copper-titanium is plated on. Then photolithographic techniques are used to etch away the sandwich, leaving only the regions for the pillars and crossover span. Finally, a preferential etch removes the copper spacing layer between the two conductors.

During a test program, 263 substrates were made. The yield was 63%; out of the 75,000 crossovers contained on these substrates, 99.2% were good. Leakage currents were measured at $10^{-11}$ amps and breakdown voltages ranged from 300 to 400 volts. Encapsulation lowered the leakage currents below this figure at 100 volts and raised breakdown voltages in some cases to over 1,000 volts.

Because beams and pillars are plated at high temperature, the former are under tension when the substrate cools to room temperature. To test beam stability, 103 substrates were cycled ten times from $-40^\circ\text{C}$ to $+150^\circ\text{C}$. Out of the 3,045 crossovers tested only three were open and four were shorted.

Circuits with the beam type crossovers have been made on the same substrate as Ta$_2$N resistors. Resistor values hardly changed during crossover fabrication. However, anodizing techniques have been developed to trim the resis-
tors if adjustment is required after the crossovers have been formed.
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  - capsule (0...1 kgf/cm²)
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- Differential pressure transmitters with
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  - bellows (0...400 mm H₂O)
  - bellows (0...35000 mm H₂O)
- Area type flow transmitters:
  - 0, 24...54, 94 m³/h
- Electromagnetic flow transmitters:
  - 0, 41...1770 m³/h
- Displacement type liquid level transmitters:
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- pH transmitters: 0...12 pH
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- Miniature indicators
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New Literature

Solderless disconnect system. Thomas & Betts Co., 36 Butler St., Elizabeth, N.J. 07207, has issued bulletin 500.3 on the Connecto-Blok solderless disconnect system for high density wiring used in numerous military and commercial communications applications requiring high reliability. Circle 446 on reader service card.

Indicator lights. Eldema, 18435 Susana Rd., Compton, Calif. 90221. H-Lites, subminiature relampable indicator lights for T-1 bulbs, are described in an illustrated four-page brochure. [447]


Operational amplifier. Analog Devices Inc., 221 Fifth St., Cambridge, Mass. 02142, offers a data sheet on the model P501 IC operational amplifier with high impedance FET input circuitry. [449]

Magnetic instrumentation. Thomas & Skinner Inc., 1120 E. 23rd St., Indianapolis 46205, has published bulletin A-937 illustrating and describing the latest addition to its line of magnetic instrumentation. [450]

Test chambers. Statham Instruments Inc., 2230 Statham Blvd., Oxnard, Calif. 93030. Choosing the correct test chamber to meet particular requirements is simplified by a compact brochure that features a handy reference chart. [451]

Flying-spot scanner tube. Warnecke Electron Tubes Inc., 175 W. Oakton St., Des Plaines, Ill. 60018. A two-page data sheet provides description, characteristics and voltage ratings of the type RW-12AB, 3-in. diameter CRT designed for high-resolution flying spot scanning. [452]

Switch and relay tester. Mason Electric Co., 3339 Verdugo Rd., Los Angeles 90065, has released a data sheet on the model 552 Chatter Monitor, a new switch and relay tester. [453]

Electrostatic recorder. Varian, Electrographics Division, 611 Hansen Way, Palo Alto, Calif. 94303. The Statos 3, an 8-channel electrostatic recorder, is described in an eight-page brochure. [454]

Audio amplifier IC. Trans-Tek Mfg. Co., South Plainfield, N.J., has available a catalog featuring a 1-watt audio amplifier integrated circuit. [455]
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Circle 207 on reader service card
Precise temperature sensing. Texas Instruments, Box 5012, Dallas 75222. Application report CA-125 shows how to use Sensistor precision temperature-sensitive resistors. [456]


Spectrum analyzer. Synstron-Donner Corp., 14844 Oxnard St., Van Nuys, Calif. 91409. Model 710/800 portable calibrated spectrum analyzer, offering universal measurement capability from 10 Hz to 50 kHz, is described in a four-page brochure. [458]

