Electronics

Putting negative reactances to work: page 44

Applying the field-effect transistor: page 53

New look at digital television: page 77

December 14, 1964
A McGraw-Hill Publication
75 cents

Below: intermediate pattern transmitted by digital tv, page 77

TOMORROW'S PRODUCTS TODAY...

UTC — PIONEERS IN MINIATURIZATION

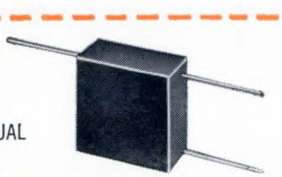
TRANSFORMERS
INDUCTORS
TOROIDS
ELECTRIC WAVE FILTERS
HIGH Q COILS
MAGNETIC AMPLIFIERS
SATURABLE REACTORS
REFERENCE UNITS
PULSE TRANSFORMERS

Design and application engineers with unique requirements have utilized UTC's advanced research and design capabilities for over 30 years. These engineering services are supported by the most complete manufacturing facilities for military and commercial production. Both stock and special custom built iron core components are available in long and short run quantities.

SUBMINIATURE AUDIO TRANSFORMER

ACTUAL SIZE

Plug-in and weldable transistor type audio transformer hermetically sealed to MIL-T-27A, Grade 4, Class R, Life X. Leads spaced on .1 radius circle to conform to "TO-5" cased semiconductors and micrologic elements. Primary impedance: 10K CT ohms; secondary impedance 2K CT ohms. Size: 5/16 dia. x 3/8" h; weight: 1/15 oz.



ACTUAL SIZE

SUBMINIATURE MOLDED AUTOTRANSFORMER

Specially designed for application where space requirements were limited to a slot less than 1/4" high. Molded unit with straight pin terminals.

Designed to MIL-T-27A for 6400 cycles, 250 ohms to 1K ohms. Size: 17/32" square x 7/32" tall; weight: 0.1 oz.

SUBMINIATURE PULSE TRANSFORMER

ACTUAL SIZE

Unique subminiature PIP construction to MIL-T-21038 type TP6SX4410CZ with weldable and solderable gold plated Dumet leads. Used for transistor blocking oscillator applications. Pulse width .05 μsec, 3 windings. Size: 5/16 dia x 3/16" h; weight: 1/20 oz.

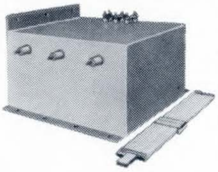
400 CYCLE ISOLATION TRANSFORMER

Ratio 1:1, 0-300 V input. Phase shift less than .1° and stable with input voltage. Electrostatic isolation greater than 200,000:1. Magnetically shielded for greater than 40 db hum reduction. Terminated with microphone connectors. Size: 3 1/8 x 2 5/8 x 4 1/8" h; weight: 4 1/4 lbs.

BAND PASS FILTER

Designed to MIL-F-18327A in a flat construction for use in printed circuits. Unit has a source and load impedance of 600 ohms. Attenuation ratings are: 100 cycles to 3 KC, ± 0.5 db; 60 cycles and 4 KC, 3 db; 4800 cycles more than 30 db. Size: 4 x 4 x 7/8" h.

THREE PHASE HIGH VOLTAGE POWER TRANSFORMER



Primary jumper hardware for easy conversion from delta to wye inputs. Made to MIL-T-27A specifications. Primary: 440 V 60 cycles delta or wye 3 phase input. Secondary: 2100 V line to line or 1215 V line to line @ 242 ma. Full load voltage ± 2% maximum regulation 5%. Electrostatically shielded to give 20:1 ratio per MIL-T-27A test @ 20 KC. Maximum ambient 70°C, temperature rise 35°C. Size: 10 x 10 x 6"; weight: 66 lbs.

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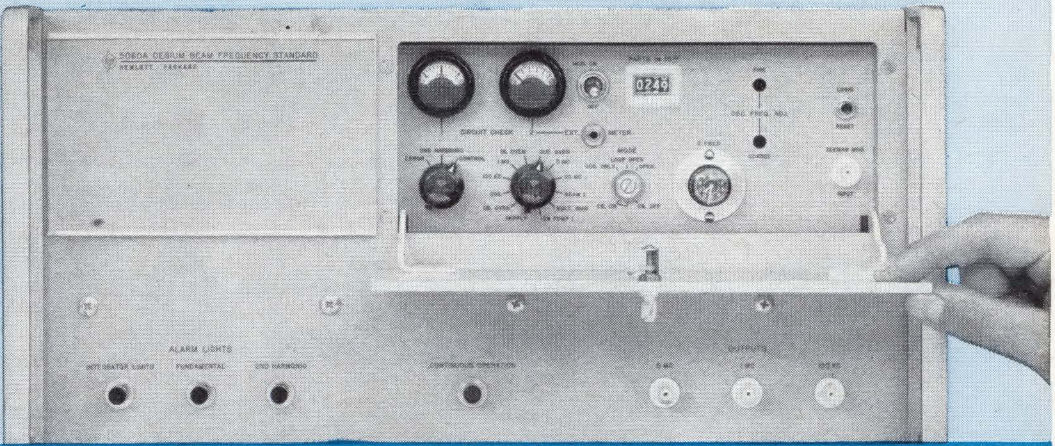
2×10^{-11} Accuracy*

from a new compact, solid-state atomic standard



Long-life Cesium 133 resonator—plus:

Reference to A_1 or UT_2 time scale

Closed-loop self-checking control circuitry

Highly stable quartz oscillator

Only 8¾" high, 65 lbs.

Here's a true primary atomic standard which offers unprecedented features in an easily portable package. Reliability assurances include automatic continuous output monitoring and a rugged, spectrally pure, high precision quartz crystal oscillator which may be operated independently of the cesium beam resonator. The resonator itself has a guaranteed operating life of 10,000 hours.

The 5060A Frequency Standard operates from standard ac power or directly from a 28 v dc source. Especially useful is the provision for output readjustment for periodic changes of the time scale itself. For instance, internationally agreed UT_2 adjustments may be made with a simple component change.

Never before such a combination: Accuracy, reliability, ruggedness, portability, easy time scale adjustment for changing requirements. Check the specifications against your military, industrial or scientific requirements. Call your Hewlett-Packard field engineer, or write for complete information on the hp 5060A, Hewlett-Packard, Palo Alto, California 94304, Tel., (415) 326-7000; Europe: 54 Route des Acacias, Geneva; Canada: 8270 Mayrand Street, Montreal.

Accuracy:	$\pm 2 \times 10^{-11}$
Long-term stability:	$\pm 1 \times 10^{-11}$ (for the life of the cesium beam tube)
Short-term stability:	rms fractional frequency deviation for 1 second averaging: $\frac{\Delta f \text{ rms}}{f} \leq 1 \times 10^{-10}$
Signal-to-noise ratio (5 mc):	At least 87 db at rated output; output filter bandwith approx. 125 cps
Harmonic distortion (5 mc, 1 mc and 100 kc):	Down more than 40 db from rated output
Output frequencies:	5 mc, 1 mc, 100 kc sinusoidal, 100 kc clock drive
Output voltages:	1 v rms into 50 ohms, clock drive suitable for hp frequency divider and clocks
Time scale adjustments:	Adjustable in increments of 10×10^{-10} by changing a component in the frequency synthesizer; automatic monitor to indicate proper operation; A_1 or UT_2 time scales supplied to order
Cesium beam tube life:	10,000 hours guaranteed (operating)
Power:	115 or 230 v ac ± 10%, 50 to 1000 cps, or 22 to 30 v dc; approx. 50 w operating
Size:	16¾" wide, 8¾" high, 16½" deep, 65 lbs.
Price:	hp 5060A Cesium Beam Standard, $15,500

**Absolute: hp model 5060A is a true primary standard whose output frequency is uniquely defined by basic physical properties of the cesium atom. The specified accuracy is achieved without reference to frequency calibration sources.*

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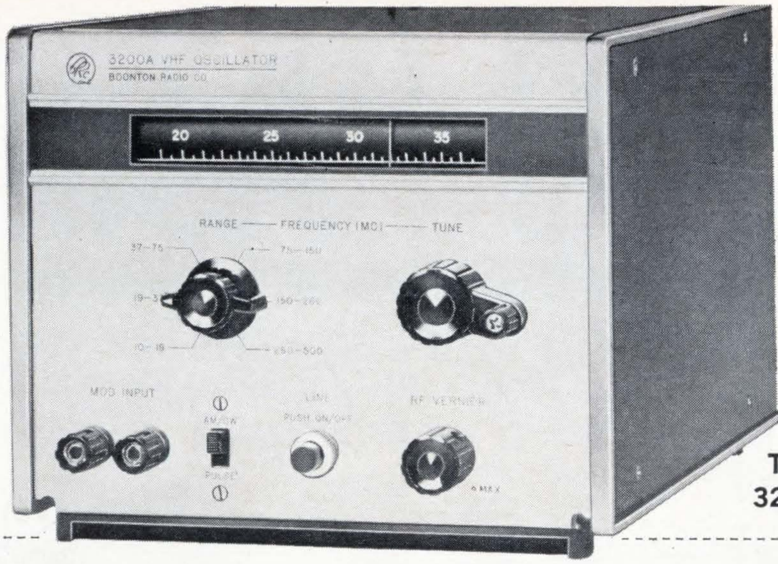
An extra measure of quality

9839

New!

VHF



TYPE 3200A

OSCILLATOR

10 Mc - 500 Mc

Features:

- ±0.002% Frequency Stability
- External AM and Pulse Modulation
- Waveguide-Below-Cutoff Output Attenuator
- Solid-State Power Supply

The VHF Oscillator Type 3200A is designed for general purpose laboratory use including receiver and amplifier testing, driving bridges, slotted lines, antenna and filter networks, and as a local oscillator for heterodyne detector systems in the frequency range from 10 to 500 mc.

The push-pull oscillator is housed in a rugged aluminum casting for maximum stability and extremely low leakage; six frequency ranges are provided for adequate bandspread on the slide-rule dial. Internal CW operation is provided; AM and pulse modulation may be obtained through the use of a suitable external source. The RF output is coupled through a waveguide-below-cutoff variable attenuator; in addition, an electrical RF level vernier is included as a front panel control.

A solid-state power supply furnishes all necessary operating voltages including regulated dc to the oscillator heaters for minimum hum modulation and maximum tube life.

Specifications:

Radio Frequency Characteristics

RF RANGE: 10 to 500 mc

RF ACCURACY:
±2% (after ½ hour warmup)

RF STABILITY:
Short Term: ±0.002* (5 minutes)
Long Term: ±0.02* (1 hour)
Line Voltage: ±0.001%* (5 volts)
*After 4 hour warmup, under 0.2 mw load

RF OUTPUT:
Maximum Power:
>200 mw* (10-130 mc)
>150 mw* (130-260 mc)
> 25 mw* (260-500 mc)
*Across external 50 ohm load
Range: 0 to >120 db attenuation from maximum output
Load Impedance: 50 ohms nominal

RF LEAKAGE: Sufficiently low to permit measurements at 1 μv

Amplitude Modulation Characteristics

AM RANGE: 0 to 30%
AM DISTORTION: <1% at 30% AM
EXTERNAL AM REQUIREMENTS: Approx. 30 volts RMS into 600 ohms for 30% AM

Pulse Modulation Characteristics

EXTERNAL PM REQUIREMENTS: 140 volts peak negative pulse into 2000 ohms for maximum power output; typically 10 volts peak (except 50 volts on 260-500 mc range) for 1 mw peak power output

Physical Characteristics

DIMENSIONS:	Height: 6½"	(16.5 cm)
	Width: 7 25/32"	(19.8 cm)
	Depth: 12 17/32"	(31.8 cm)

Power Requirements

105-125/210-250 volts, 50-60 cps, 30 watts

Price: 3200A: $475.00
F.O.B. Rockaway, New Jersey

BOONTON DIVISION

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tem described represents a considerable dollar volume for the electronics industry, and a possible substitute for part of the curtailed defense production. To illustrate the potential magnitude of this program, an installation in each vehicle, which is estimated at a minimum cost of $20, represents, for the 60 million vehicles presently on the road and those to be produced at a current production rate of 12 million vehicles a year, a gross business of about $4 billion over a 10-year period. To this must be added about $2 billion for equipment external to the motor vehicle.

N.A. Moerman
Roslyn Heights, N.Y.

▪ Engineering consultant Moerman's enclosed document describes Emvac (moving vehicle auto control).

The Emvac system is a network of stationary traffic-command radio transmitters, each with one or more modes of operation, and receiver-translators in each motor vehicle. On receiving automatically transmitted traffic-command information, the vehicle operator is alerted, by an audio signal, to either a specific traffic violation or an impending traffic-control point.

An electric generator (alternator) to produce the source of audio tones is built into the vehicle drive mechanism and delivers energy only during motion of the vehicle. Receipt of the command signals by the receiver-translator selectively switches the audio signal to communicate to the operator, by sound patterns and pitch, the information on the traffic situation confronting him.

Moerman feels that the Emvac system would be important where a driver goes too fast, passes a stop sign, or disregards a signal. It might, to some extent, have an effect on the drunken driver. These four areas constitute over 50% of the factors contributing to fatal accidents.

A further elaboration of Emvac (not described) would apply to driving left of center, failing to yield right of way and possibly to other improper driving.

There are three frequency channels, two to detect the speed limits of 35 and 65 miles an hour; the third is a "caution" channel to alert the driver to exercise care and observe visual markers.

On channel 1, the driver who exceeds the 60-mph limit hears a high-pitched tone. When the driver reduces speed below 60 mph the sound disappears.

On channel 2, the driver who exceeds 35 mph hears a steady tone of lower frequency than the channel-1 warning. An intermittent tone on channel 2 cautions the driver not to exceed 35 mph, as there are poor road conditions ahead.

On channel 3, a steady low-pitched tone means stop; an intermittent tone indicates caution, and a short intermittent tone (blips) is a call to be on the alert.

Xmogrification

Because Hoffman's house organ is called "The Transmitter," we were distressed by the same thing that bugged reader Rudolf F. Graf: the acceptability of the term "xmitter" [Nov. 16, p. 4]. Were this to go to its ultimate, beyond the xformer and xistor Graf proposes and the xfer, xient, xpose and xom your staffers conceive, just think what might happen!

Our business xactions, both xcontinental and xAtlantic, would have to be xcribed so intricately that our secretary (the one who wears those dark, xparent nylons and louses up xitive verbs) might become xfixed and need a xfusion, something we'd naturally never want to xpire.

Moreover, we'd find ourselves xlating words beginning with "x" so that we'd be talking about trans-rays, transylophones and the element transenon.

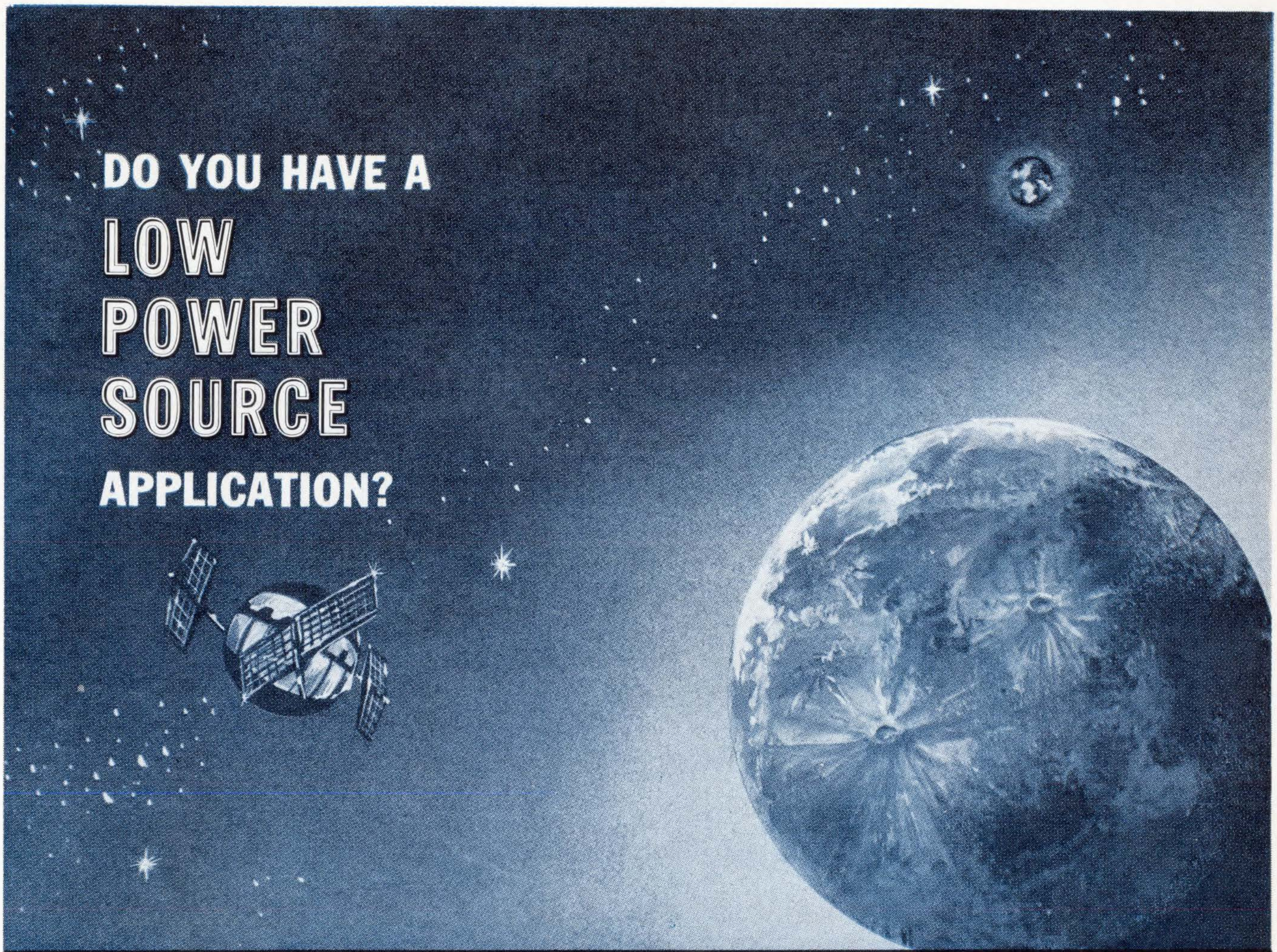
Maybe we were better off when we still had Tom Swifties!

Al Bernsohn
Hoffman Electronics Corp.
El Monte, Calif.

Controlling interest

General Micro-Electronics, Inc., is a subsidiary of the Pyle-National Co., rather than of the Victor Comptometer Corp. [Nov. 30, p. 47].

William C. Croft
Pyle-National Co.
Chicago



Motorola's New Low-capacitance "O-pf" Transistor Is Fastest At Micro-power Logic Levels!

Until now, micro-power circuits using the best available devices have been severely limited to switching speeds in the 10 to 20 kc range. Today, these same circuits, designed with the new Motorola silicon NPN 2N3493 O-pf* micro-power transistor, can operate in the 1 mc range . . . *an improvement factor of 50 to 100 times!*

A new Motorola fabrication process has made possible the development of what is probably the world's smallest transistor junction . . . a transistor whose capacitance virtually approaches the "zero" point ($C_{tc} = 0.2$ pf, $C_{te} = 0.3$ pf – case capacitance $\cong 0.3$ pf) . . . permitting faster switching speeds at lower power levels than ever before!