Capacitor catalogs. Del Electronics Corp., 250 E. Sandford Blvd., Mount Vernon, N.Y. 10550, has available a complete set of catalogs for wrap and fill, hermetically sealed, ceramic cased, phenolic cased, and polystyrene capacitors. [459]

Time-sharing systems. General Electric Co., Schenectady, N.Y. 12305. Features of the GE-400 time-sharing systems are described in 28-page booklet GEA-8868. [460]

Linear IC applications. Signetics Corp., 811 E. Arques Ave., Sunnyvale, Calif. 94086, has available a 24-page brochure detailing its line of linear devices and more than 45 specific applications for both the circuit and system designer. [461]


P-c connectors. Continental Connector Corp., 34-63 56th St., Woodside, N.Y. 11377, has available an 80-page P-c connector catalog covering printed card and tape cable applications. [464]

Transmission line cables. Aci Inc., 206 Industrial Center, Princeton, N.J. 08540, offers a brochure on Signaflo flat transmission line wiring systems designed to offer plug-in adaptability for the most popular digital small and desk-top computers. [465]

P-c materials. Westinghouse Electric Corp., West Mifflin, Pa. 15122, has published a comprehensive guide (B-9542)
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New Literature

to its Micarta copper-clad materials for use in rigid, multilayer and flexible printed circuits. [466]

Digital sine generator. Unigon Industries Inc., 200 Park Ave., New York 10017, has issued a data sheet on the model SC-90 all-digital sine generator. [467]

Magnets. Reed Switch Developments Co., 34 Lincoln Ave., Greenwich, Conn. 06830, has published a bulletin describing magnets for reed switching. [468]

Microminiature potentiometer. Minelco, 600 South St., Holbrook, Mass. 02343. Properties and characteristics of the model MP32 microminiature trimmer potentiometer are highlighted in a comprehensive data sheet. [469]

Instrumentation tape and reels. Ampex Corp., 401 Broadway, Redwood City, Calif. 94063. Brochure T-349 describes the low-abrasive characteristics of the 700 series magnetic instrumentation tape and precision design features of the company's tape reels. [470]


Frequency calibrator. Motorola Communications and Electronics Inc., 1301 E. Algonquin Rd., Schaumburg, Ill. 60172. Brochure TIC 3455 describes the model S1315A frequency calibrator. [472]

Digital memory modules. Electronic Products Division of Corning Glass Works, Corning, N.Y. 14830, has published data sheet MCA-5.07 on its low cost, high speed digital memory modules. [473]

Interchangeable thermistors. Fenwal Electronics Inc., 63 Fountain St., Framingham, Mass. 01701. Catalog L-6 covers Uni-Curve curve-matched interchangeable thermistors. Copies are available upon letterhead request. [474]

Rotary switches. Cherry Electrical Products Corp., 1650 Old Deerfield Rd., Highland Park, Ill. 60035. New lever wheel and thumbwheel rotary switches are described in an eight-page brochure. [474]

Hybrid circuits. Cermex Division of Frenchtown/CFI Inc., 8th and Harrison Sts., Frenchtown, N. J. 08825, has published a four-page bulletin describing company capabilities for the manufacture of custom thick film hybrid circuits. [475]

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Cartridge-type vtr
to be marketed
by Victor of Japan

RCA to handle
Canadian satellite's
production

Plessey in bid
for ILS business

The decision of the Victor Co. of Japan to market a video cartridge recorder signals the start of a period of competitive maneuvering before consumer electronics manufacturers settle down to a standard vtr format. That’s the view of industry observers, who point to the fact that every Japanese producer of vtr’s now uses a different format.

Victor’s announcement comes close on the heels of Sony’s decision to put its money on a cassette [Electronics, May 12, p. 239]. Victor’s, which the company plans to market in the first half of 1970, uses a cartridge measuring 5.51 by 5.51 by 0.91 inches and containing one-half-inch-wide tape. The tape speed is 7.5 inches per second, and maximum playing time is 30 minutes. The tape to be recorded or played back is inserted into a slot and the mechanism inside automatically threads it.

The new cartridge, Victor points out, is about one-seventh the size of Sony’s, and the playing time about one-half. The Victor cartridge cannot be removed from the recorder unless it is completely rewound. The recorder, which measures about 18 by 16 by 8 inches and weighs nearly 8 pounds, uses the direct f-m combined recording system announced by Victor last March; this technique permits it to record the 4.5 MHz NTSC color signal at the slow tape speed. The recorder has a built-in modulator so that color or black-and-white programs can be played back by connecting the recorder to tv antenna terminals. Audio is on dual stereo tracks. The recorder will sell for $550. Unrecorded cartridges will be priced at about $27; prerecorded tape, less than double that.

RCA Ltd., Montreal, looks sure to be prime contractor for the satellite portion of Telesat Canada’s communications system. With launching of the communications satellite scheduled for late in 1971, preliminary work is expected to get under way by the beginning of next month.

Meanwhile, the bill setting up a tri-partite corporation to operate the system has gone through its third reading in the House of Commons, and final approval is expected by the end of the current session. Government and common carrier companies will each have a 30% interest in the new corporation, with 40% of the shares to be available to the public.

Although RCA Ltd. will be prime contractor, negotiations are still in progress on how to allocate subcontracts to retain as much business as possible for Canadian companies. It’s figured that RCA will wind up with about 30% and rival Northern Electric will get about 25% with the balance spread around to other contractors. No details on contract assignments have been disclosed as yet, but Northern Electric is most likely to be given responsibility for the transponder portion. The final contract with RCA is not expected to be signed for at least four months.

In a move to become a leading international supplier of the next generation of aircraft instrument landing systems, the Plessey Co. has submitted a system proposal to the Radio Technical Commission for Aeronautics in Washington. An RTCA committee is working on a new ILS specification and has about a dozen proposals, all from U.S.-owned companies except for Plessey’s.

Because about half the world ILS market involves American aircraft,
the choice of the RTCA committee is likely to be a major factor in determining which spec is eventually accepted as the standard by the International Civil Aviation Organization.

The Plessey proposal is based on a system developed by the Royal Aircraft Establishment and called a correlation-protected ILS. It replaces tone comparison of vhf signals, used on present systems to correct glide path in azimuth and pitch. Instead, the CPIILS compares the time of arrival at the aircraft of microwave pulses or random noise patterns transmitted simultaneously from both sides of the runway and above and below the correct vertical approach path.

West Germany's Olympia-Werke AG is jumping into desk-top calculators in a big way. Hot on the heels of the disclosure that it would buy 30,000 calculators in the next year from Japan's Matsushita Communications Industrial Ltd. [Electronics, June 9, p. 201], West Germany's largest maker of office machines revealed plans to start up calculator production in Northern Ireland.

In mid-June, following up on earlier Olympia contacts, Roy Bradford, Northern Ireland's trade minister, visited the main Olympia plant in Wilhelmshaven. Current company thinking calls for a plant in the Belfast area to open by year-end with a workforce of several hundred.

Behind the Northern Irish venture, says Olympia, is the foothold it gives the company in the seven-nation European Free Trade Association and its growing market for calculators. That market is expected to take off when Great Britain changes over to decimal currency—and decimal accounting—in February 1971. And while details of production are still being worked out, the move to calculator manufacture should provide an in-house market for components made by Olympia's parent, AEG-Telefunken, West Germany's second largest electronics-electrical combine.

England's Hawker Siddeley Dynamics will be prime contractor for the European Space Research Organization's 200-pound scientific satellite ESRO 4, scheduled for launch in September 1972.

ESRO 4 will actually be the fifth in the series and will replace the more expensive TD/2 satellite, canceled last year. It will bear close resemblance to ESRO 2, launched in May 1968, but will have a more sophisticated magnetic attitude control system to allow eight maneuvers under ground control.

On board ESRO 4 will be five experiments contributed by universities in Britain, Germany, the Netherlands, and Sweden, and originally scheduled for TD/2.