Actually, the capacitance of the 2N3493 "0-pf" device is *so low* that other circuit considerations (stray capacitance, wire length, etc.) have now become the circuit speed limiting factors.

Write for the new Designer's* Data Sheet for the Motorola "0-pf" 2N3493 transistor. It includes limit curves directly applicable to "worst case" switching circuit designs as well as sufficient information to permit the design engineer, in most cases, to design his circuits entirely from the data sheet alone.

If power, weight, and space are problems in *your* application, Motorola's new "0-pf" annular epitaxial passivated 2N3493 transistor could very well be the answer. Contact your nearest Motorola semiconductor district office or distributor for evaluation units today, or write Technical Information Center, Box 955, Phoenix, Arizona 85001.

4-Lead TO-18 Pkg.

ELECTRICAL CHARACTERISTICS

BV_{CBO}	12 V MIN
BV_{CEO}	8 V MIN
BV_{EBO}	5 V MIN
h_{FE} @ 10 μA/0.5 V	25 MIN
h_{FE} @ 100 μA/0.5 V	40 MIN (20 MIN @ −55°C)
h_{FE} @ 500 μA/0.5 V	40-120
f_T @ 1mA/3 V	400 MC MIN
C_{ob} @ 3 V	0.7 pf MAX†
C_{ib} @ 0.5 V	0.7 pf MAX

†Includes 0.3 pf can capacitance

* Trademark of Motorola

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People

Clyde Skeen, the new president of Ling-Temco-Vought, Inc., seems to be the man designated to spearhead the company's announced policy of diversification, particularly in the aerospace and electronics fields. He succeeds Gifford K. Johnson, who resigned.

Skeen was executive vice president of the Temco Electronics & Missiles Co. when it was merged with Ling-Altec Electronics, Inc. When the third leg was added to the Ling-Temco-Vought triangle, with the acquisition of Chance Vought Aircraft, Inc., Skeen was a "prime mover" in the deal, according to James J. Ling, chairman of LTV.

Skeen is one of the few Vought people still in the LTV organization.

Broad experience. Skeen has both financial and operations experience. Among his associates the 47-year-old executive is known as a "management type."

At the Boeing Co. he was hired as an accountant, and moved up to controller. He then transferred to systems management, and soon became first vice president and director of program management. He had responsibility for the Minuteman intercontinental ballistic missile, and became a strong exponent of program management. In 1960, Robert McCulloch, Temco's president, persuaded him to move to Temco.

Diversification has also caught up with Skeen in his home life. He and his wife, Helen, have a new daughter, Shelly, who joins two sons, Bill and Jim.

Skeen's activities extend beyond his duties with Ling-Temco. He's been active in financial, electronics, and aerospace organizations.

He was graduated from Kansas State College, and in 1945 he completed a course in advanced management at Harvard University's Graduate School of Business Administration.

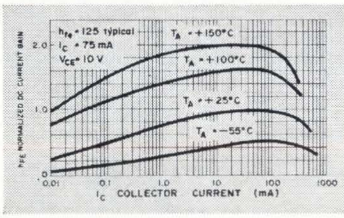
Every time we give John Szafranski one of our Leaf-Lets, he tries to destroy it.

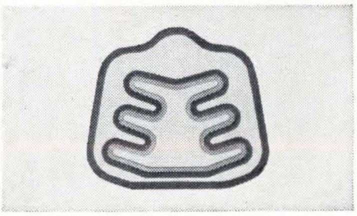
He's found it's not easy to do. John's reliability group has the job of destructive testing units from our Leaf-Let* transistor production run. Before John's wrecking crew pulls out sample lots, we've gone through rigid process controls to insure inherent reliability in our silicon planar devices. Every single unit is completely checked out and random samples are set up for life and reliability test data. (We're generating stacks of reliability material.)

Then John's boys go to work. They pick random samples and really test them. They bake them in hot ovens, freeze them to low temperatures Eskimos never thought of, drop and shake them till their teeth rattle, run enough current through them to melt junctions, and generally do what they can to see how far beyond maximum ratings the Leaf-Let can perform.

John is still getting surprised.

Like "Purple Plague," he just can't get it in our Leaf-Lets. Which isn't surprising since we use aluminum lead wires bonded to the base and emitter so we just don't have the combination that can lead to the $AuAl_2$ plague. And Beta linearity. Look at that curve, all the way up to 0.8 amp I_C. That's due to our rather unique Leaf-Let configuration. The geometry gives us low saturation voltage ($V_{CE(s)}$ = 0.25 V typical at 150 mA) and gain bandwidth product up to 500 mc. (John frequently comes up with better figures but we like to be conservative . . . and safe.)





And all of this performance is available in TO-5 and TO-18 packages for types 2N2217-2N2222, 2N2217A-2N2222A, 2N2845-2N2848. Several meet military specifications. Get more information from your nearest Bendix sales office. Contact them, or us, but, don't call John. He's out in the lab scheming up new and unusual tortures so he can give you further proof of the Leaf-Let's outstanding reliability.

Trademark

Bendix Semiconductor Division

HOLMDEL, NEW JERSEY

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Meetings

Computerized-Purchasing Seminar, NDEI; Dryden East, New York, **Dec. 14-16.**

General Systems Knowledge Symposium, Society for General Systems Research, IEEE; American Association for the Advancement of Science, Montreal, **Dec. 26-31.**

Reliability and Quality Control National Symposium, ASQC, IEEE, IES, SNT; Hotel Fontainebleau, Miami Beach, **Jan. 12-14.**

Fundamental Phenomena in the Material Sciences Annual Symposium, Ilikon Corp.; Sheraton Plaza Hotel, Boston, **Jan. 25-26.**

Northwestern University Science Symposium, NU; Pick-Congress Hotel, and Thorne Hall of Northwestern University, Chicago, **Jan. 28-29.**

Winter Power Meeting, PEEC/IEEE; Statler-Hilton Hotel, New York, **Jan. 31-Feb. 5.**

Institute on Information Storage and Retrieval, The American University; The Willard Hotel, Washington, **Feb. 1-4.**

On-Line Computing Systems Symposium, UCLA Extension Service, Informatics, Inc.; University of California, Los Angeles, **Feb. 2-4.**

Winter Convention on Military Electronics, PTGMIL & L.A. Section of IEEE; Ambassador Hotel, Los Angeles, **Feb. 3-5.**

Electrical/Electronic Trade Show, Electrical Representatives Club, Electronic Representatives Assn.; Denver Auditorium Arena, Denver, **Feb. 15-17.**

Solid-State Circuits International Conference, University of Pennsylvania, IEEE; University of Pennsylvania and Sheraton Hotel, Philadelphia, **Feb. 17-19.**

Annual West Coast Reliability Symposium, ASQC, UCLA; Moore Hall, University of California Los Angeles, **Feb. 20.**

Particle Accelerator Conference, AIP NSG/IEEE, NBS, USAEC; Shoreham Hotel, Washington, **Mar. 10-12.**

ISA National Conference on Instrumentation for the Iron and Steel Industry, ISA; Pick-Roosevelt Hotel, Pittsburgh, **Mar. 17-19.**

IEEE International Convention, IEEE; N.Y. Coliseum and New York Hilton Hotel, New York, **Mar. 22-25.**

Society of Motion Picture and Television Engineers Semiannual Conference and Exhibit, SMPTE; Ambassador Hotel, Los Angeles, **Mar. 28-Apr. 2.**

Electron Beam Annual Symposium, Pennsylvania State University, Alloyd Corp.; Pennsylvania State University, University Park, Pa., **Mar. 31-Apr. 2.**

Electronic Parts Distributors Show, Electronic Industry Show Corp., New York Hilton and Americana Hotels, New York, **Mar. 31-Apr. 4.**

Cleveland Electronics Conference, Cleveland Electronics Conference, Inc., IEEE, ISA, CPS, Western Reserve University, Case Institute of Technology; Cleveland Public Auditorium, Cleveland, **Apr. 6-8.**

Conference on Impact of Batch-Fabrication on Future Computers, PGEC/IEEE; Thunderbird Hotel, Los Angeles, **Apr. 6-8.**

IEEE Region 3 Meeting, Region 3 of IEEE; Robert E. Lee Hotel, Winston-Salem, N.C., **Apr. 7-9.**

Electronic Components International Exhibition, FNIE, SDSA; Parc des Expositions (Fair Grounds), Paris, **Apr. 8-13.**

Telemetering National Conference, AIAA, IEEE, ISA; Shamrock-Hilton Hotel, Houston, Tex., **Apr. 13-15.**

Call for papers

Electron Beam Annual Symposium, Pennsylvania State University, Alloyd Corp.; Pennsylvania State University, University Park, Pa., Mar. 31-Apr. 2. **Jan. 15** is deadline for submitting 300-word abstract to A.B. El-Kareh, Chairman, 7th Electron Beam Symposium, 203 Electrical Engineering East, The Pennsylvania State University, University Park, Pa. Topics include physics of electron, ion, and light beams; application of energy beams to microminiaturization and thin films, welding and materials, and melting and evaporation; new energy beam equipment and processes.

National Aeronautic and Space Engineering Meeting, SAE; Los Angeles, Oct. 4-8. Deadline is **Jan. 15** for submitting papers to Society of Automotive Engineers Western Branch Office, 999 N. Sepulveda Blvd., El Segundo, Calif.

Catching data in a mach 15 windstorm, with an accuracy of better than 0.75 microvolts

. . . that was the problem. Astrodata's solution was a data acquisition system under complete computer control. Performance indicates end-to-end uncertainty for the over-all system, using 2.5 mv full-scale signals, is less than 0.75 μv, or 0.025% of full scale (3 sigma). Correct us if we're wrong, but to our knowledge, this is the most accurate low-level data system ever built.

The general-purpose, on-line, digital computer controls the rate at which data from a number of wind-tunnel sites is acquired, selecting data from 240 input channels.

Operators at each remote wind-tunnel site, in one case up to 500 ft. from the central system, have a comprehensive control and readout console. They may request any of several data acquisition runs. The computer honors the request, in accordance with a pre-arranged site priority, loads the appropriate program from a master tape, then organizes the central system as required to execute the requested program.

Perhaps you don't have a hypersonic wind tunnel to control, but you do have other problems in the data acquisition and processing, telemetry, or range timing instrumentation fields where Astrodata's vast experience in dynamic information handling and hybrid computer techniques can help you. *Write for your free copy of our 20-page brochure, "Astrodata's Systems Experience."*

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BOURNS TOTAL VALUE

In 1958, when you paid $3.60 (100-piece price) for a TRIMPOT® Model 200 potentiometer, you got the best buy of the day. Today, for the same price, you get an even better buy.

Power rating of Model 200 is now 100% higher. In addition, Model 200 now meets the steady-state humidity requirements of MIL-STD-202B, Method 103. Materials, too, are better. In 1959, when copper-plated printed-circuit pins were the industry standard, Bourns switched to gold-plated grade-A nickel pins. The results: better weldability, better solderability, better reliability. (Three years later, MIL-STD-1276 required this change of *all* printed-circuit components.)

Bourns products undergo this kind of upgrading constantly. Rather than wait for imposed standards to dictate improvements, Bourns sets higher standards with products that anticipate tomorrow's needs. Obviously, this philosophy puts quality above cost; however, through stringent production efficiency programs, Bourns keeps prices down.

Ever-rising quality—at competitive prices—is part of Bourns Total Value. It's one of the many reasons more adjustment potentiometers throughout the world bear the Bourns label than any other. It's one sound reason for *you* to investigate Bourns products, too.

THIS IS BOURNS TOTAL VALUE / Always your best value in potentiometers

EXCLUSIVE RELIABILITY PROGRAM

The Bourns Reliability Assurance Program is the only one of its kind in the potentiometer industry. Its primary goal is reliability! It frequently requalifies *all* standard models to insure conformance with published specifications. It also makes available free test data, saving you the time and expense of quality verification. Conducted in *addition* to quality control, it makes Bourns potentiometers the most thoroughly inspected and tested units available.

SUPERIOR QUALITY CONTROL

One-fifth of all Bourns employees work in quality control or reliability monitoring. This is one of the highest personnel ratios of QC employees and inspectors in the electronics industry. In addition, all standard Bourns products undergo extensive in-process and 100% final inspection. These facts help account for the company's return rate of only 0.2% (2 units returned of each 1000 shipped!), one of the lowest on record.

MOST ADVANCED PRODUCTS

As the pioneer in adjustment potentiometers, Bourns has set the standards for an entire industry—in new products, in product improvements, in materials, in processes. Innovations such as the RESISTON® carbon and PALIRIUM® film elements and the virtually indestructible SILVERWELD® termination demonstrate that Bourns is constantly pushing the standards higher.

LARGEST SELECTION

Bourns offers the world's largest selection of potentiometers and an extensive line of precision potentiometers, relays and microcomponents. This single-source capability means less shopping around, avoidance of costly specials.

BEST AVAILABILITY

The factory maintains a constant reserve of more than 500,000 units. In addition, more than sixty distributors across the nation carry complete stocks of Bourns adjustment potentiometers. Whatever you need in potentiometers, you can depend on Bourns for an off-the-shelf answer.

OUTSTANDING APPLICATIONS HELP

Bourns maintains a staff of ten professional Application Engineers whose sole job is to give you technical assistance. Each of these specialists serves a specific geographic area. All are extremely able and anxious to help you cut time, corners and costs.

LONGEST EXPERIENCE, RELIABILITY

Bourns—originator of the TRIMPOT® lead-screw-actuated potentiometer—has been making adjustment potentiometers longer than any other manufacturer. Bourns products have the longest reliability record, too, having performed successfully in every major U.S. missile and space program. And the record continues: in today's world-wide markets, far more adjustment potentiometers bear the Bourns label than any other.

COMPETITIVE PRICES

Depth of product line and high production efficiency allow Bourns to meet or beat the prices of competitors—despite its heavy extra expenditure for product reliability. Furthermore, Bourns "holds the line" on prices while continually upgrading its products. In those cases where a Bourns unit is slightly more expensive, you can be sure that the small extra cost means considerable extra value. It is a firm Bourns policy *never* to compromise quality for price.

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Editorial

A better mousetrap isn't enough

Back in the 19th century, Emerson said, "Build a better mousetrap and the world beats a path to your door." That was a long time ago in a world that has disappeared.

Today in the electronics industry, suppliers know the customers aren't beating a path to anybody's door. A company has to ferret out the customer and offer him a product that meets a real need. In addition, the customer often expects more than just a product. He wants engineering service, maintenance help, parts availability and quick delivery.

Sometimes these services are more important than the product itself. Their existence means that the engineer who designs an electronic product has to know about a lot more than circuits and components. He has to be much closer to the customer's operation. He has to know what the customer is trying to do.

Although it is well known that application information is usually needed to design a product for an industrial, medical or consumer market, engineers seldom appreciate how important it is in military electronics too.

Today the Pentagon is anxious to have electronics companies volunteer hardware solutions to problems. Military buyers are encouraging electronics companies to use their own imaginations to identify a military problem—even if military men are not aware of it—and then design and build gear that will solve it.

This situation offers more opportunities and more challenges to engineers. It can be the basis for a mountain of new products. But the big problem is supplying what the customer really wants and not what he thinks he wants.

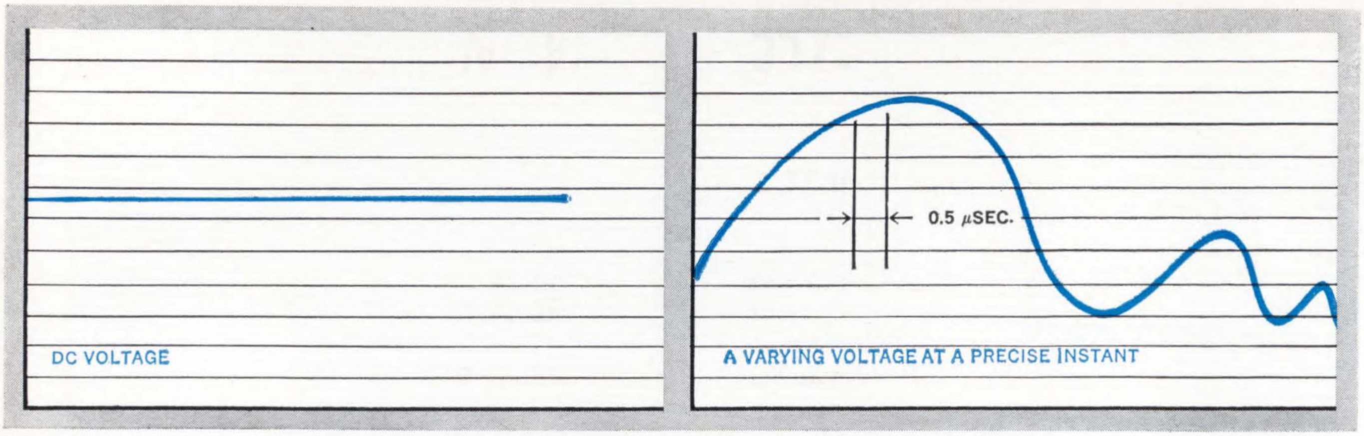
Some experts in product planning draw a distinction between what a customer needs and what he wants. Too often, the planners explain, the customer doesn't really know what he wants.

A product designer in the industrial electronics field suggests that the engineer first learn what the customer has to do in his own plant. From this the engineer can establish the performance requirements for a new product.

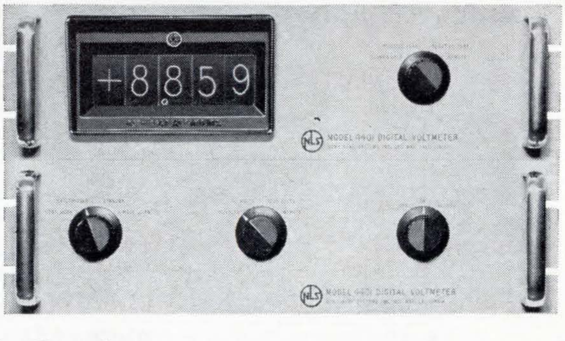
In the consumer field it is even more difficult, because consumers cannot tell you in advance what they want. It takes an imaginative product designer to supply a radical new product and an astute marketing man to sell it.

Probably the best example of this kind of success is the electric toothbrush with its electronic recharging mechanism. Nine out of ten consumers would have laughed at it in a market survey, but nobody is laughing at the sales—$40 million a year—that this new product is racking up.