Texas Instruments' new plant in Ingolstadt in southern Germany, the company's sixth in Europe, will employ about 500 and concentrate on production of plastic-encapsulated transistors . . . Ampex Corp. will build a plant in Battice, Belgium, to manufacture magnetic tape . . . Yugoslavia's Nikola Tesla factory in Zagreb has a $16 million backlog of orders for automatic telephone and telegraph equipment to be delivered in 1969. One-third is marked for export . . . Control Data Corp. is reported pushing hard to win approval for installation of its 6600 in a Japanese computer center . . . Page Europa, Rome, won a $6.5 million contract for installation of NATO command communications in Lisbon.
European pacemaker’s a pace setter

Seven-nation syndicate on Continent develops long-lived battery that needs less nuclear fuel than U.S., British versions; wristwatch battery may be next

**For long-lived** nuclear pacemaker batteries, there’s a considerable market in the offing and the first to tap it could well be a seven-nation syndicate set up within the European Nuclear Energy Association (ENEA).

The syndicate has developed a battery that needs only half as much plutonium 238 as those of its British and American competitors. What’s more, the multinational group, made up of firms and government agencies from Austria, Denmark, France, Spain, Sweden, Switzerland, and West Germany, has an edge in time if all goes according to plan. Better still, an offspring of the Continental battery may one day power wristwatches and open up yet another vast consumer market.

**Gallic.** The group developing the battery and a pacemaker to pair with it has a strong French accent. France’s Commissariat à l’Énergie Atomique, the country’s nuclear agency, devised the plutonium fuel source. The other main element in the battery—its semiconductor thermocouple—is the work of France’s Société Alcatel. Other major contributors to the project include France’s Thomson-CSF and West Germany’s Siemens AG.

Largely because of Alcatel’s bismuth telluride thermocouple package, the ENEA battery needs only 150 milligrams of Pu 238, compared with more than 300 milligrams for the battery in the works at the U.K. Atomic Energy Authority and the one developed in the U.S. by the Nuclear Materials and Equipment Corp. The ENEA battery generates 700 microwatts and the British battery, 540 µW [Electronics, March 31, p. 180].

Trials on dogs have just begun in a Paris hospital and the ENEA hopes the pacemaker will be ready for test implants in human patients by early 1970. That’s about six months ahead of the British planning. The U.S. nuclear battery too, has been implanted in a dog but doesn’t seem likely to get clinical tests until at least 1970 but more probably not before 1971.

Thus far, the electronics in the ENEA pacemaker are standard, but Alcatel is working on new circuitry that is expected to reduce the power-supply level from the 5 volts needed now to the 2 volts the battery develops. That will end the need for a d-c to d-c converter and further reduce the plutonium needs—to less than 100 mg. The converter consumes as much power as the rest of the circuitry.

ENEA officials expect the pacemaker will sell for about $2,000, about 25% more than nonnuclear versions.

**Timing.** While ENEA pushes on with the pacemaker, some of the group’s members, led by a large Swiss watch producer, are moving toward a long-lived battery for wristwatches. The producer, Baumgartner S.A., has already built a prototype timepiece that is supposed to run for at least 20 years.

Company officials say the battery doesn’t just replace a mercury cell. Details are a secret but Baumgartner director Karl Adler does hint that the battery’s alpha particles oscillate in conjunction with a quartz crystal.

Baumgartner insists its watch will cost no more than present top-quality watches and says it will radiate less than old-style radium watch dials. The battery operates on tritium, the element now used for luminescent dials. Although the Swiss firm hopes to start making production models in perhaps two years, nuclear-industry sources are somewhat skeptical. They doubt cost and radiation problems can be solved that quickly.

**Japan**

**Rubbed out**

Among electronics components, nothing has withstood the onslaught of change as well as the potentiometer. Even in the most sophisticated of today’s equipment, the pots basically are what they were in the early days of radio—a wiper over a resistance element. Aye, there’s the rub that makes a pot wear out.

A way without wear there is, though. Field plates with magneto-
resistive material on them make contactless potentiometers when paired with magnets. Siemens AG of West Germany more than two years ago found one way to make practical devices. Even more promising, thinks Shohei Kataoka of the Japanese government's Electrotechnical Laboratory, is a technique—adapted from integrated-circuit making—developed by a group he heads.

Six Japanese companies have shown an interest in Kataoka's work, and he expects to work out a commercial production technique with one or two of them. That should make possible contactless pots for less than $1.40. The price is too high for mass-produced radios and TV sets, of course; but it's within reason for quality hi-fi gear and for industrial equipment.

Barred. The key to large-resistance swings in field plates is getting rid of the Hall effect—the electric field that develops across a current-carrying conductor when there's a magnetic field present. In a magnetoresistor, the two fields tend to cancel out one another. Siemens does away with the Hall field by using a semiconductor material combination that has needle-like nickel antimonide structures dispersed in indium antimonide. Kataoka's plates have shorting bars embedded in them. The bars are put down on an InSb single-crystal slab 10- or 15-microns thick by photoetching and then alloying. Roughly, it's the same process used to lay down ohmic contacts on an IC.

Full circle. Because the shorting bars are embedded in the InSb and not part of the crystal structure as the NiSb needles are, the Japanese plates can be made with circular resistance tracks. This is a big advantage, since the variation in a magnetic field can then be handled by a rotating permanent magnet. Linear motion is much harder to obtain since the plates are small, on the order of 5 millimeter-diameter for the circular version.

To get high swings of resistance for its contactless pots, Kataoka's group cascades three elements on a single plate. The second element's basic resistance is five times that of the first, and the third element's resistance is 25 times that of the first. That way, although the basic change in resistance with magnetic field is 7:1, the ratio of output voltage is 342:1.

Direct drive
Tell a high-fidelity aficionado that a turntable has direct drive and he'll probably sneer at you. The term conjures up cheap phonographs produced before World War 2 that wowed and rumbled along at a speed of 78 revolutions per minute.

Direct drive, however, is on its way back into the hi-fi lexicon. At this month's Consumer Electronics Show in New York, the Matsushita Electric Industrial Co. introduced a turntable having a signal-to-noise ratio better than 60 decibels during playback. This ratio is so high that the noise added by the turntable turns out to be less than a master record's inherent wow and rumble.

Matsushita achieves this performance with a new low-speed motor in which a permanent-magnet rotor is fixed directly to the turntable. The wound stator is powered by three-phase current generated by transistor oscillators that operate off a 15-volt supply.

Best of two worlds. The transistor motor, Matsushita maintains, combines the best features of a-c and d-c motors while it eliminates the need for such mechanical elements as speed changers, idlers, and drive belts.

Like a d-c motor, Matsushita's motor has high starting torque—at 33 rpm, it's up to full speed in half a revolution. Like an a-c motor, Matsushita's new drive has no brush-commutator combination to generate noise, but there's no a-c hum to contend with either.

And there's practically no torque ripple; since the motor speed is either 33 or 45 rpm, any unbalance in the rotor would at worst generate subaudio noise—less than 1 hertz. Fast-running a-c motors generate rumble noise when they're just slightly unbalanced.

Steady. To achieve precise operation of the turntable, Matsushita employs analog control rather than the on-off signals most often used for transistor motors.

The control signal is picked off three pairs of coils wound in the stator. One coil in each pair has 50-kilohertz signal applied to it; the voltage output of the second coil indicates the rotor position. This is because the coupling between the two coils is varied by a toothed wheel, that spins with the turntable. Speed variation from no-load to load conditions—when the load is 2-grams needle pressure—is a very low 0.15%.

Guarding the gates
Sometimes circuit designers run up against a situation where they'd like to use MOS transistors but don't because voltage surges might damage the relatively fragile transistor gates.

Protection for the gates, of course, isn't hard to come by. A pair of diodes will do the trick. But the extra diodes are a nuisance in some circuits. So there's a niche for transistors with their own protection.

In Japan, the Tokyo Shibaura
Electric Co. (Toshiba) has a transistor with protective diodes on a separate chip in the same package. Going the competition one better, the Matsushita Electronics Corp. has developed an MOS transistor with the diodes integrated on the same chip. The company still has to set a date to start selling the device but has given it a catalog number 3SK36.