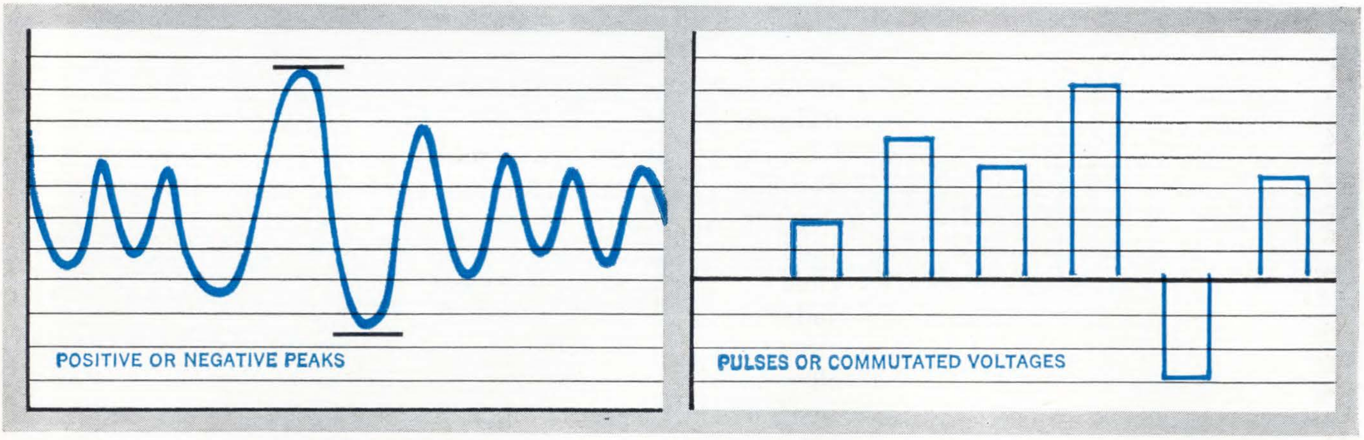
Today more than ever an electronics company's success—and an engineer's too—depends on a company's ability to produce and sell new products. But it takes a lot more than just a better mousetrap.



TALK ABOUT VERSATILITY...



This NLS dvm measures all these



Here is the digital voltmeter that brings unmatched accuracy and versatility to measurement of a varying voltage and peak voltages—plus doing virtually everything other dvms do.

Most significant, the NLS 4401 Clamp-and-Hold Model solves the problems associated with measuring a varying voltage at a definite point in time—with accuracy never before approached. No longer need you be restricted by 1) excessive or unpredictable "disconnect time" (lag between command to measure and actual measuring) 2) error caused by voltage change during measurement 3) error from low or variable input impedance 4) restricted input voltage range 5) low accuracy and calibration drift.

Consider the 4401 for such applications as measuring pulsed parameters of semiconductors . . . measuring transients in pressure, temperature, etc. . . . gyro and accelerometer tests . . .waveform studies . . . vibration analysis . . . wherever you must measure a varying voltage or voltage peaks.

The all-electronic 4401 has a disconnect time of less than ½ microsecond—and it is totally unaffected by voltage change occurring after that time. Other basic features that account for its great capability in measuring varying voltages include: a constant input impedance of 10 megs . . . three ranges—±9.999/99.99/999.9v . . . 4-digit display . . . extremely high slewing rates (rate at which 4401 can "catch up to" and "follow" input changes)—up to 300,000 v/sec on the highest range. Contact NLS for more information or to see the 4401 in action. Price complete: $6,185.

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Electronics Newsletter

December 14, 1964

Some Clevite semiconductor units sold

Clevite Corp.'s sale of its semiconductor operations in New England, on the West Coast and in Europe further underlines the continuing shakeout in the industry.

The Clevite Semiconductor division's Waltham, Mass., unit is the third New England semiconductor business to close its doors in as many years. In 1961 Columbia Broadcasting System, Inc., dissolved CBS Electronics, which had tube and semiconductor plants in Danvers, Newburyport and Lowell, Mass. In 1963 the Raytheon Co. liquidated its germanium semiconductor manufacturer in Lewiston, Maine, continuing only its silicon operations in Mountain View, Calif.

The Federal Reserved Bank of Boston estimates that New England employment in the electronic component industry dropped by more than 5,000 jobs in the 1962-63 period. [Electronics, Nov. 2, p. 88] Clevite is selling the Massachusetts plant to Honeywell, Inc. Assets other than the real estate are being sold to the International Telephone & Telegraph Corp. Honeywell's Electronic Data-Processing division, headquartered in Wellesley Hills, Mass., will consolidate its engineering, research and development groups in the $4-million plant.

ITT will also buy Clevite's semiconductor unit in Palo Alto, Calif., all outstanding common shares of Intermetal, GmbH, in Freiburg, West Germany, and the semiconductor operations, which are part of Brush Clevite, Ltd., England.

Selling imperfect semiconductors

What do you do with 30 million semiconductors that don't meet production specifications?

Motorola, Inc., may have the answer: **sell them at regular prices to original equipment manufacturers like toy and electronic organ makers who don't need top-performance devices.** Organ makers, for example, use 5 million assorted transistors a year.

The Fairchild Camera & Instrument Corp. takes a different tack: offer them as an industrial line at lower prices.

Motorola won't sell to dealers who might give the devices a new brand name and offer them at discount prices, because they say such a sales program hurts franchised distributors.

Recently, Motorola started weeding out the low-level transistors from its silicon production lines and offering them at about 30 cents each in lots of 5,000—but only to original equipment manufacturers. The company says that demand is much greater than the supply.

Fast computers at low cost

To combat the rising cost of high-speed computers, a new technique of parallel data-processing has been developed by the Rome Air Development Center. It is known as the centrally controlled iterative array computer, and it has processing modules arranged in a 10 by 10 square matrix. It is the first general-purpose computer capable of **up to 100 simultaneous parallel operations.**

The center will use the experimental computer to conduct further studies into high-speed parallel processing.

Electronics Newsletter

Fitting sonar to ship's hull

TRG, Inc., has developed a sonar system that it says provides a longer range and better target definition than existing sonars. The sonar's planar-array type antenna is long and slender and fits flush along the keel of a ship to reduce drag. Present sonars are housed in a bulb-like projection directly under the ship's bow.

The system uses new mechanical resonators to increase the array's acoustic impedance. This prevents energy loss when the array is steered near its own plane, transfers greater sound energy into the water and reduces hull noise in the signal return.

System studies on the conformal array are now being conducted by the Navy's Bureau of Ships.

Golfball-sized radar receivers

Air Force scientists have shrunk a radar receiver to the size of a golfball.

The receiver performs as well as models 200 times larger and 50 times heavier. The instrument, developed at the Rome Air Development Center, is believed to be the first microminiaturized wideband limiting amplifier ever developed with an output 6,000 times as strong as the input signal (a gain of 39 decibels) with a bandwidth ratio of 12 to 1 (capable of amplifying signals over a frequency range of 1,000 to 12,000 megacycles per second).

Big computers for everybody

If an engineer could have a large computer at his fingertips, he would be able to tackle complex problems quickly without going through the red tape of getting clearance to use the machine.

The General Electric Co. has come up with a system that uses that concept—and it does it economically.

The GE system consists of several desk-top Teletypewriters connected to a medium-size computer. An engineer is able to type his problem into the computer and within seconds get his answer.

The system encourages engineers to tackle more difficult problems because of the easy accessibility of the computer.

GE to close transformer plant

The General Electric Co. is closing its Holyoke, Mass., plant and withdrawing product lines in specialty high-voltage power-supply systems and high-voltage oil-filled specialty transformers for electronic applications.

The reasons: **A continuing decline in the available market** for high voltage specialty transformers; a less-than-anticipated growth opportunity in the market for high-voltage power-supply systems; **and drastically lowered price levels arising from worsening overcapacity in the industry.**

Down-to-earth job for space scientists

Aerospace companies in California may soon be turning their attention from Mars and the moon to the state's traffic problems.

Gov. Edmund Brown is soliciting bids from a number of the state's aerospace companies. He wants them to concentrate their scientific sophistication on earth-bound problems.

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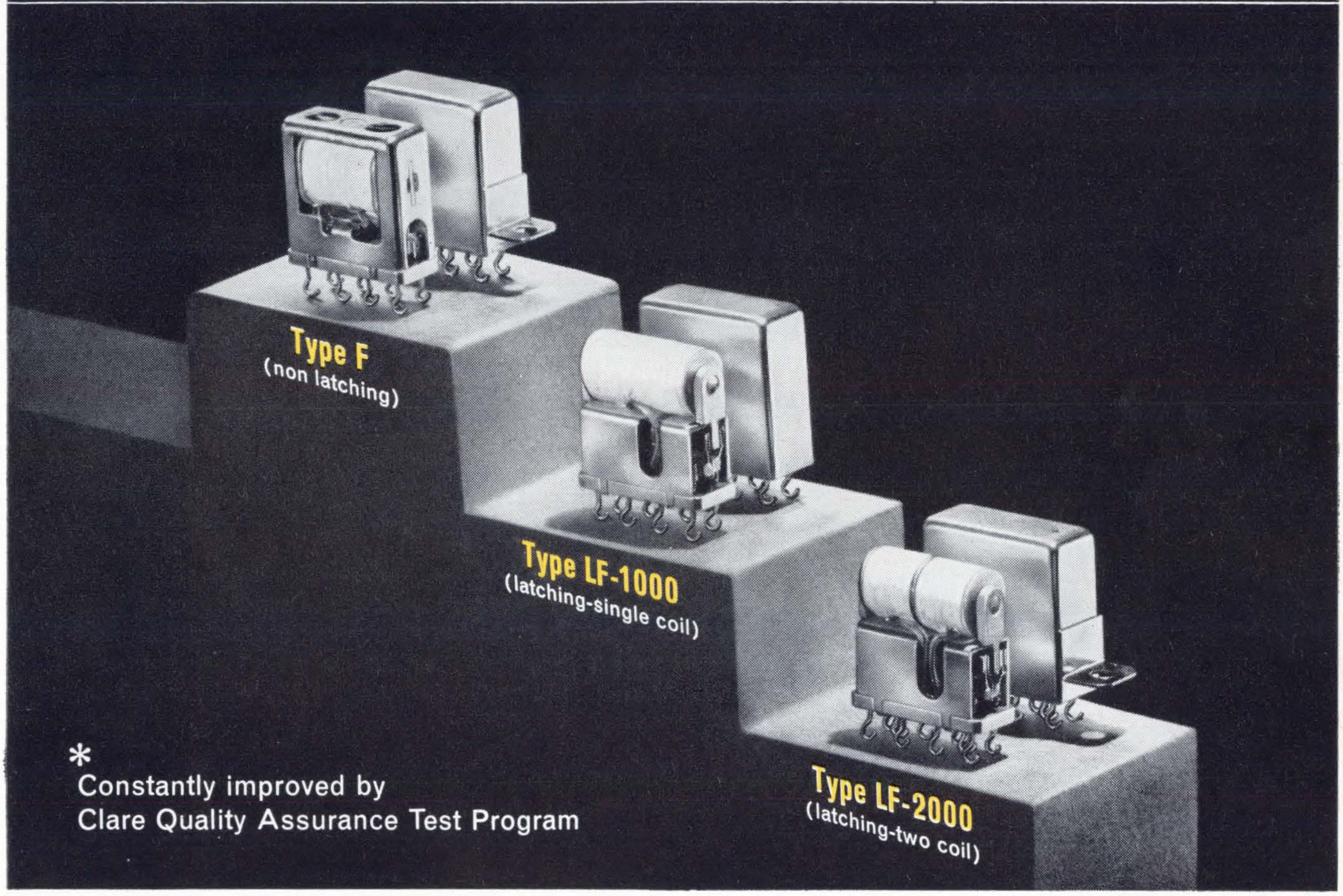
for maximum RELIABILITY* in adverse environment



Small, lightweight Clare Military-Type Relays not only meet the rigid specifications of MIL-R-5757D... they actually surpass them. They provide the highest standards of reliability ever obtained from large-volume, production line relays. Yet they are available at competitive prices and for prompt delivery.

How is this possible? The Clare Quality Assurance Test Program continually analyzes sample lots...tests them to failure...to learn the cause of breakdown, whether it be materials, processes or people. If necessary, corrections are then made to produce ever-increasing reliability.

So, whether your requirement is for Type F Relays (for non-polarized, single-side-stable, single coil operation), or Type LF Relays with magnetic latching (for polarized, bi-stable, single or double-coil operation), these relays give assured reliability and maximum contact life at high or low load level... under extreme conditions of shock, vibration and temperature. Available with either welded or soldered enclosures.

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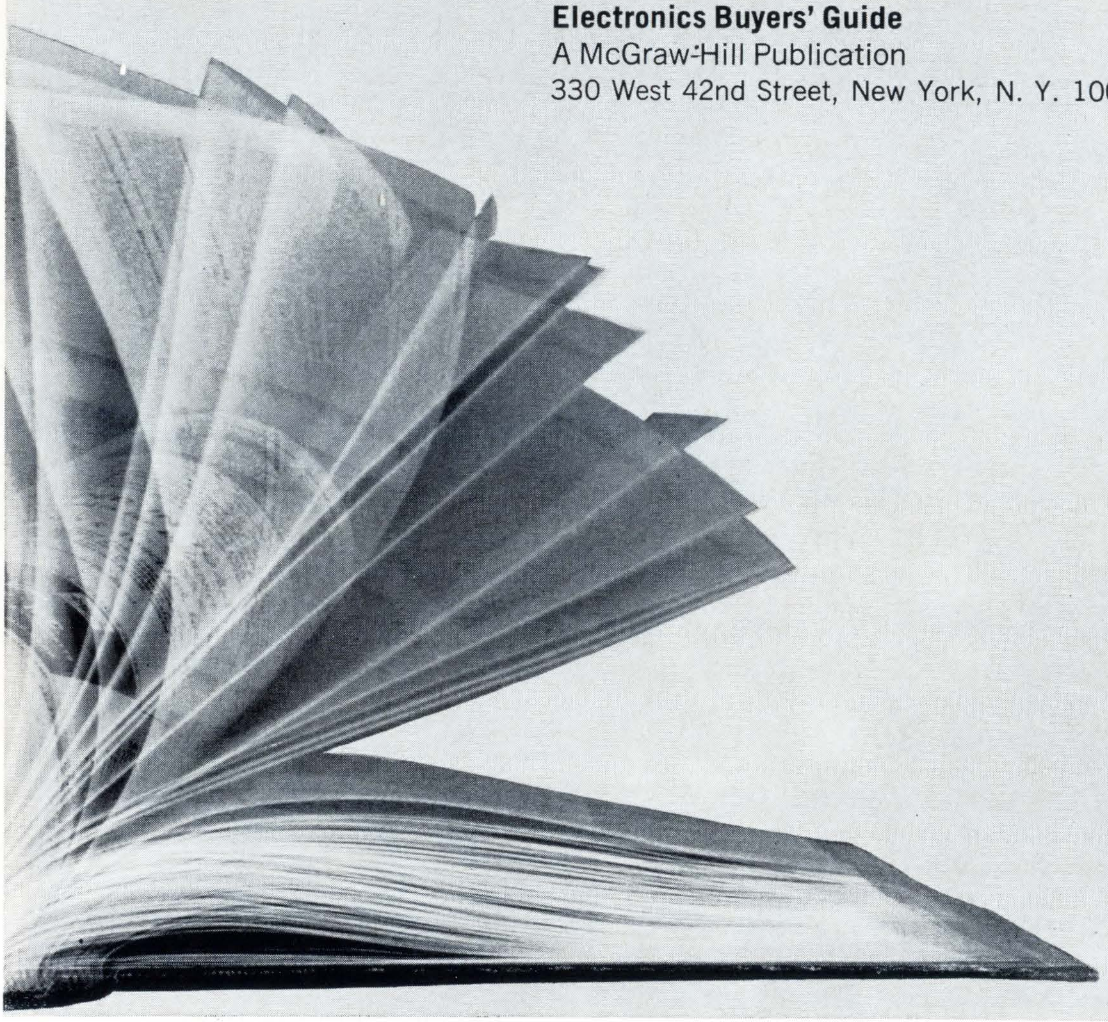
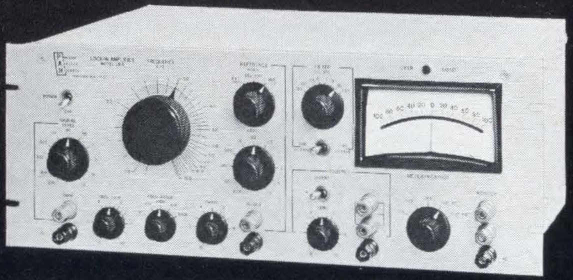



Whitney Darrow Jr.

Measure extremely weak signals in the presence of noise



Transistorized Lock-In Amplifier — Model JB-5

The model JB-5 Lock-In Amplifier provides the theoretical optimum technique for measuring extremely weak signal intensities in the presence of noise. It is a universal narrow band coherent detection system and includes: high Q continuously tunable selective amplifiers, phase sensitive detector, d.c. amplifier, selective d.c. filtering, continuous phase control, signal modulating oscillator, meter monitor and recorder drive circuits. The system is essentially an extremely narrow band detector, the center frequency of which is locked to a particular frequency at which the signal information has been made to appear. As a result, complete freedom from drift between the detector center frequency and the characteristic frequency is obtained regardless of how narrow the bandwidth is made.

Technical Features:

Frequency Range: 1.5 CPS to 150 KC continuously tunable in five ranges.

Time Constants: 0, 0.001, 0.01, 0.1, 1, 3, 10 seconds, and EXT. Single and double section RC filtering.

Gain: (rms AC in to push-pull DC out) — Greater than 9,000.

Outputs: (a) ±5 volts DC maximum, balanced to ground into high impedance load. (b) ±1 ma or ±½ ma switch selectable into pen recorder of less than 2K internal resistance.

Frequency Selective Amplifiers: Selectivity characteristic of tuned amplifiers in signal and reference channels is that of parallel resonant circuit with a Q of approximately 25 (NOT TWIN-T TYPE).

Operating Modes: External, Selective External or Internal Reference. Lock-in accepts sinusoidal or nonsinusoidal reference signal or provides sinusoidal 5V p to p reference from internal oscillator.

Price: $1,350.00

Also Available: Model JB-4 with identical specifications except frequency range limited from 15 CPS to 15 KC; price $990.00.

The low-level signal recovery capabilities of PAR Lock-In Amplifiers can be significantly extended with the addition of a PAR Model CR-4 Low-Noise, High-Gain Pre-Amplifier. The Model CR-4 is exceedingly quiet and features:

- differential input
- selectable high (50M) or low (20K) input impedance
- 20 to 80 DB gain
- selectable bandpass 1 CPS to 300 KC
- long life Hg or rechargeable NiCd battery pack
- completely transistorized
- rugged printed circuit construction
- 6½" wide, 5" high, 8¾" deep
- easily panel mounted
- price without batteries: $575.00
- also available: several optional features such as impedance matching input transformer and fast recovery Model CR-4A with selectable bandpass from 10 CPS to 300 KC

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PRINCETON APPLIED RESEARCH CORP.

Dept. D, Box 565, Princeton, New Jersey

Electronics Review

Volume 37
Number 31

Computers

RCA's Spectra 70

If there were any doubters left who did not believe that microelectronics are sweeping into commercial computers, the Radio Corp. of America convinced them last week. With its eye on International Business Machines System 360 computers (announced last May), RCA unveiled Spectra 70, a brand-new line of computers built with integrated circuits.

Aware of the hot pursuit, IBM increased its pace too. It announced that deliveries of the Series 360 would begin several months earlier than planned. Deliveries of the smallest machines will start in the second quarter of 1965 instead of the third; the larger units will be out in the third and fourth quarter instead of 1966.