Back-to-back. The diodes are integrated into the substrate back-to-back and connected between each gate and the source-substrate common line. The diodes have a breakdown voltage of 20 volts, more than enough to protect the two gates, whose insulation can withstand about 100 volts. Tomisaburo Okumura, who heads the group that developed the transistor, says it suffers no damage when a simulated lightning pulse of 15,000 volts is applied to the antenna terminals of a tv tuner using the transistor.

The two diodes have a pnp configuration and in fact together they resemble a pnp transistor. A simple way of obtaining the diodes, then, would have been to diffuse an n region into the substrate and then put a p region in the center of the n region. But this way the avalanche breakdown voltage in one direction—from the n region to the p region of the substrate—would be about 70 volts, too high for comfort.

To get equally low avalanche breakdown voltages in both directions, Matsushita surrounds the n regions with a common p region. The junction between them is vertical and the common p region is connected by ohmic material through the p substrate to the source-substrate common line.

Belgium

Aluminum's on the beam

Beam leads, almost everyone agrees, are the best way to link monolithic integrated circuits to the outside world. And so far, there's little dispute that the best beam leads are made of gold, using the technique devised five years ago by the Bell Telephone Labs. But gold beam leads face a challenge. Manufacture Belge de Lampes et de Matériel Électronique (MBLE), an affiliate of Philips' Gloeilampenfabrieken, had started working on aluminum beam leads about the same time Bell Labs announced its process. Now the Belgian firm has started pilot production at a rate of a million circuits a year.

What's more, MBLE has started selling a line of IC-handling and testing equipment. One machine already has been delivered to the Amperex Electronic Corp., a division of North American Philips. An ultrasonic welding unit will follow this month.

A natural. Thierry Neuluyts, MBLE's chief engineer for beam-lead work, can cite all kinds of advantages for aluminum leads. "It's the usual contact metal for planar devices," he explains. "Adding beam leads to a classic crystal requires special treatment that modifies electrical characteristics. Aluminum is easy to bond ultrasonically. And there are no reliability problems due to contact of dissimilar metals with aluminum thin-film paths."

Along with aluminum beam leads, MBLE has developed a set of auxiliary substrates for hybrid circuits. These subcarriers, glass or ceramic plates a few millimeters square, carry most of the active devices in a hybrid circuit. Because of the interconnections on these subcarriers, crossover is eased for the main substrate.

Windows. In MBLE's technique, devices are formed in the basic wafer by the usual planar process. But after opening the contact windows, a layer of aluminum 0.25 mil thick is vacuum deposited on the wafer. The aluminum is engraved by phosphoric acid to get conducting paths from the contact windows that extend about 4 mils beyond the edges of the devices. MBLE says the 0.25-mil aluminum is all that's needed for direct connection to interdigitated windows as narrow as 0.2 mil and spaced 0.2 mil apart.

To produce the active-device subcarriers, MBLE starts with a 2-by-3-inch glass plate covered on both sides by aluminum. Then, anywhere from 100 to 300 interconnection patterns are etched on one side, with rectangles—each matching an interconnection pattern—going on the other side. The chips are bonded to the connection-pattern subcarriers in a batch.

The plate is then glued, chip-side down, upon a stainless steel plate. A glue layer thick enough to embed the chips is used. Then the glass is etched out from backside using the aluminum rectangles as masks. When the glue is dissolved, the subcarriers are separated.

Proof. MBLE equipment designers put the subcarrier-hybrid technique through its paces to build a digital frequency synthesizer. It provides 10,000 channels in the 2-to-12-megahertz range.

By using the subcarriers, MBLE was able to pack the digital circuitry into 10 modules. With conventional hybrid circuits, the same synthesizer needed 42 modules. And the subcarrier hybrids needed only 29 square centimeters of thin-film area compared with 92 for conventional hybrids.

Australia

Outback changeover

Australia's flying doctors, who supply the island continent's sparsely populated outback with emergency medical aid, are facing a crisis: the privately financed service must replace all its double sideband or a-m radio equipment with single sideband gear.