As the Spectra 70 made its debut (named Spectra because the series covers the whole line, and 70 because the company believes it is the machine of the 1970s), RCA engineers bragged it was a notable step ahead of the system 360. Spectra 70 uses integrated circuits compared to System 360's hybrid microelectronics. But unlike IBM, which is making its own, RCA is buying circuits designed to its own specifications from Fairchild Semiconductor.

Multilingual machines. In the Spectra 70 line are four compatible general-purpose machines and more than 40 peripheral devices. The series is "multilingual," meaning it can use the programs of other computers, including the IBM 360 programs, as well as those of the RCA 301, 3301 and 501 computers. Rental prices range from $800 to $22,550 a month with deliveries scheduled to begin next fall.

The four computers are the 70/15 (an input-output terminal system), 70/25 (magnetic-tape processing system), 70/45 (mass random-access and scientific system) and 70/55 (management information and scientific system). The two larger ones use monolithic integrated circuits, several per chip, with switching times of 7 nanoseconds or less. Because of the microelectronics, computer cabinets have shrunk to one-third their usual size.

The two smaller RCA Spectra computers use the discrete-component circuit boards of the 301 and 3301 computers. Memory cycle speed for the 70/15 is two microseconds; for the 70/55, 840 nanoseconds. Memory sizes ranges from 4,096 to 524,288 eight-bit bytes.

Tied together quietly. In addition, the computers use a new circuit interconnection technique to reduce signal interference among adjacent circuits and eliminate most conventional wiring. Called "platter wiring" it consists of multilayer bonds, 17 inches square, with two signal layers and four voltage layers. A ground shield eliminates crosstalk.

Two external layers of printed wiring carry logic wiring into plated-through holes, to which 48-pin connectors are soldered as receptacles for 112 plug-in cards and 18 external connectors. The connector pins extend through the board and serve as additional wiring posts in the backplane.

Instrumentation

Search for new standards

Magnetic tape recorders and reproducers for missile-range instrumentation have come a long way since the mid-1950s when present production standards went into effect.

Now two committees are revising those standards. Before the revisions are adopted, however, some heated arguments are expected between manufacturers and users.

Need agreed. Everybody agrees that some standards must be changed to accommodate complex new equipment that handles more information than before. Present standards were written for narrow-band machines—0.5 to 1 megacycle. Now many companies are using machines with bandwidths up to 1.5 megacycles.

Two groups are tackling the standards. One is the telemetry work group of the Interrange Instrumentation Group; the other is the aerospace research and testing committee of the Aerospace Industries Association.

Their goal is a set of standards that will guarantee interchangeability of equipment and tape recordings, simplify systems, and reduce the amount of hardware needed.

One dispute. Some major disagreements seem to be shaping up. One argument centers on whether the voice track should be included on the telemetry tapes, as put forth by the instrument group.

Many manufacturers feel just as strongly that such a combination would result in degradation of the recording head's performance. The manufacturers want a separate head to handle voice, with a wider voice track optional to the purchaser. This, they insist, increases performance and reliability.

One manufacturer has even suggested standards governing the input and output impedance characteristics to permit equipment makers to change to a modular system. This would allow greater interchangeability of equipment.

Broader bandwidths. The standards are expected to formalize specifications on all systems up to 1.5-megacycle predetection recording. Also, frequency-modulation standards are due for a major reworking. Moving to the ultrahigh-frequency channels will allow for greater bandwidth. The requirement for a precision crystal-reference frequency for time-base correction is being added, and an attempt is being made to make the timing standards more consistent. The general feeling is that when the standards are finally published, which may take as long as two years, they will not agree with any one manufacturer's equipment.

The proposed standards were sent out in September for review by tape-recorder makers and users. Comments will be returned to the committees; then the fun is expected to begin.

Military electronics

$1 billion order

The Air Force is embarking on a major avionics development program for later models of the F-111 fighter-bomber that could eventually lead to a $1-billion outlay for the electronics industry.

Requests for bids have been mailed to 103 companies. Replies are due the first week in January. The goal is to have the equipment ready by early 1969.

Final design. The Air Force indicated that it would select three contractors to carry on competing studies. It hopes to be able to settle on a final design in about a year. For development work alone, the Air Force will invest between $160 million and $200 million.

The proposed equipment, called the Mark II, will go into the F-111s that are being produced at the time the new avionics package is ready. Thus, approximately 1,150, or 85% of the 1,350 planes the Air Force hopes to buy, will contain the new equipment. The first 200 planes will be equipped with Mark I gear, called by Alexander Flax, Assistant Air Force Secretary for Research and Development, "the best state-of-the-art equipment on any attack airplane" [Electronics, Nov. 2, p. 22].

The Air Force hopes that production-line systems won't cost more than $750,000 each. At this price, the Mark II, with modifications, probably could be used in other attack aircraft.

Breadboard components. In the Mark II program, the Air Force wants to take advantage of the performance gains promised by broadboard components now in the exploratory or advanced development phases—projects funded by both the government and industry. It is seeking improvements in navigation accuracy, all-visibility capabilities, target detection, terrain avoidance, bombing accuracy and air-to-air interception. The mean-time-to-failure goal has been set at 150 hours.

The Air Force is not setting firm requirements for the Mark II. Rather, it is asking the design competitors to say: Here is what we think can be done, making use of both advanced components and newly designed ones, and here is how long we need to do it.

The design study is to cover navigation, communications, computer and display, infrared search and detection, optical tracking, automatic terrain-following radar, attack radar and identification of friend or foe.

Television or lasers. The Air Force is leaving open, for instance, whether television or lasers should be used for optical tracking. As for the air-to-air missile, design competitors may suggest use of an existing missile, improvements on an existing missile or a completely new missile compatible with Mark II avionics. The Air Force has not yet settled on what air-to-air or air-to-ground missiles will be used on the initial F-111s.

Simultaneous with the design study, the Air Force is funding separate evaluation studies of several advanced attack radars and inertial navigation systems already in prototype form.

In developing Mark II, the Air Force will maintain close contact with the Navy's ILAAS (integrated light attack avionics system) project. Currently competing in the project-1 definition phase for ILAAS are the Sperry Rand Corp., the AC Spark Plug division of the General Motors Corp. and the Autonetics division of the North American Aviation Corp.

The ILAAS system will integrate the data from all avionics equipment and feed it into a computer. New technology, such as microelectronics, digital processing and lightweight inertial navigation will be incorporated in the system to increase its effectiveness.

ILAAS will go into the Navy's new light-attack plane, Val, if it is ready in time. If not, it will be used in Vax, the planned follow-on to Val for the 1970s.

Exchange ideas. Both the Air Force and Navy expect to exchange ideas and perhaps equipment between ILAAS and Mark II. But there are major differences in design philosophy that will restrict this exchange. Sensor improvements, for example, are not the primary aim of ILAAS, though they are of Mark II.

Weather radar

The first production model of Lear Siegler, Inc.'s cloud-detection radar was shown this month at Hanscom Field in Bedford, Mass. The radar is part of the Air Force's $60-million program to modernize its weather service.

The radar sets cost $27,000 each and they will be delivered to stations throughout the world in 1965 [Electronics, Sept. 21, p. 34].

The modernization program, known as the 433L System, is managed at the field's Electronic Systems division under the direction of Lt. Col. Robert L. Houghten. The United Aircraft Corp. is the prime contractor.

No interruption. The program calls for gradual incorporation of new equipment and techniques to enable the service to meet its increasing requirements. The modernization had to be accomplished without interruption or suspension of the operating weather service, so a building-block concept was devised in which system improvements such as the weather radars are phased into use as they become available.

Production contracts are scheduled to be awarded next spring for 300 weather-map recorders, 20 transmitters and 20 radiosonde data computers. A production contract for the final item in the program, 23 balloon-launching systems, will be awarded in November, 1965.

Ready in 1967. All developmental work will end in the summer of 1966, with the system due to become completely operational in September, 1967. The first equipment in the program to go operational was a satellite readout station; stations were installed at 19 military facilities.

The program was started in 1958 as a combined effort of the Air Force Weather Bureau and other government agencies. In 1961, the Weather Bureau dropped out of the program and the Air Force continued the development alone. The air weather service furnishes weather information and forecasting to the Army as well as the Air Force. The Navy does its own.

Speed is vital. Since weather information is perishable, it is useful for command and control decisions only when it is collected and transmitted quickly. This means an increased use of weather computers, an essential part of the 433L program. Also, the new system tailors forecasts to specific operational requirements, and uses updated techniques for display.

The processed weather information is in some cases a direct input to command and control systems. The 13 pieces of equipment involved in the program vary from portable tactical sensors, such as a temperature-dew point measuring kit, to radar systems. Computer programs have been developed for analyzing the raw weather data at Military Weather Central, located in Offutt Air Force Base, Neb., the headquarters of the Strategic Air Command.

Communications

Disaster-proof network

The Bell System has put into service a new underground transcontinental coaxial cable that adds 9,000 telephone circuits to the 15,000 that already span the country and provides a communications link from New York to California that is nearly disaster-proof.

Two sections of Bell System's blast-resistant cable are spliced to join the East and West Coasts. The 12-tube coaxial link provides six sets of 1,860-channel circuits and two spare sets in case of failure. Wires carry alarm and control circuits.

Bell's 4,000-mile buried cable, four to five feet below ground, can ride out most natural disasters—floods, hurricanes, cyclones—and even nuclear blasts short of a direct hit. It can withstand pressures of a hundred pounds per square inch.

Added to existing Bell microwave-repeater channels and the recent Western Union nets, which links 19 major cities, the hardened circuits give United States military planners several alternate routes for emergency command and control.

Stations below ground. Along the route, carefully skirting major nuclear targets, are 900 underground amplifier stations. In addition, 11 manned communications centers are included. One- and two-story buildings under ground, built of reinforced concrete, are accessible through lead-lined concrete doors weighing 3,600 pounds.

Personnel enter the first door via a small entrance building and must await its closing before they can proceed through the second door. Nuclear sensors seal off normal ventilation immediately, switching air filters in to avoid contamination by fallout. A three-week supply of food and water is provided.

From New York to Washington there are two cables, each containing eight coaxial conductors. Westward, a single cable contains 12 coaxials.

The coaxials are used in pairs, for transmissions in opposite directions. Each pair carries up to 1,860 simultaneous conversations. However, two coaxials are reserved as spares, to be switched in automatically if others fail. There are also 50 to 300 wires for control and alarm circuits or for short-distance communications.

The Bell L-3 carrier-frequency system used requires repeater amplifiers every four miles. A new system, the L-4, will be tried next year, but will require transistor amplifiers in precast manholes spaced every two miles. However, with L-4 each pair of coaxials can handle 3,600 conversations.

Microwaves. Meanwhile, the capacity of Bell's TD-2 cross-country microwave network has been increased to 6,000 circuits from 2,400. In addition, the TH system, operating at six gigacycles (TD-2 uses 4 Gc) has a working capacity of 10,800 circuits and uses the same towers. Duplication is scheduled to be completed by 1967. For shorter legs from the main microwave net to cities nearby, Bell has developed TJ and TL systems operating at 11 Gc. Finally, a short-haul 6-Gc TM system was put into use last June.

Although a single microwave tower and its equipment is vulnerable to sabotage, Bell has van units located strategically and can replace a complete microwave station in about 20 hours—less if the antenna is intact.

Washington, New York, San Francisco and Los Angeles are linked with 15 other major cities through the Western Union Telegraph Co.'s 7,500-mile microwave network that avoids major nuclear targets and Bell System installations. Western Union's microwave capacity is 600 voice bands.

Components

Connectors not changed

In the November 2 issue of Electronics, a story in Electronics Review (Connectors: Act 2, page 25) concerning Amphenol-Borg and the 26500 connector stated, "A large airline was reported to have replaced 10,000 connectors of the 26500 type with 1599's." The story continued "But David McNally, president of Amphenol's connector Division, says Amphenol has received no such report." As a matter of fact, Electronics, in fairness to Amphenol, must say that present information indicates that 10,000 of Amphenol-Borg's 26500 connector have not been replaced.

Avionics

Quiet talk

A new, completely self-contained communications set cuts out the screaming jets and roaring propeller noises and permits easy talk between a ground crew and pilot.

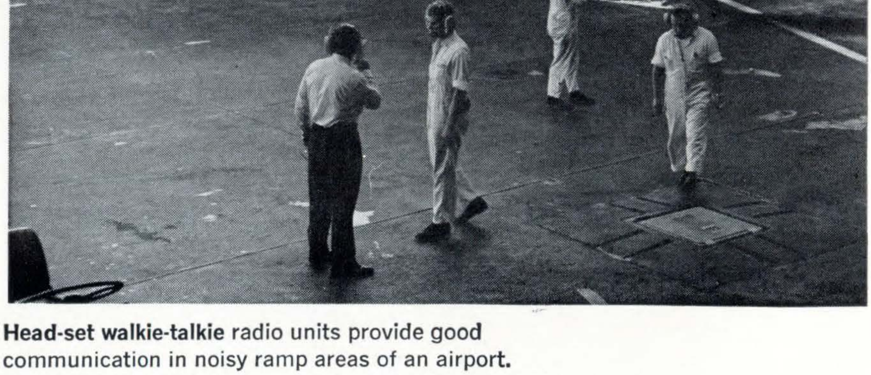
The transceiver, capable of reliable communications in ambient noise-pressure levels as high as 135 decibels (0.002 dynes per square centimeter reference) was developed by the Bendix Radio division of the Bendix Corp. in Baltimore as a headset to increase the safety and efficiency of ramp operations.

Stamping out noise. The set, called the RTH-23A, has been designed for use at high noise levels. The earpods use standard defenders that help to reduce background noise. Electronics inside the earpod reduces noise further and improves the defender's basic design. The headset also uses a special sound-pressure noise-cancelling dynamic microphone that makes use of the noise field surrounding the microphone itself as part of the noise-cancelling dynamics.

An automatic volume control, which is a background noise-sensing circuit, controls the receiver's audio output into the earphones. When the background noise is below 110 decibels, the audio into the earphones is two milliwatts; as the noise level increases to 130 decibels, the audio output level increases linearly to 100 milliwatts. The dynamic earphones and microphone have an audio-frequency response to six kilocycles, compared with the four-kilocycle response of a standard carbon noise-cancelling microphone. The increased audio-frequency response improves speech intelligibility by about 20%.

Compact. The solid-state headset transceiver weighs only three pounds. This includes the complete very-high-frequency transmitter, the receiver, rechargeable battery, headband antenna and hand-held push-to-talk switch. With the antenna, which does not protrude from the headband, the unit has a range of about 1,000 feet; with a halo-type antenna the range can be almost doubled.

The RTH-23A operates in the 118- to 136-millicycle band, although other frequency ranges and modulation types are available.



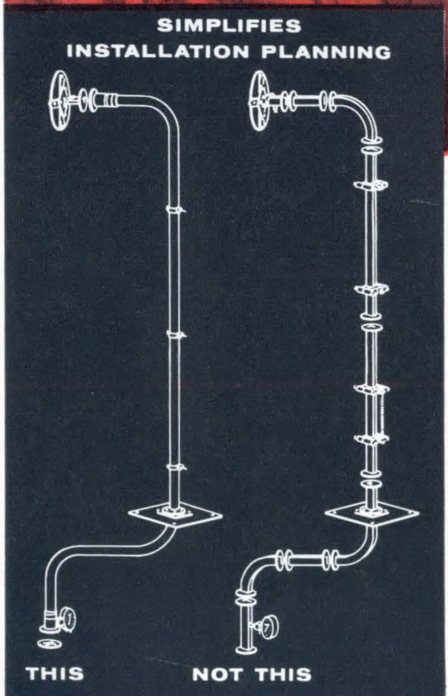
Head-set walkie-talkie radio units provide good communication in noisy ramp areas of an airport.

Advanced technology

A laser standard?

The laser is making it easier to measure length, and eventually may even become the primary standard.

Use of lasers in the standards field has been under investigation for years by the Commerce Department's National Bureau of Stand-



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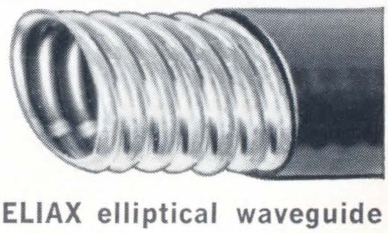

Continuous lengths . . . flexible. HELIAX elliptical waveguide eliminates the echo distortion caused by the numerous bends, twists, and flange joints of a conventional waveguide run. Attenuation is also reduced*. HELIAX flexibility simplifies planning and handling. Installation requires only unreeling, attachment to tower, and connection to equipment. Write today, or ask your Andrew sales engineer for complete information on this new Andrew waveguide development!

*At 6700 Mc, HELIAX elliptical waveguide loss is 1.5 db/100 ft. compared to 1.9 db/100 ft. for rectangular waveguide.

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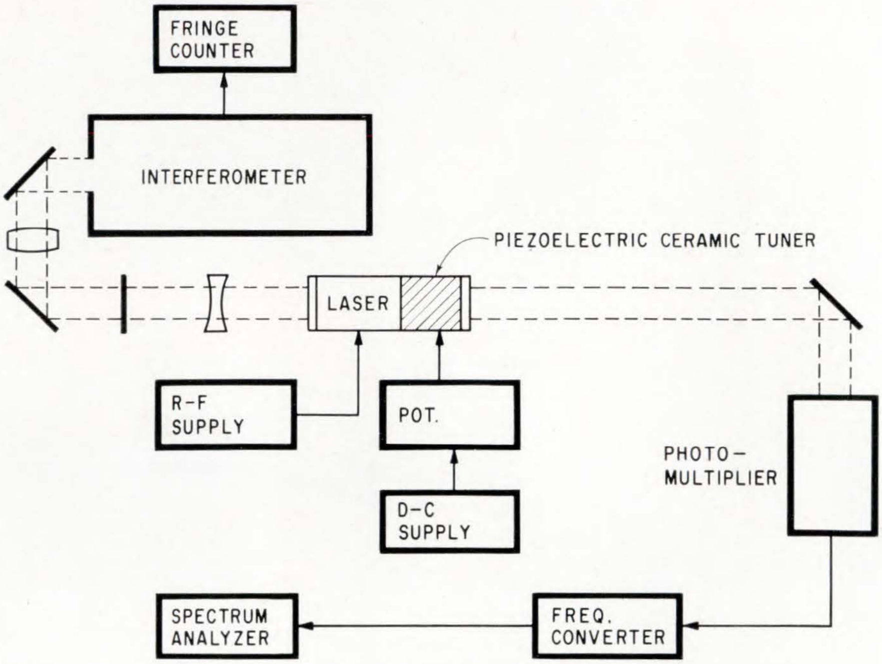
ards. Recently, for the first time, a helium-neon gas laser was used successfully to measure the length of a standard meter by interferometry. As this new technique is refined further, it may be possible to use the laser as a working standard for calibration measurements. Compared with conventional methods, it is easier to use, more powerful, and has greater range.

Lasers are now being used by commercial companies for measurements on high-precision optical systems—for example, to measure thicknesses of mirror layers at the Bell Telephone Laboratories, and to grind accurately shaped mirrors and lenses at the Perkin-Elmer Corp. However, using laser interferometry to measure lengths of about a meter, and specifically for standards measurements, is an innovation of the National Bureau of Standards.



Laser wavelength is electronically tuned and continuously monitored while a measurement is taking place in the optical interferometer at the top.

The standard. The international meter is now defined as 1,650,763.73 wavelengths of a certain spectral line given off by krypton-86, an isotope of a rare gas. The interferometric measurement is complex, and the krypton-line source can measure distances only of the order of one-tenth of a meter so that several such measurements have to be added up to make a meter.

In contrast, says A. G. McNish, chief of the bureau's metrology division, the gas laser can easily provide accurate measurements of interference of over a meter. If equipment becomes available, he adds, these accurate measurements can be extended to several kilometers. The accuracy of the laser measurement is about the same as the krypton method—one in 10^6—but the extra measurement length and the high beam power of the laser make the laser measurement much easier.

The chief question remaining is whether the gas-laser wavelength can be reproduced as accurately as that of the krypton method. The emission wavelength of a present-day gas laser depends on the dimensions and shape of the tunable resonant cavity, and this is susceptible to changes with environmental variations. The bureau is conducting research into this aspect.

Beam is split. The bureau's gas laser operates at 6,238 angstrom units. During measurement, its mode is kept constant by adjusting the radio-frequency power supply, and the length of its tunable cavity could conceivably be coupled, by a servo loop, to a krypton-86 standard.

The laser beam is used with a special interferometer that splits the beam; half travels across the distance to be measured and then returns to establish a pattern of interference fringes with the other half. The fringes, which occur every half-wavelength, are counted electronically. Conventional light sources, such as krypton arc lamps, produce interference fringes that fade out after a few hundred thousand wavelengths; in contrast, laser interference fringes would remain sharply distinguishable even after many kilometers.

Eventually, says McNish, it may be possible to achieve a redefinition of the international standard meter in terms of a laser-emitted wavelength. Such a major action would involve approval by the International Committee on Weights and Measures, of which the United States is a member. At present, however, the bureau says it is "merely exploring the possibility of such a redefinition."

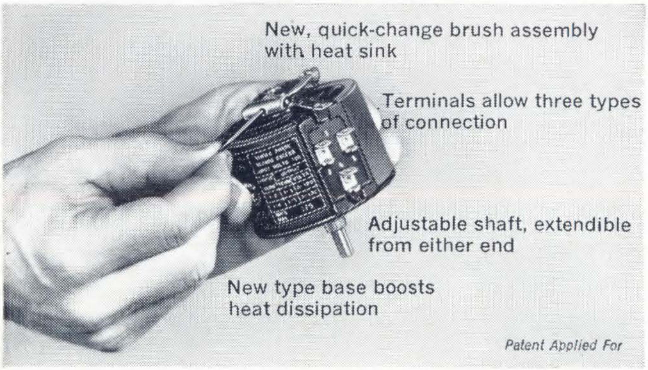
Better mirror, better laser

Bell Telephone Laboratories says it has developed a near-perfect mirror that is able to sharply boost the intensity of a laser.

The mirror-making technique, developed by Bell Labs researcher D. L. Perry, is said to produce a mirror so nearly perfect that its light loss cannot be detected. Bell Labs is research arm of American Telephone & Telegraph Co.

A laser mirror is made by coating a blank with layers of optically transparent dielectric material that have alternately high and low indexes of refraction. Each dielectric layer is applied in turn by melting it in an evacuated bell jar and allowing it to evaporate onto the blank. The thickness of each layer is kept at one-quarter the wavelength of the laser light so that components of reflected light from each layer add up in phase, thus reinforcing the reflected beam.

Practical limit. The most direct way to increase mirror reflectivity



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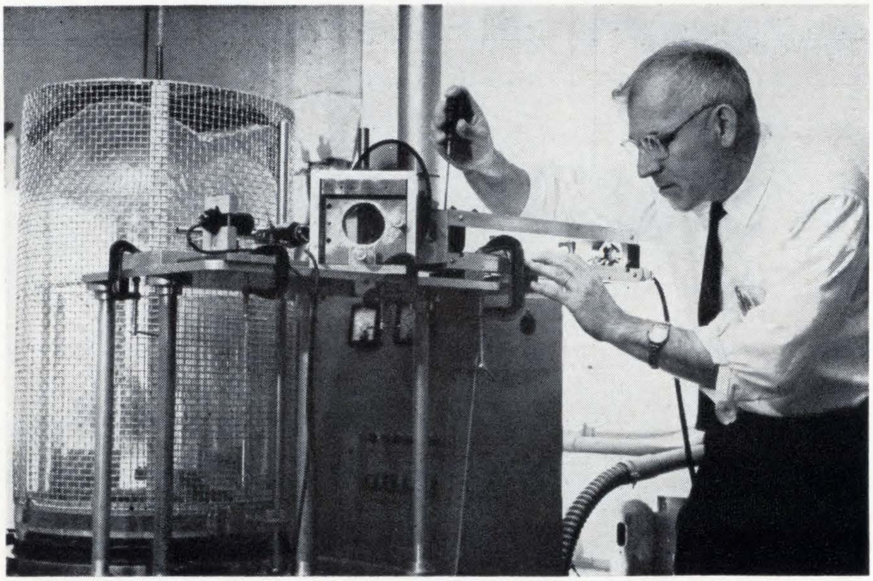


Gas-laser ratiometer that monitors thickness of material on near-perfect mirror is adjusted by D. L. Perry, who developed the technique.

is to increase the number of dielectric layers, but the practical limit for the best mirrors up to now has been 15 layers. After this point, the benefits of additional layers are negated by increased absorption and, more important, by increased light scattering.

Light scattering, caused by contaminants and larger particles of dielectric, has been nearly eliminated by two refinements, one in the method of evaporating the dielectric and the other in the method of cleaning the blank. Now any number of layers can be added, but since 100% reflectivity is approached asymptotically, 35 layers is the most used.

The previous method of evaporating the dielectric, heating it in powdered form to the melting point, would often free particles that are larger than molecules. In Bell's process, the dielectric is heated in chunks at a precise temperature just below the melting point.

Careful handling. The common practice of final cleaning by passing a glow discharge over the blank to vaporize any contaminants, it was discovered, does more harm than good. The glow dislodges previously deposited coatings on the side of the bell jar, causing them to fall onto the clean blank. Glow-discharge cleaning has been eliminated simply by more careful handling of the blank before putting it into the jar.

One other factor contributes to the success of the mirror: the accuracy with which the thickness of each layer is measured as it is evaporated onto the blank. This is accomplished by a light ratiometer, which compares the output from a gas laser directly, and the light that is reflected from a monitoring slide in the bell jar. As the material on the slide builds up to one-quarter of a wavelength, the reflected light approaches either a maximum or a minimum.

Space electronics

Tracking Apollo

Earthbound tracking stations will keep the Apollo spacecraft under constant surveillance during its 70-hour trip to the moon, its two-day orbiting of the moon while explorers study the lunar surface, and the 70-hour trip back to earth.

Three stations will be aboard instrument ships equipped with antenna systems especially designed to track Apollo. These antennas will be accurate enough to meet the stringent requirements of the mission, and rugged enough to withstand high wind and seas.

The Reeves Instrument Co., a division of Dynamics Corp. of America, has a $2.5-million contract to build a 30-foot tracking antenna for each of the first three Apollo tracking ships.

Multimode feed. The biggest departure from conventional tracking-antenna design will be the use of a single multimode horn feed rather than the usual four single-mode horns. The multimode feed is expected to illuminate the reflector more efficiently, resulting in higher accuracy and an error-channel gain 2 to 3 decibels higher than usual.

The antenna, which is to be used without a radome, must be able to hold its position even in wind up to 60 knots per hour. To increase rigidity and eliminate gearing errors, torque-motor drives replace gear trains for azimuth and elevation positioning. A single motor is used for control of elevation, rather than the customary two. The single motor, in the center of the dish, will have its weight concentrated on the azimuth bearing. It will have a fixed rotor and will have its stator coupled to the dish. Elimination of a bearing and a motor also increase reliability.

'As good as any.' Stanley Freeman, project manager at Reeves, says the total dynamic tracking accuracy will be 1.5 minutes of arc, including servo, line-of-sight and other errors. "That's as good or better than any in the field."

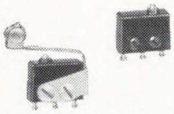
A digital computer will store the trajectory profile and point the antenna toward the spacecraft. In addition, a gyroscope system will stabilize the antenna platform. To compensate for a ship's motion, an integrating accelerometer will give angular correction to the antenna.

The antennas are expected to be completed long before the Apollo shot that is scheduled for 1969. They'll probably be used in earlier space shots.

Two other ships with 12-foot antennas will track the returning spacecraft at the end of the mission. Reeves also expects to build these antenna systems and the telemetry antennas.

HONEYWELL

MICRO SWITCH Precision Switches



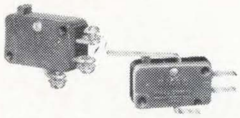
"1SX," Smallest Subminiature Switches available: Long-life, high electrical capacity. Size: .35" x .50" x .20". Variety of auxiliary actuators. SPDT. Rating: 7 amps, 115 or 230 vac; 4 amps ind. and 7 amps res., 28 vdc. Available with gold contacts for dry circuits.

"SM" Subminiature Switches: Small, light weight. 5 or 10 amp versions. Auxiliary actuators available. Size: .78" x .52" x .25". SPDT. Ratings: 5 amp "SM"—5 amps, 125 or 250 vac; 3 amps ind. and 5 amps res., 28 vdc. 10 amp "41SM"—10 amps, 125 or 250 vac; ¼ hp. 125 or 250 vac. 5 amp version available with gold contacts.

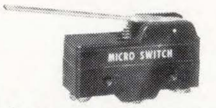
"HM" Hermetically-sealed, Subminiature Switches: Sealed metal-to-metal and glass-to-metal. Interchangeable with other subminiature switches. High-temperature and corrosion resistant. Temperature range, —300° to +500° F. SPDT. .49" x .79" x .25". Rating: 3 amps ind. and 5 amps. res., 28 vdc.

"SE" Environment-proof Subminiature Switches: Small, sealed. Temperature range, —65° to +212° F. Size: .81" x .88" x .34". Auxiliary actuators available. SPDT. Rating: 5 amps, 125 or 250 vac; 3 amps ind. and 5 amps res., 28 vdc.

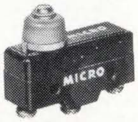
1CS1 Reed Switch: For dry circuit applications requiring long life, low power actuation. Consists of low reluctance metal reeds, hermetically sealed in inert gas filled glass tube. Actuated by permanent magnet or magnetic coil. Size: .105" diameter x 1.5". Rating: .100 amp, 120 vac; .125 amp, 32 vdc.



"V3" Miniature Switches: Small, high capacity. Screw, solder or quick connect terminals. Can be gang-mounted. Integral actuators (shown) or auxiliary actuators. SPDT or SPST. Size: .74" x 1.09" x .40" (without terminals or actuator). Rating: 15 amp, 125 or 250 vac; ½ amp, 125 vdc; ¼ amp. 250 vdc. Gold contact versions available.

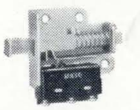


"Z" General Purpose Basic Switches: Rigid lever ideal for slow cams and slides having low operating force. Size: 1.33" x 1.94" x .69". Variety of terminals and actuators. Rating: 15 amps, 125, 250 or 480 vac; ½ amp, 125 vdc; ¼ amp, 250 vdc.

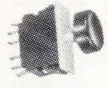


"BZ-2RDS" Basic Switches: Elastomer boot and cover seal protect against dust and moisture. Large diameter plunger and 1/16 inch overtravel. Variety of circuitry and terminals. Size: 1.94" x 1.64" x .69". Rating: 15 amps, 125, 250 or 480 vac; ½ amp, 125 vdc; ¼ amp, 250 vdc.

12 MA Actuators: Fit on pin-plunger switches for pushbutton applications. Attractive black, red, and green plastic buttons in ½" and 1" sizes. Anodized mounting hardware.



"AC" Interlock Switches: Used on electrical or electronic equipment to cut power safely when doors or drawers are opened for servicing. Automatic reset. Size: 1.18" x 1.10" x .34".



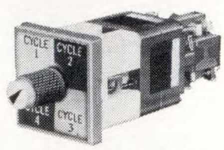
"DM" Pushbutton Switches: Attractive, rugged snap-in panel mount. SPDT or DPDT circuitry. Three button styles, ½" to 1" diameter, red or black. Rating: 10 amps, 125 or 250 vac; ⅓ hp, 125 or 250 vac. Size shown: 1.85" x 1.25" x .68".

"PB" Pushbutton Switches: Snap-action button mechanism with subminiature basic switches. 2, 3 or 4 poles. SPDT. Compact. Size shown: 1.54" x .78" x .91".

"302PB" Miniature Lighted Pushbutton Switches: Occupies less than one cubic inch of space. Alternate action, momentary action, or indicator units. Long lamp life. 15 screen color combinations. Size: 1.3" x .99" x .81".

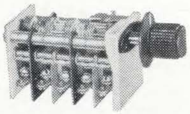
3MN Basic Switches: Two-circuit double-break for limit or control functions. Integral terminals permit gang-mounting without separate insulating barriers. Combined width of three switches, only 2.03". Rating: 15 amps, 120, 240, 480 or 600 vac; 0.8 amp, 115 vdc; 0.4 amp, 230 vdc. Size: 2.50" x 1.20" x .68".

"Series 2" Modular Lighted Pushbutton Switches: Round or rectangular operator units. Maintained, momentary or magnetic pull-in action. Variety of color screens. 20 switch modules. Size: 3" x 1¼" x 1".



Coordinated Manual Control: Combines lighted legend display and heavy duty or electronic duty contact blocks in compact, sealed assembly. Units available—pushbutton, rotary selector, selector-push, and indicator only. Variety of color-coded displays, up to seven lines of legend. Requires only 2 5/16" x 2 5/16" panel front space.

"TS" Bushing-mounted Toggle Switches: Sealed lever and keyed bushing. Multi-circuit switching. 1 and 2 pole. Size: 2.24" x 1.13" x .63". Rating: 15 amps ind., 25 amps res., 30 vdc; 10 amps ind. and 15 amps res., 125 vac.



"1RM" Multi-pole Rotary Switches: 15 amp. capacity, up to eight switching units. Two-position switches are standard—up to eight positions available. Gold-contact and hermetically-sealed assemblies available. Size: shown: 2.5" x 1.6" x 1.5".

Mercury Switches: Offer reliability in contaminated atmospheres. Many sizes, capacities, and operating characteristics. Hermetically sealed glass tube. Enclosed switch shown: 1.88" x .53" diameter.

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A quick glance into the MICRO SWITCH line helps you find an economical off-the-shelf answer to most any switch problem—whether it involves space or weight limitations, circuitry, actuation, environment, indication, reliability, or any of the other countless switch requirements. Most every time you avoid the special you may have thought necessary. The MICRO SWITCH line is that extensive and is continually expanding with new developments. A few of the hundreds available are shown above.

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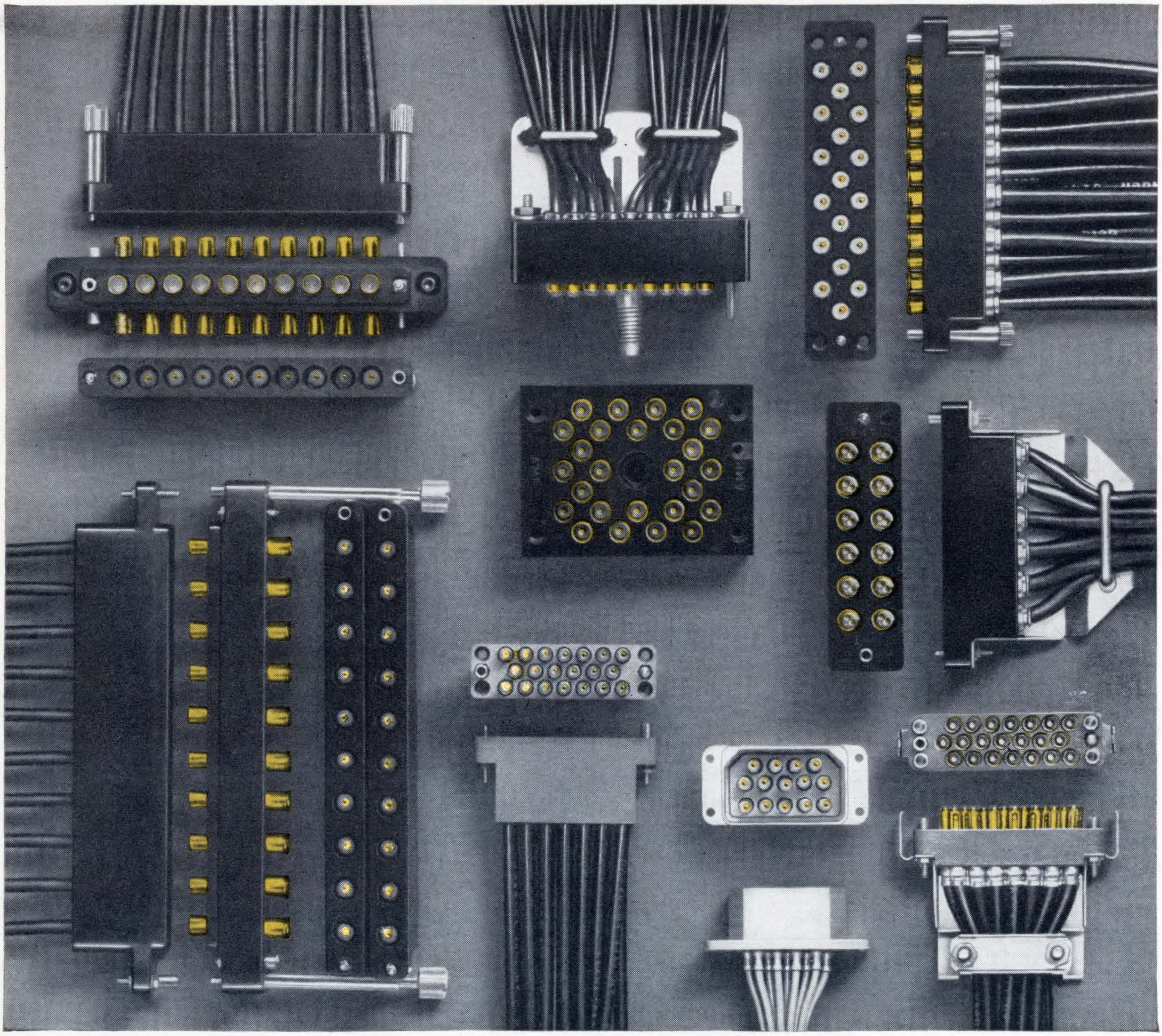

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Washington Newsletter

December 14, 1964

Electronics grows at fast rate

The electronics industry is growing faster than United States industry as a whole.

The new census of manufacturers, the authoritative index of industrial growth, done every five years by the Department of Commerce, says **that between 1958 and 1963, "value added" by electronic component companies rose 78%, from $1.4 billion to $2.5 billion.** The increase for U. S. industry as a whole was 34%, from $141 billion to $190 billion. "Value added" is the difference between the cost of products and the cost of materials used to produce them. When viewed together with the number of employes, value added gives a measure of trends in productivity.