In all, 12 bases must be equipped with the newer, expensive equipment, because ssb will ease congestion and it's more powerful. The result will be twice the number of channels for the world's largest h-f network.

New base station equipment must be operating by 1970. The old equipment put out a carrier wave modulated on both sides; the new version will have a double unit—the first will emit an ssb signal plus a carrier so that its trans-
mission can be picked up by both new ssb transceivers and old a-m equipment. In 1975, when all outposts will have converted a switch will be thrown at base stations to cut out the carrier wave and transmit a pure ssb signal. The final system will then be operating on 300 watts while outpost transceivers will work on 25 watts. Frequency range will be 2, 4, 5, and 6 megahertz, with each base station having at least three frequencies.

One drawback of the new equipment will be that many homesteaders with only elementary radio knowledge will find repairs and adjustments more difficult, although the new equipment should require less attention than much of the old gear, some of which dates back to 1930. However, manufacturers will be required to set up service outlets before they will be licensed to sell transceivers.

Great Britain

Hybrids in a hurry

Many an instrument maker would like nothing more than a production line to knock out hybrid circuits in a hurry. Trouble is, instrument runs are too short to justify setting up an intricate special line.

For a producer of semiconductor production equipment, the instrument makers' problem is a challenge. And a small London company, the Vacwell Engineering Co., has picked up the gauntlet. Vacwell has built a machine that very nearly automatically bonds semiconductor chips, capacitors and like components to substrates. And for the operator, it's just a matter of dialing in different number settings to shift from one kind of hybrid circuit to another.

Vacwell will start evaluation tests shortly, using the machine to make circuits for instrument-making subsidiaries of its parent company, the Electronic Machine Co. If the tests are successful, the company probably will build similar equipment for other firms. Vacwell officials believe the machine could sell for less than $25,000.

One at a time. Controlled by a semiskilled operator, the machine can put down as many as 18 chips on substrates ranging up to 2¼ by 1½ inches. Chip sizes can be as small as 0.015-inch square or as large as 0.25-inch square, and they're positioned with an accuracy of 10 microns.

The substrates are built up one at a time, following a program written for the circuits; each bonding counts as a step in the program.

To set up a bonding sequence, the operator sets a row of figures on the control panel, matching them to the figures on the program. When this is accomplished, the control electronics position the substrate and move a chip container under a vacuum probe.

At the same time, a television image of the container and probe show up on the control panel, alongside a projected image of the circuits being made up. The operator, with a rolling-ball control, rotates the chip container until there's a chip right under the probe. Actually, the probe is a pair of probes mounted coaxially. The larger of the two is normally retracted unless outside chips are involved.

After the probe drops the chip onto the substrate, a second control is used to align the edges of the chip and the substrate. The operator then checks the chip's configuration against the projected circuit image to make sure the right chip is in the right position.

Fini. Then the machine takes over to make the bond. The substrate is carried in a box heated to about 30°C below the melting point of the solder on the chips. A hot gas jet, directed onto the chip, melts the solder under it. If the bond looks good on the tv monitor, the operator then punches a "finish" button and the next step in the program appears on the panel.
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If you'd like more information on EG&G pulsed Xenon Flashtubes and Systems, or for that matter on any of our products, such as thyratings, krytrons, spark gaps, transformers, photodiodes, thermoelectric coolers or light instrumentation, write: EG&G, Inc., 166 Brookline Ave., Boston, Mass. 02215. Tel.: 617-267-9700. TWX: 617-262-9317. On west coast telephone 213-464-2800.
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For more information on RCA coaxial cavities and RCA CERMOLOX Tubes, see your local RCA Representative. For technical data on specific types, write: RCA Electronic Components, Commercial Engineering Section F-19T-3, Harrison, N. J. 07029.

RCA Coaxial Cavities—Available Off-the-Shelf

<table>
<thead>
<tr>
<th>RCA TYPE</th>
<th>TUBE</th>
<th>POWER OUTPUT (Watts)</th>
<th>MODE</th>
<th>FREQUENCY (MHz)</th>
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<tr>
<td>Y1010</td>
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