Value added for electron tubes dropped from $286 million to $236 million and employment declined from 37,000 to 24,000. Cathode-ray picture tubes increased from $67 million to $123 million, but employment went up only 2,000, to 11,000. Electron transmitting tubes increased from $166 million to $206 million, with no increase in employment. **Semiconductors increased from $187 million to $477 million,** with an employment increase from 23,000 to 58,000. **Electronic components nearly doubled, from $729 million to $1.4 billion,** with an employment increase from 109,000 to 171,000.

Manned space lab at the crossroads

White House budget writers in the next few weeks will set the course of the proposed manned orbiting space laboratory.

Two directions are possible: Either the Air Force will retain its program for the orbiting lab and use the huge Titan IIIC that is taking a $1 billion to develop, or, to save money, the National Aeronautics and Space Administration will work with the Air Force and use NASA's three-man Apollo spacecraft instead of the Air Force's two-man Gemini.

If the program is developed jointly, NASA's capsule and booster, the Saturn IB, will be used, and NASA will probably use the Titan IIIC—designed specifically for the space lab—for some future space probes.

If the Air Force is able to persuade the budget makers to let the service develop the program on its own, NASA's own manned orbiting space station will probably be delayed until the 1970s.

Development bugs plaguing missile

The Navy's surface-to-air missile system is still running into development problems. **Funds for production won't be included in fiscal 1966's defense budget.**

The system is needed to provide protection against enemy bombers for convoys, landing craft and hunter-killer submarine forces. These vessels are usually accompanied by destroyers armed with Tartar, Terrier and Talos air-defense missiles. But these are short-range missiles and cannot knock down a bomber that stands off and fires long-range missiles.

At first, the Navy tried to develop the Typhon missile for this mission, but dropped it because the guidance and control mechanism called for a radar so huge is could only be mounted on a vessel as large as a cruiser. It then shifted to the advanced surface missile system, but so far the weight and size problems have only been partly solved.

Defense Department officials are considering requiring that the Navy's system and the Army's air defense system have much in common. The

Army missile, to be mounted on track vehicles, is to be capable of knocking down both aircraft and short-range tactical missiles. It would replace the Hercules and Hawk missiles.

Another step in cost cutting

The Pentagon may extend its cost-cutting program into another area.

Under a proposed regulation, **the government would be able to buy directly components in a weapon system being furnished by the contractor on a sole-source basis.** This step would be allowed if the Pentagon decides that volume buying or competitive bidding would save the government money.

Industry associations will have until Jan. 25 to comment on the proposals.

Pentagon seeks its patent rights

The Pentagon wants to be sure it's getting its money's worth when something is invented under a military contract.

Comptroller General Joseph Campbell is showing increasing concern over the failure of contract administrators to make sure that defense companies disclose such inventions to the government. In two recent investigations involving Lockheed Aircraft Co.'s subsidiary, the Lockheed Missiles & Space Co., and Thompson Ramo Wooldridge, Inc., Campbell **alleges the government's patent rights were jeopardized because it wasn't aware it had title rights as rights to use the inventions without paying royalities.**

Washington seeks faster printing

Government pressure is growing for faster automatic typesetting by photography, sparked by an explosion in printed scientific and technical information.

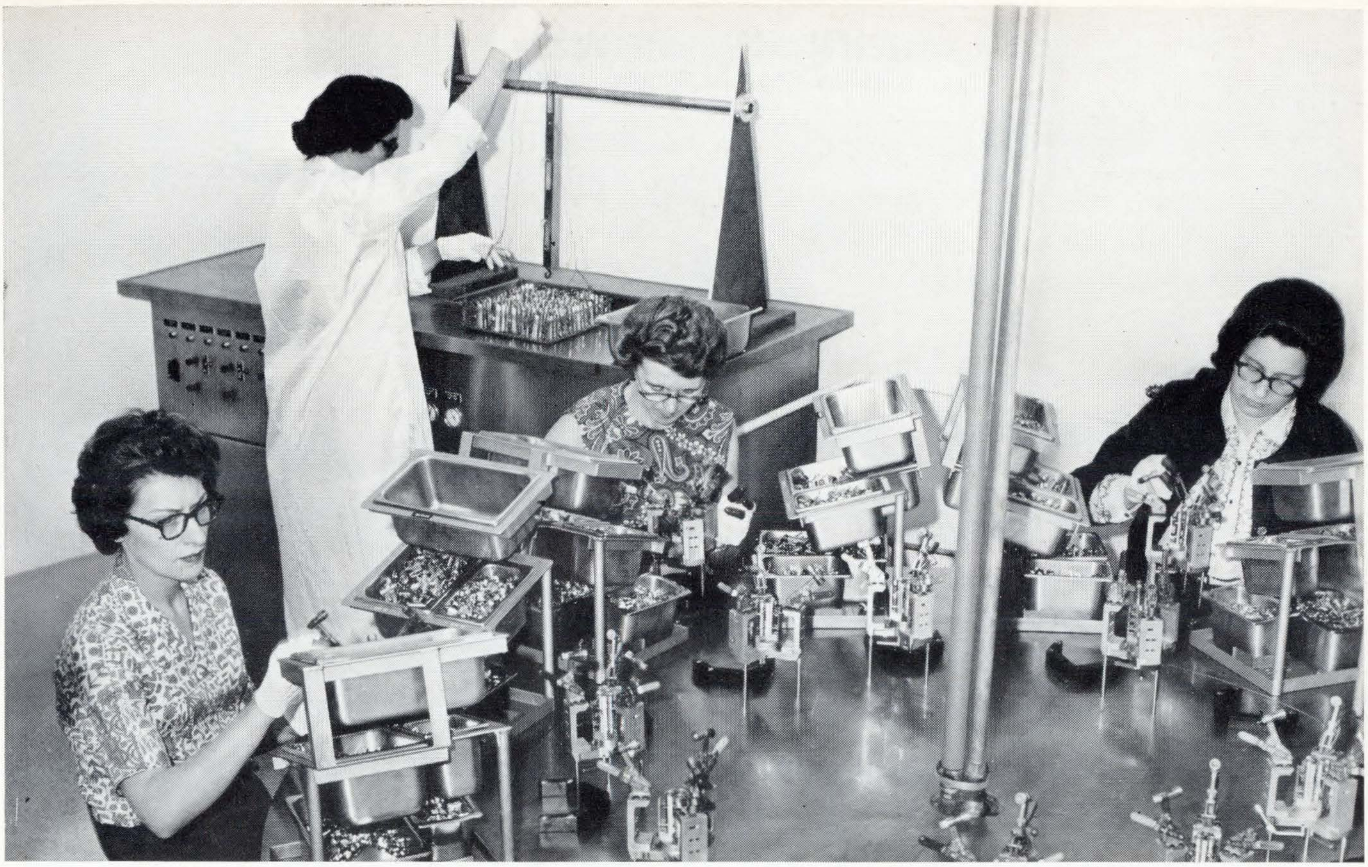
The Pentagon, for example, threatened to pull its printing business out of the Government Printing Office unless that office could match the speed of the electronic printing system developed for the National Library of Medicine by the Photon Corp.

The Printing Office recently awarded a development contract to the Mergenthaler Linotype Corp. for a fully electronic Linotron printer that can reproduce four pages a second. And the Air Force has given a $4 million order to Mergenthaler and to CBS Laboratories, a division of Columbia Broadcasting System, Inc., for two such systems.

Photon, to remain competitive, is developing a second-generation system that is faster and more completely electronic.

Addenda

The Defense Department hopes to save money by taking away from the military branches responsibility for passing on security clearances for employes of its contractors. The job will be handled in a new industrial security clearance office to open at Columbus, Ohio, in March. . . . The Defense Department is turning to computers to assist it in finding new government employment for workers losing jobs as a result of the military base-closing program. A pilot program operated from the Defense Electronics Supply Center at Dayton, Ohio, and covering six Midwestern states will be applied nationwide starting in February.



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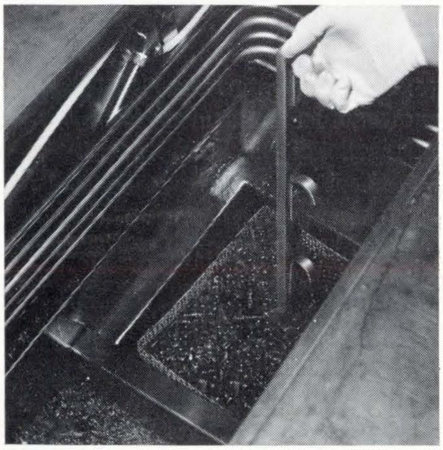
Rauland uses FREON® TF to "super-clean" color-TV picture-tube subassemblies

Cleaning of color-TV tube gun subassemblies is a critical operation because of the extremely high voltages to which they will be subjected. Any particulate matter not removed could cause arcing and a blown tube . . . any leftover lubricants would seriously affect the rise time and service life of the tube. For this critical cleaning operation, the Rauland Corporation, Chicago—a division of Zenith Radio Corporation—uses FREON TF solvent.



This combination cleaning system was engineered specifically for the Rauland Corporation by G. S. Blakeslee Co., Chicago, Illinois. It is just another example of the complete cleaning system engineering you can expect from your representative for Du Pont FREON®.

Now, cleaning of the subassemblies is a quick, simple, low-cost operation . . . thanks to a cleaning system engineered and installed by a FREON solvent sales agent. This cleaning system uses FREON TF. The combined action of extremely low surface tension and high density enables FREON TF to penetrate minute crevices and effectively release and float away soils . . . even particulate matter. This results in complete, residue-free cleaning.

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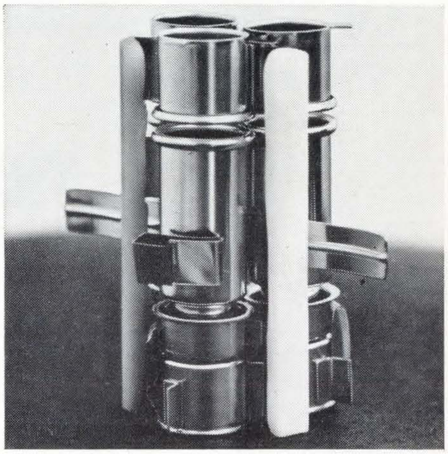

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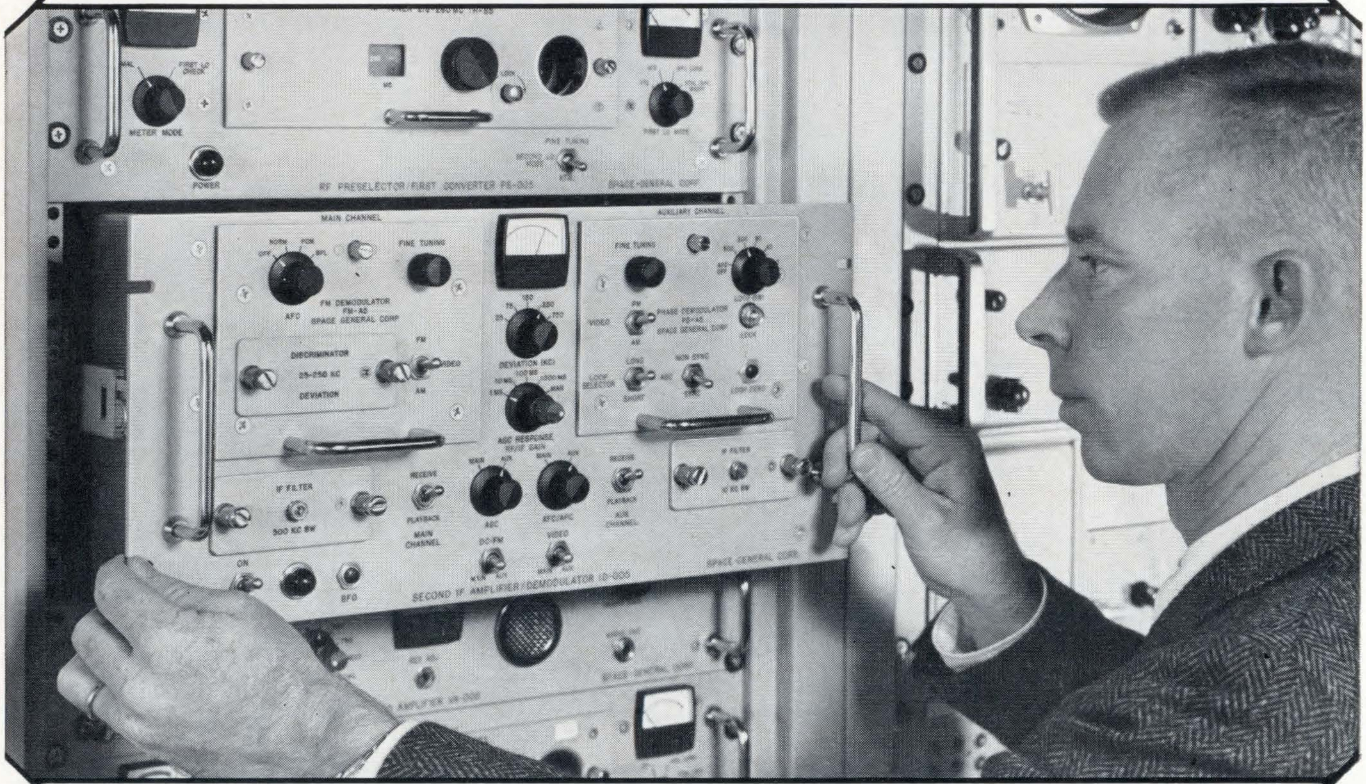

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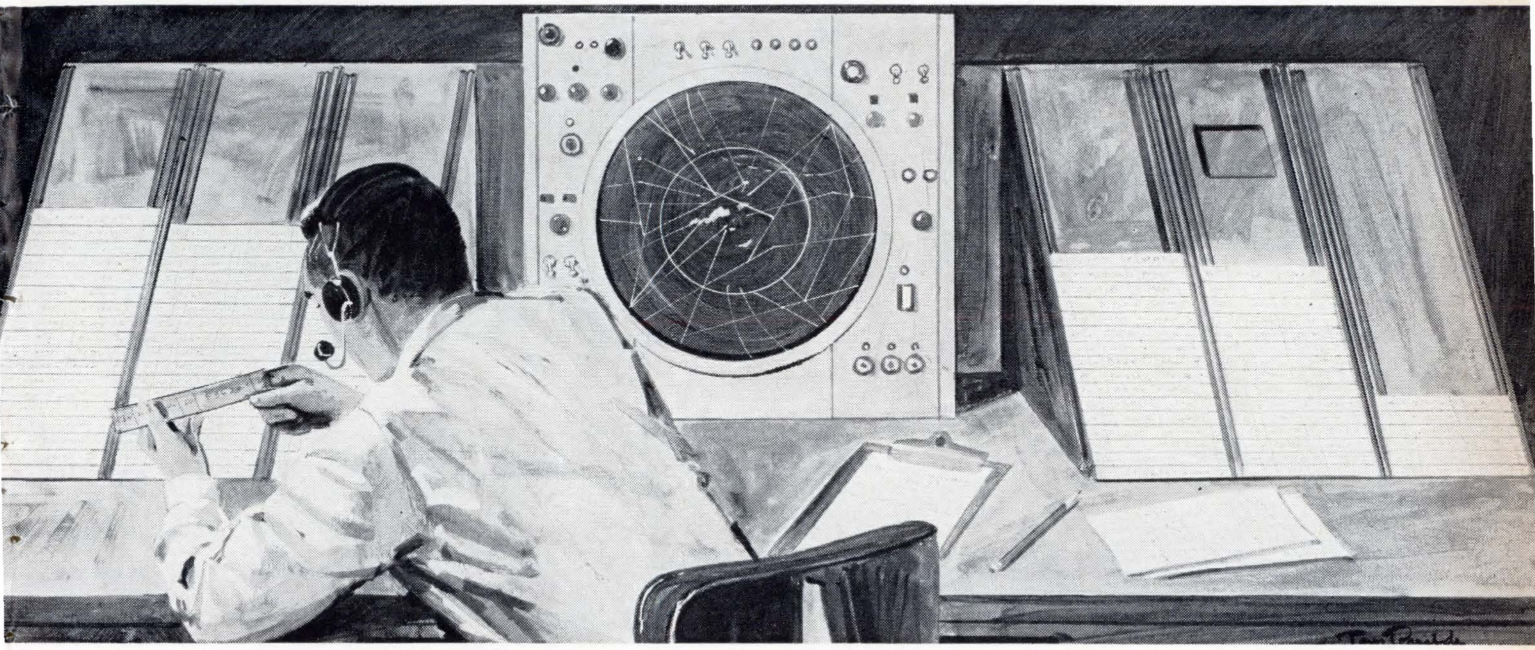
FAA is upgrading area weather reporting



with a new Westinghouse picture transmitting system

Continuing its emphasis on greater air safety, the Federal Aviation Agency is conducting intensive R&D work to improve weather reporting. In an important step forward, Westinghouse is designing and building for FAA evaluation two prototype systems which will transmit ultra-clear weather pictures from remote radar sites to the air traffic control centers.

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Heart of the Westinghouse system is a vidicon type storage camera which is specially designed for slow scan or delayed readout applications. For the FAA system, readout will be on a two-minute frame basis, providing a brilliant, high-resolution image of slowly changing weather patterns on the air traffic controllers' displays.

The prototype systems, to be in operation at FAA sites on the East Coast by late 1964, represent a growing family of Westinghouse equipment for civilian aircraft and airport traffic control. These special-purpose systems are typical of Westinghouse capabilities in the design and manufacture of advanced electronic systems for defense and space. For information, write to Westinghouse Electric Corporation, P.O. Box 868, Pittsburgh, Pennsylvania 15230. J-02368

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Product Highlights

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1245-6-7	Q-Meter and Oscillators	1 kc to 300 mc	203
995A/2M	FM/AM Signal Generator	1.5 mc to 220 mc	204
2090	Noise Loading Test Set (Transistorized)	Up to 2700 Channels	205
7816	Twelve Channel Noise Generator	300 cps to 3400 cps for mux/demux	206
1313	¼% Universal Bridge	7 Decade Ranges LCR	207
Autospec	Telegraph Error Correcting Equipment	Up to 75 Bauds	208

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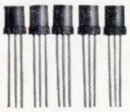

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GENERAL ELECTRIC

APPLICATIONS	FEATURES	TYPE	h_{FE} min.	h_{FE} max.	BV_{CEO}	f_t (typ) mc	†PRICE EACH 10,000 quant.	POSSIBLE REPLACEMENT FOR
SMALL SIGNAL AMPLIFIERS d.c. Beta Groupings. Instrument & High Fidelity pre-amplifiers (2N3391, 2N3391A). Oscillators, and amplifiers, and mixers to 30 mc.	Ultra High Beta	2N3390	400	800	25	120	0.35	Possible replacement for most germanium and silicon alloy transistors used in both amplifier and low frequency switching circuits including: 2N1302, 1304, 1306, 1308.
	High Beta, Low Noise; 1.9 db. typ. N.F.	2N3391	250	500	25	120	0.30	
	High Beta, Controlled Low Noise; 1.9 db. typ. N.F.	2N3391A	250	500	25	120	0.33	
	h_{FE} min = 150	2N3392	150	300	25	120	0.29	
	BV_{CEO} = 25 volts	2N3393	90	180	25	120	0.28	
	Extra Low Price	2N3394	55	110	25	120	0.27	
	Spread Type: 2 groups*	2N3395	150	500	25	120	0.29	
	Spread Type: 3 groups*	2N3396	90	500	25	120	0.28	
	Spread Type: 4 groups*	2N3397	55	500	25	120	0.26	
	Spread Type: 5 groups*	2N3398	55	800	25	120	0.28	
	h_{fe} 13 typ. at 20 mc.	2N2711	30	90	18		0.40	
	h_{fe} 16 typ. at 20 mc.	2N2712	75	225	18		0.42	
	Low C_{OB}: 5 pf. max.	2N2715	30	90	18		0.40	
	Low C_{OB}: 5 pf. max.	2N2716	75	225	18		0.42	
SMALL SIGNAL AMPLIFIERS a.c. Beta Groupings. Audio amplifiers; video amplifiers; hi-fi and stereo amplifiers; Garage door openers; dictaphone equipment; organ circuits.	BV_{CEO} = 25 volts	2N2923	90△	180△	25	120	0.27	
	h_{fe} min = 150	2N2924	150△	300△	25	120	0.29	
	h_{fe} min = 235	2N2925	235△	470△	25	120	0.31	
	Spread Type: 5 groups*	2N2926	35△	470△	18	120	0.24	
	Spread Type: 4 groups*	16A667	55△	470△	18	120	0.25	
	Spread Type: 3 groups*	16A668	90△	470△	18	120	0.26	
	Spread Type: 2 groups*	16A669	150△	470△	18	120	0.28	
	High ac Beta	16A567	400△	800△	18	120	0.33	
MEDIUM POWER AMPLIFIERS AND SWITCHES These device types satisfy circuit needs with higher dissipation requirements and high voltage breakdown.	900 mw, 25 volts	2N3402	75	225	25	120	0.38	Can be used to replace most NPN germanium types in industrial circuits. Also, can be substituted for the following in some circuits: 2N696, 2N697, 2N1711.
	900 mw, 25 volts h_{FE} = 180 min.	2N3403	180	540	25	120	0.40	
	900 mw, 50 volts	2N3404	75	225	50	120	0.50	
	900 mw, 50 volts h_{FE} = 180 min.	2N3405	180	540	50	120	0.52	
	360 mw, 25 volts	2N3414	75	225	25	120	0.33	
	360 mw, 25 volts h_{FE} = 180 min.	2N3415	180	540	25	120	0.35	
	360 mw, 50 volts	2N3416	75	225	50	120	0.44	
	360 mw, 50 volts h_{FE} = 180 min.	2N3417	180	540	50	120	0.46	
SWITCHES Types recommended for use in medium speed computer circuits.	Similar to 2N914	16J1	30	—	14	350	0.41	Possible substitute for 2N914, 2N706, 2N708.
	Similar to 2N708	16J2	30	—	14	350	0.39	
For peripheral equipment.	$V_{CE(SAT)}$ = 0.3 volts max.	2N2713	30	90	18	120	0.50	For use in low frequency industrial switching circuits.
	t_d = 60ns t_r = 35ns t_s = 85ns t_f = 40ns	2N2714	75	225	18	120	0.52	
	Spread Type: 3 groups*	16B670	30	540	18	120	0.33	
HIGH FREQUENCY AMPLIFIERS From audio to 200 mc am, fm, and TV application at video: 4.5, 10.7, 45, 88-108 and 54-216 mc. UHF Oscillator (16G2)	Max. oscillation freq.: 800 mc	16L62	20	40	30	250	0.36	Possible substitute for: 2N916, 2N760; possible replacement for many MADT, PADT, and MESA types.
	Max. available gain: 22.6 db. @ 100 mc	16L63	35	70	30	300	0.36	
	Min. h_{FE} = 60	16L64	60	120	30	350	0.39	
	Spread Type: 3 groups*	16L60	20	120	30	300	0.33	
	Max. available gain: 40.7 db. @ 10.7 mc	16L42	20	40	18	250	0.29	
	C_{OB} = 3.5 pf max.	16L43	35	70	18	300	0.29	
	Min. h_{FE} = 60	16L44	60	120	18	350	0.31	
	Spread Type: 3 groups*	16L40	20	120	18	300	0.26	
	UHF Oscillator, VHF Amp.; 4.0 db. typ. N.F.	16G2	20	—	12	1000	0.83	Possible substitute for: 2N918
HIGH PERFORMANCE RADIOS These types are recommended for AM if, rf, and converter sockets. Also useful in FM-AM combinations.	8.5 db. max. N.F. @ 2 mc and 20 Ω Rg	16L2	20	40	30	250	#	Can be used to replace most germanium types in IF, RF and converter circuits 2N696‡, 2N697‡, 2N1711‡. ‡beta comparison
	8.5 db. max. N.F. @ 2 mc and 20 Ω Rg	16L3	35	70	30	300	#	
	8.5 db. max. N.F. @ 2 mc and 20 Ω Rg	16L4	60	120	30	350	#	
	10.5 db. max. N.F. @ 2 mc and 20 Ω Rg	16L22	20	40	30	250	#	
	10.5 db. max. N.F. @ 2 mc and 20 Ω Rg	16L23	35	70	30	300	#	
	10.5 db. max. N.F. @ 2 mc and 20 Ω Rg	16L24	60	120	30	350	#	
	10.5 db. max. N.F. @ 2 mc and 20 Ω Rg	16L25	100	320	30	400	#	

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Technical Articles

Putting negative reactance to work: page 44

Most engineers generally ignore the concept of negative reactance. But a better understanding of it when designing networks sometimes leads to spectacular results. The designer faces fewer restrictions and often can build a network that couldn't be attained any other way.

The field-effect transistor, part 2: page 53

Part I of this series discussed devices. This section describes applications of FETs in circuits.

1. Designing circuits with MOS FETs
II. Low-noise FETs sound good to audio designers
III. Reducing input capacitance in FET amplifiers
IV. One MOS FET does the job of 14 circuit components
V. How the field-effect transistor works in a single-stage amplifier
VI. The field-effect transistor as a high-frequency amplifier
VII. A FET micropower amplifier
VIII. MOS FET circuit symbols

Digital television shrinks bulky bandwidths: page 77

For years, engineers have been investigating digital tv, which transmits binary-coded picture data instead of analog data. Here's a system that puts the picture into a reasonably narrow channel.

Coming December 28

- **The field-effect transistor, Part 3: more applications**
- **Designing to withstand radiation in space**
- **An infrared device stops freeloading at parking meters**
- **Measuring signal-to-noise ratio**

Using negative reactance for independent phase and attenuation

Now the designer can obtain nearly ideal performance from oscillators, amplifiers, closed-loop systems, delay lines and filter networks

By Clarence I. Jones
Alan I. W. Frank Corp., Pittsburgh

William P. Caywood Jr.
Point Consulting Co., Pittsburgh

Everard M. Williams
Carnegie Tech, Pittsburgh

The concept of negative reactance has generally been neglected by engineers. Except for some limited applications in the telephone industry, the circuit designer avoids it because he does not know how to apply it and he is more familiar with positive reactance. However, with a better understanding of negative inductance and negative capacitance, the engineer can design networks with attenuation and phase responses that are independent of each other.

When designing a network with specific phase-attenuation characteristics, the network function often results in a form that can't be built with positive reactances. However, when the designer uses negative reactances as circuit elements, he faces fewer restrictions than with positive reactances.

By independently specifying phase and attenuation, the designer can obtain nearly ideal performance characteristics from such circuits as oscillators, amplifiers, closed-loop systems, delay lines and filter networks.

The use of negative reactances is demonstrated by a design procedure for an ideal lumped-parameter delay line in which the attenuation is always zero and the phase shift varies linearly with frequency.

The zero-attenuation and linear phase-shift requirements are imposed on the impedance equations of a simple T-section delay line. Solving these equations results in a network reactance-frequency function that cannot be realized with positive capacitors and inductors. A network with negative and positive reactances will be synthesized, and it will be shown that the network closely approximates the required reactance-frequency function of the ideal line, yielding the required attenuation and phase shift.

Defining negative reactance

The definition of negative reactance is based on frequency and voltage-current phase relationships, just as with the positive reactance. However, the fundamental difference is that a negative inductance has the voltage-current phase relationship of a positive capacitance, and a negative capacitance has the voltage-current phase relationship of a positive inductance. Consequently, measurement at more than one frequency is required to determine a negative reactance.

More specific definitions:

- The magnitude of the reactance of a negative inductance increases as frequency increases. The time displacement between the voltage across and

The authors

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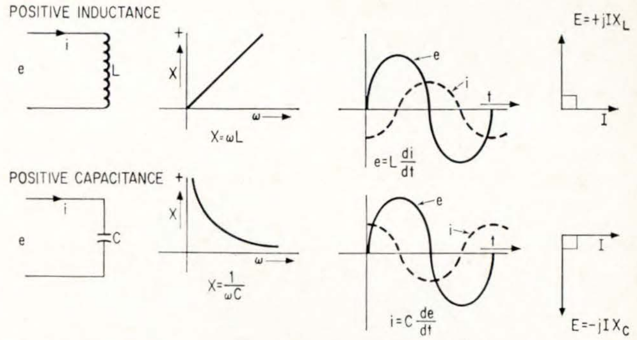
William P. Caywood Jr. received his Ph.D from the Carnegie Institute of Technology in 1952. He is the founder and owner of the Point Consulting Co. and has written several papers on servomechanisms.

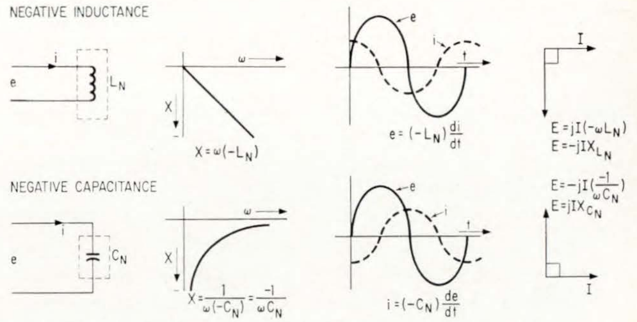
the current through a negative inductance is identical to that of a positive capacitance—current leads voltage by 90°.

- The magnitude of the reactance of a negative capacitance decreases as frequency increases. The time displacement between the voltage across and the current through a negative capacitance is identical to that of a positive inductance—current lags voltage by 90°.

The voltage and current waveshapes and phasor diagrams for ideal positive and negative reactances are illustrated at the right. A capacitor or an inductor enclosed in a dashed box indicates it has a negative reactance.



Reactance as a function of frequency and current and voltage displacement in sinusoidal and vector notation are shown for positive inductance and capacitance.



Voltage lags current and magnitude increases with frequency for a negative inductance. Current lags voltage and magnitude decreases with frequency for a negative capacitance. Negative reactance components are enclosed in dashes.

Negative impedance converter

A negative reactance having the performance characteristics defined above, isn't convenient to obtain with a single device. A positive capacitor or inductor must be made to respond "negatively" by a negative impedance converter.

An ideal negative impedance converter would be a four-terminal device that presents at one pair of the terminals the negative of the impedance connected across the other pair.

The basic negative impedance converter consists of an impedance and a voltage or current amplifier connected so that there is a negative impedance at the input terminals of the converter.

An amplifier with a gain greater than one, connected as shown in the circuit diagrams (p. 46, top) will produce a negative input impedance.

Simple negative reactance networks

In a constant phase network the output voltage is in phase with the input voltage at all frequencies, but the output-input amplitude ratio varies with frequency.

Since the voltage-current phase relationship of a negatitve capacitance is the same as the voltage-current phase relationship of a positive inductance, and likewise a negative inductance has the same phase as a positive capacitance, the networks behave as reactive voltage dividers with zero phase shift between input to output. The attenuation characteristics of these circuits are identical to those of any other double-reactance (positive) network—the attenuation increases 40 decibels per decade at higher frequencies.

Constant phase networks could be added to circuits such as operational amplifiers to obtain zero phase shift at all frequencies and an arbitrarily steep attenuation cut-off characteristic at some required frequency. An amplifier with these characteristics in a closed-loop or feedback system will provide quality system performance while removing the need for the stability of individual components, as well as simplifying the many compensation design techniques usually required.

Phase inversion networks

Both networks at bottom of page 46 appear to be common types in which current leads voltage. However, the lower network contains a negative capacitance. The attenuation-frequency characteristics of these networks are identical, but the phase of the quadrature component E_R of the input voltage is inverted. This is shown by the phasor diagrams associated with each network.

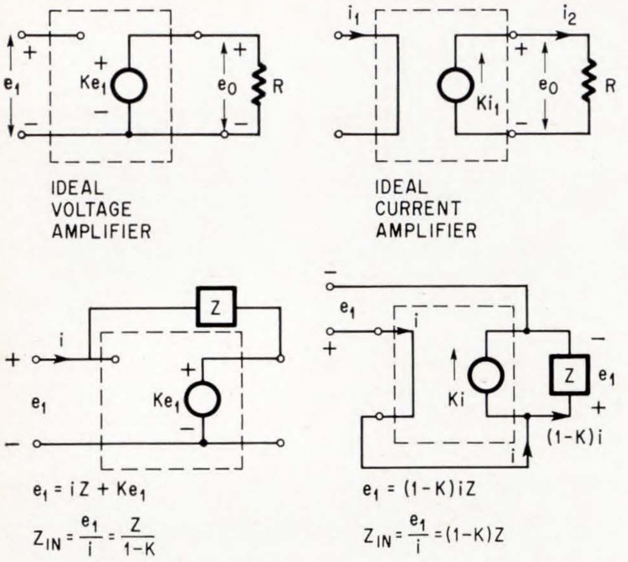
Phase inversion networks also can be used to stabilize closed-loop systems. For example, the R(—C) network shown (p. 46) can be added to a low-pass system and adjusted so that its break point coincides with the break point of the low-pass system. The result is an amplitude response that falls 20 decibels per decade faster than the attenuation of the low-pass network. The inverted phase shift of the negative network tends to cancel the phase shift of the low-pass system, yielding a system with virtually no phase shift.

Designing an ideal delay line

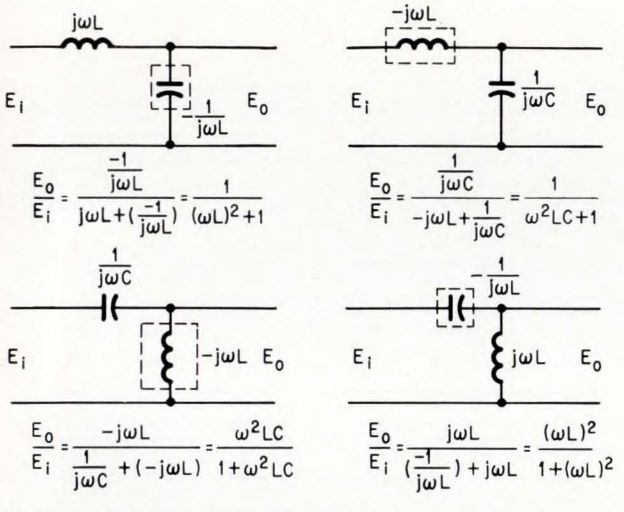
The application of negative reactances can be shown by designing a delay line in which the attenuation is zero and the phase shift is linear with frequency up to some cut-off frequency. The characteristic impedance Z_0 of the T-section of a simple delay line (p. 47, top) is given by

$$Z_0 = (Z_1^2 + 2Z_1 Z_2)^{1/2}. \quad (1)$$

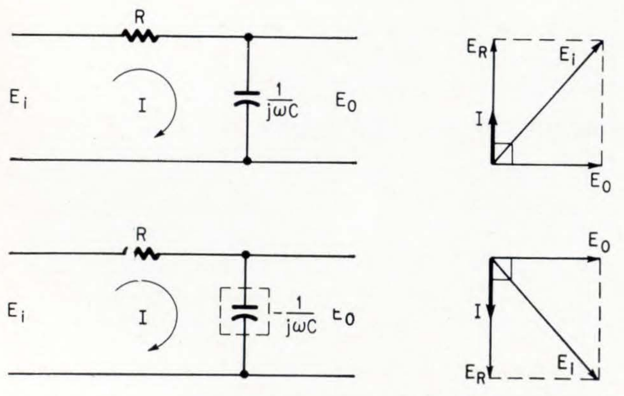
The propagation constant of the section, γ, is defined as the natural logarithm of the ratio of the input current I_1 to the output current I_2 when the section is terminated in Z_0. Solving the voltage



Negative impedance converter consists of an ideal voltage or current amplifier plus an impedance. For a gain greater than one, a negative impedance can be measured at the input terminals of the converter.



Phase response is constant in these networks, but the attenuation varies with frequency.



Phase inversion of the network current response can be achieved with negative reactances. The phasor diagrams show that the current is inverted 180° from an RC network to an R (–C) network.

equation of the second loop of the network for I_1/I_2 as a function of the network impedances and from the definition of the propagation constant:

$$\gamma = \ln \frac{I_1}{I_2} = \ln\left[\frac{Z_1+Z_2+(Z_1^2+2Z_1Z_2)^{1/2}}{Z_2}\right].$$

Expressing the above equation in its exponential form and adding its inverse, the following equation may then be written:

$$\epsilon^{+\gamma} + \epsilon^{-\gamma} = \left[\frac{Z_1+Z_2+(Z_1^2+2Z_1Z_2)^{1/2}}{Z_2}\right] + \left[\frac{Z_2}{Z_1+Z_2+(Z_1^2+2Z_1Z_2)^{1/2}}\right]$$

and reducing to its simplest terms results in

$$\epsilon^{+\gamma} + \epsilon^{-\gamma} = \frac{2(Z_1+Z_2)}{Z_2}.$$

From the fundamental definitions of the hyperbolic trigonometric functions

$$\cosh \gamma = \frac{\epsilon^{+\gamma} + \epsilon^{-\gamma}}{2} = 1 + \frac{Z_1}{Z_2}$$

and from the whole angle-half angle hyperbolic trigonometric identity

$$\sinh \frac{\gamma}{2} = \left(\frac{\cosh \gamma - 1}{2}\right)^{1/2} = \left(\frac{Z_1}{2Z_2}\right)^{1/2}. \qquad (2)$$

Since any impedance can be expressed in terms of its resistive and reactive components, let

$$Z_1 = R_1 + jX_1$$
$$Z_2 = R_2 + jX_2$$

substitute these terms into equation 2, rationalize, and the result is:

$$\sinh \frac{\gamma}{2} = \left[\frac{(R_1R_2+X_1X_2)}{2(R_2^2+X_2^2)} + j\,\frac{(X_1R_2-X_2R_1)}{2(R_2^2+X_2^2)}\right]^{1/2}.$$

For convenience, let

$$A^2 = \frac{(R_1R_2 + X_1X_2)}{2(R_2^2 + X_2^2)} \qquad (3)$$

$$B^2 = \frac{X_1R_2 - X_2R_1}{2(R_2^2 + X_2^2)} \qquad (4)$$

then

$$\sinh \frac{\gamma}{2} = [A^2 + jB^2]^{1/2} \qquad (5)$$

Both sides of the relation above must be expressed in simple real and imaginary terms, so that the propagation constant γ can be determined in terms of its real and imaginary components: α = the attenuation constant and β = the phase shift. With $\gamma = \alpha + j\beta$, the left side of the above equation expands as follows

$$\sinh \frac{\gamma}{2} = \sinh \frac{\alpha}{2} \cos \frac{\beta}{2} + j\cosh \frac{\alpha}{2} \sin \frac{\beta}{2}$$

To express the right side, $(A^2 + jB^2)^{1/2}$ in simple real and imaginary terms, convert to its polar equivalent (see vector diagram right).

$$(A^2 + jB^2)^{1/2} = (A^4 + B^4)^{1/2}\, \epsilon^{j\frac{\theta}{2}}$$

Expressing $\epsilon^{j\frac{\theta}{2}}$ in its sine and cosine term (Euler's theorem), applying the circular trigonometric whole angle-half angle identities and reducing to its simplest form

$$(A^2 + jB^2)^{1/2} = \left[\frac{(A^4+B^4)^{1/2}+A^2}{2}\right]^{1/2} + j\left[\frac{(A^4+B^4)^{1/2}-A^2}{2}\right]^{1/2}.$$

The real and imaginary part of equation 5 are equated and squared

$$\sinh^2\frac{\alpha}{2}\cos^2\frac{\beta}{2} = \frac{1}{2}\left[(A^4 + B^4)^{1/2} + A^2\right] \quad (6)$$

$$\cosh^2\frac{\alpha}{2}\sin^2\frac{\beta}{2} = \frac{1}{2}\left[(A^4 + B^4)^{1/2} - A^2\right] \quad (7)$$

Dividing equation 7 by $\cosh^2\frac{\alpha}{2}$ and equation 6 by $\sinh^2\frac{\alpha}{2}$, adding, applying the hyperbolic trigonometric whole angle-half angle identity, finding the least common denominator and eliminating terms, gives

$$\cosh^2\alpha - 2(A^4+B^4)^{1/2}\cosh\alpha - 2A^2 - 1 = 0$$

For the lossless delay line being designed, $\alpha = 0$. The equation above, therefore, reduces to $B^4 = 0$. Substituting this value into equation 4 gives

$$R_2 = R_1\left(\frac{X_2}{X_1}\right).$$

Next, dividing equation 7 by $\sin^2\frac{\beta}{2}$ and equation 6 by $\cos^2\frac{\beta}{2}$, subtracting, applying the circular trigonometric whole angle-half angle identity, clearing fractions and eliminating terms, gives

$$\cos^2\beta + 2(A^4 + B^4)^{1/2}\cos\beta - 2A^2 - 1 = 0$$

Inserting the value $B^4 = 0$ in this equation and solving for A^2,

$$A^2 = \frac{1 - \cos^2\beta}{2(-1 \pm \cos\beta)} = -\frac{(1 \pm \cos\beta)}{2}.$$

The ambiguous $\pm$ sign is a result of the radical term in the previous equation. Later, a simple test will determine which sign is correct.

Substituting the value $R_2 = R_1\left(\frac{X_2}{X_1}\right)$ into equation 3 and equating the result with A^2 as determined from above gives

$$\frac{X_1}{2X_2} = -\frac{(1 \pm \cos\beta)}{2}$$

At this point, the proper sign may be determined by assuming a delay line without loss. This means that in equation 2, $\alpha = 0$ in the left member ($\gamma = \alpha + j\beta$) and that $R_1 = R_2 = 0$ in the right member.

From these assumptions

$$\sinh\frac{j\beta}{2} = \left(\frac{X_1}{2X_2}\right)^{1/2}.$$

In trigonometric form

$$\left(\frac{1 - \cos\beta}{2}\right)^{1/2} = \left(\frac{1 \pm \cos\beta}{2}\right)^{1/2}.$$

The result clearly indicates that the negative sign is required and therefore

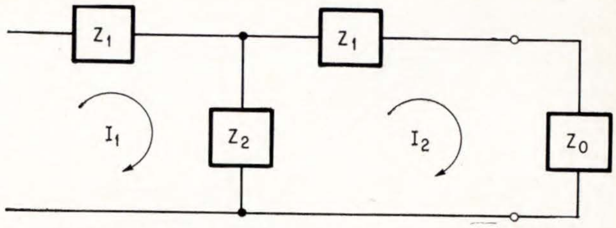
$$X_2 = \frac{-X_1}{1 - \cos\beta}.$$

The second goal of this investigation is to design a delay line with a phase shift as a linear function of frequency, $\beta = \pi\frac{\omega}{\omega_0}$, ($\omega_0 = 2\pi f_0$ and f_0 is the cutoff frequency).

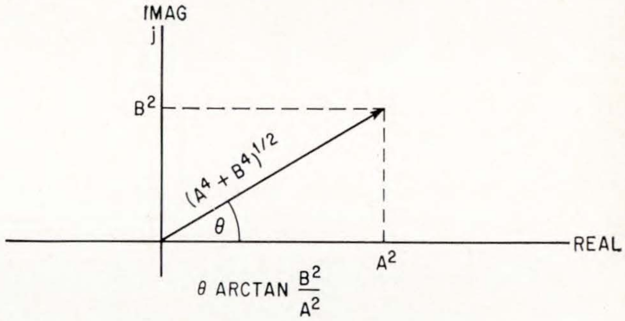
Substitute this value of β into the equation above.

$$X_2 = \frac{-X_1}{1 - \cos\pi\frac{\omega}{\omega_0}} \quad (8)$$

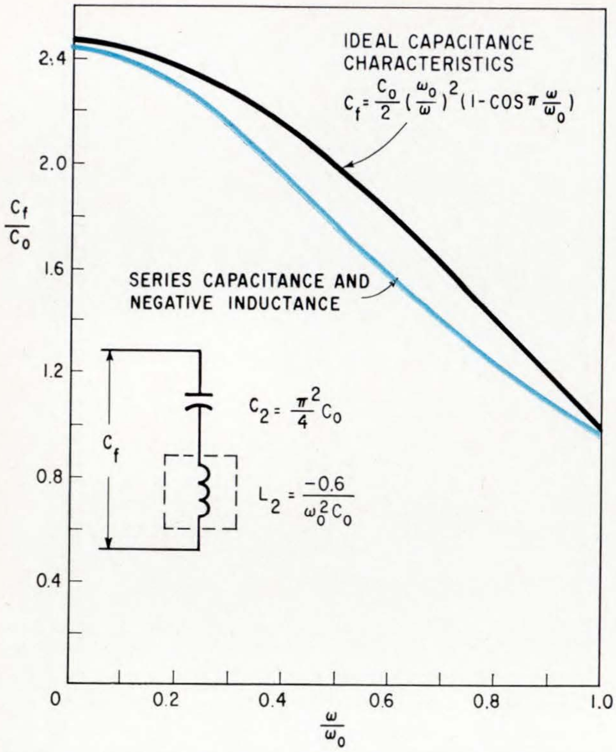
Similarly, R_2 can be related to R_1 in the same way; but, because the resistances correspond to the inherent losses of the delay line, which are quite small in practice, and to simplfy this analysis, it is assumed that $R_1 = R_2 = 0$. Therefore, it is neces-



In T-section of a simple delay line, Z_0 represents the characteristic impedance of the line. The natural logarithm of I_2/I_1 is defined as the propagation constant of the delay line.



Vector diagram shows the radical term $(A^2+jB^2)^{1/2}$ in polar form. It must be expressed in polar form before it can be resolved into a simple real and imaginary part.



To fit the curve of the ideal capacitance function at two points, a circuit with two reactances must be synthesized. The solution of the component values in this circuit results in a negative inductance. The synthesized network reactance as a function of frequency closely approximates the ideal capacitance function.

sary to consider only the reactance relationship.

The phase shift of the delay line can now be directly related to the reactances of the line.

Intuitively, X_1 is accepted as an inductive reactance. This satisfies the reactance equation because X_2 must be infinite at zero frequency, and X_2 and X_1 are of opposite sign. Setting $X_1 = j\omega L_1$ in the reactance equation yields

$$X_2 = \frac{-j\omega L_1}{1 - \cos \pi \frac{\omega}{\omega_0}}.$$

This equation can be conveniently expressed in the following manner:

$$X_2 = \frac{1}{j\omega}\left[\frac{\omega^2 L_1}{\left(1 - \cos \pi \frac{\omega}{\omega_0}\right)}\right] = \frac{1}{j\omega C_f}$$

where

$$C_f = \frac{\left(1 - \cos \pi \frac{\omega}{\omega_0}\right)}{\omega^2 L_1}. \qquad (9)$$

At $\omega = \omega_0$ equation 8 reduces to the expression relating the positive reactances of a simple T-section delay line (constant-k network). The cut-off frequency in terms of the network component values is given by

$$\omega_0 = \left(\frac{2}{L_0 C_0}\right)^{1/2}$$

where L_0 and C_0 are the values of the inductance and capacitance at cut-off frequency.

But if X_1 is assumed to be an inductance that does not vary with frequency, then

$$L_0 = L_1 = \frac{2}{\omega_0^2 C_0}.$$

Substituting this value for L_1 in equation 9 yields

$$\frac{C_f}{C_0} = \frac{1}{2}\left(\frac{\omega_0}{\omega}\right)^2\left(1 - \cos \pi \frac{\omega}{\omega_0}\right)$$

where

ω_0 is the cut-off frequency
ω is the frequency of interest
C_0 is the value of the network capacitance at ω_0
C_f is the value of the network capacitance at ω.

The graph, at the left, shows a plot of this function for C_f/C_0 vs ω/ω_0.

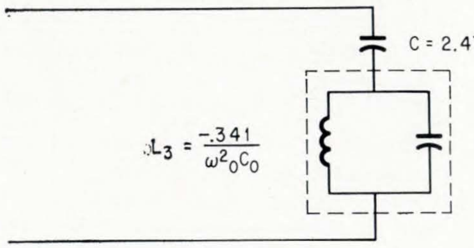
A network must be synthesized that has the same reactance-frequency characteristic as shown in the graph, that is, a capacitive reactance that varies from $\frac{\pi^2 C_0}{4}$ at zero frequency to C_0 at the cut-off frequency ω_0. A curve-fitting method is applied to this graph to determine the values of the components in a reactance network that would approximate the same curve. For a first approximation, a network with two reactances is required to fit the curve at two points. The simple series L-C circuit is assumed. Selecting $\omega = 0$ and $\omega = \omega_0$ as the extremes of the curve to be fitted, C_2 may then be written

$$C_2 = \frac{\pi^2 C_0}{4}.$$

The series reactance of C_2 and L_2 must equal the reactance of C_f as given by the equation

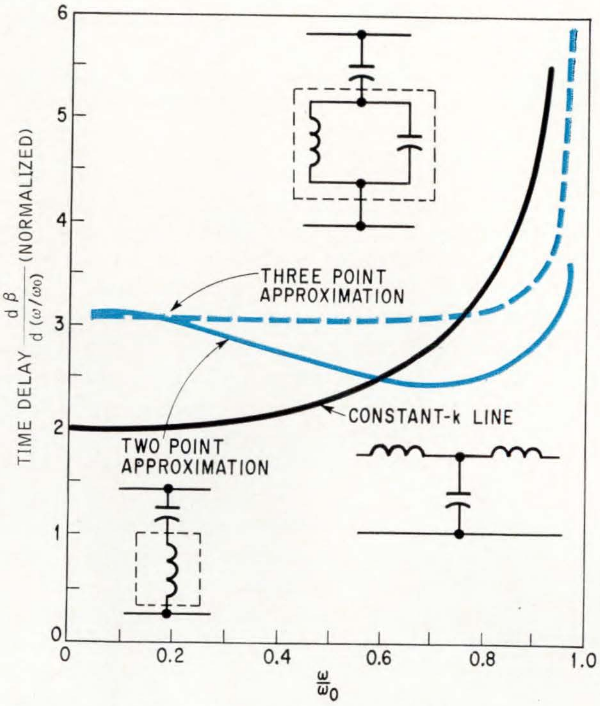
$$\frac{1}{j\omega C_f} = \frac{1}{j\omega C_2} + j\omega L_2$$

Solving for the value of L_2 at the second point of the curve where $\omega = \omega_0$ and $C_f = C_0$, and substituting for the value of C_2, previously determined,

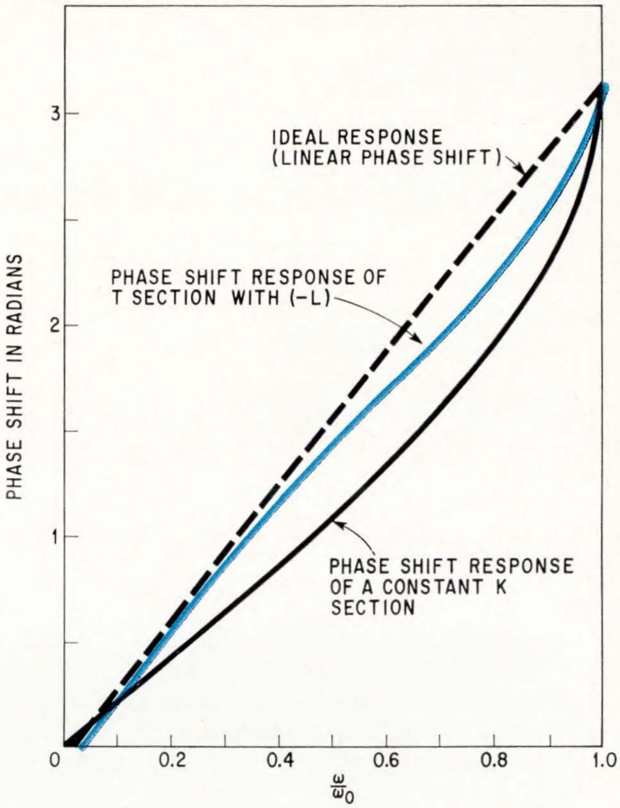


Network with three reactances is required to fit the ideal function curve at three points for a closer approximation.

Time-delay and phase-shift response curves



Fitting the ideal function curve at three points requires two negative reactances. The result is a constant delay from zero frequency to almost cut-off frequency.



Phase shift of the synthesized network is approximately constant. The phase-shift response of a constant-k section delay line (all reactances positive) is shown for comparison.

into the equation, gives

$$-\frac{1}{\omega_0 C_0} = -\frac{1}{\omega_0 \frac{\pi^2}{4} C_0} + \omega_0 L_2$$

$$L_2 = \frac{1}{\omega_0^2 C_0}\left(\frac{4}{\pi^2} - 1\right) = -\frac{0.595}{\omega_0^2 C_0}$$

The solution results in L_2 having a negative inductance. The reactance of the network synthesized by fitting the curve at two points is plotted as indicated by the red line on the graph and shows a close approximation to the ideal capacitance function. The graphs above compare the phase response and the time delay of the ideal and synthesized networks as a function of frequency.

Three-point approximation

Curve-fitting with a three-point approximation results in a delay line that is closer to the ideal than when two-point approximation is used.

The same end points are taken as with the two-point curve-fitting method. As before, $C_f = C_0$ at $\omega = \omega_0$ and $C_f = \frac{\pi^2 C_0}{4}$ at $\omega = 0$.

Referring to the graph that compared the ideal network with that obtained with the two-point approximation, it is observed that the maximum deviation of C_f from the ideal is at $\omega = 0.6\omega_0$. Therefore, this point will be chosen as the third point to yield a better approximation to the curve. From the equation for C_f/C_0 as a function of frequency, $C_f = 1.82C_0$ at $\omega = 0.6\omega_0$. Tabulating the three points

$\omega = 0$	$C_f = 2.47C_0$
$\omega = 0.6\omega_0$	$C_f = 1.82C_0$
$\omega = \omega_0$	$C_f = C_0$

The impedance equations for the circuit shown page 48, bottom, are written for each of above conditions and the values of the reactances are solved simultaneously.

The results of the simultaneous solution are indicated by the values of the components in the network.

The three-point approximation approaches the ideal curve for C_f/C_0 so closely that it is impractical to demonstrate the results graphically. However, calculations show that the maximum deviation from the optimum value for C_f by the two-point approximation is 12%, while the three-point approximation yields a maximum deviation of 0.6%.

The graph for the time delay obtained with the three-point approximation (red dashes) shows that the time delay is linear from $\omega = 0$ to $\omega = 0.7\omega_0$.

A delay line was constructed with the component values obtained from the two-point approximation. The delay time was measured at 57% greater, and the rise time was much shorter, than in a constant-k delay line with the same cut-off frequency and the same number of sections.

Circuit design

Designer's casebook

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

Diode-coupled Schmitt trigger

By Donald D. Robinson,

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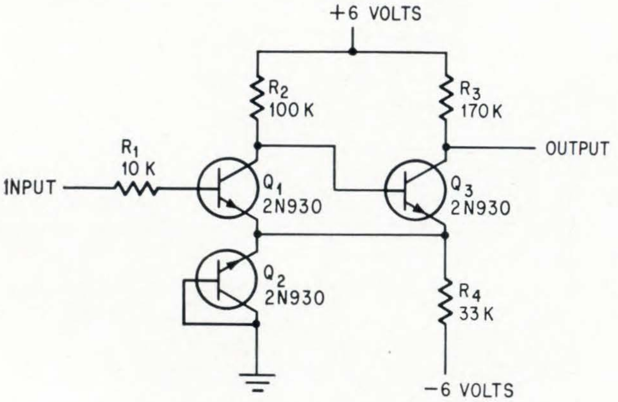
A diode-coupled Schmitt trigger can be useful in many applications including pulse-width modulation of a d-c voltage for switching amplifiers; wave shaping; over- or under-voltage monitoring; current monitoring; analog-to-digital interface circuits, and self-test circuits.

In the circuit shown, the base of transistor Q_2 is connected to its collector. The transistor's base-emitter junction forms a diode. Connected in this manner, Q_2 provides an exceptionally good match to the base-emitter characteristics of Q_1, and biases the emitter of Q_1 below ground potential by a magnitude equivalent to the V_{BE} drop of Q_2. As a result, the required input trigger voltage is only a few millivolts. The circuit has a very low temperature coefficient when matched transistors are used for Q_1 and Q_2.

The low dynamic resistance of the diode formed by the base-emitter of Q_2 replaces the regenerative feedback resistor usually connected between emitters of Q_1 and Q_3. This results in a very low hysteresis (difference between circuit turn-on and turn-off voltages). The resistance divider coupling, usually employed between Q_1 and Q_3 in a conventional Schmitt trigger, is eliminated because silicon transistors with low saturation voltages are used.



Base-emitter junction of transistor Q_2 is used as a forward-biased diode. This eliminates the regenerative feedback resistor usually connected between the emitters of Q_1 and Q_3.

As a result, the forward gain is increased and the snap action of the trigger is improved. The power-handling capabilities of the diode-coupled Schmitt trigger are also improved because the emitter voltage of Q_1 does not change significantly before Q_1 is switched on. This is particularly desirable for driving relays or solenoids, and in control systems where symptoms of electronic indecision such as chattering must be avoided.

Typical hysteresis of the input trip voltage is 10 millivolts with a temperature coefficient of +0.1 mv per degree C. The d-c input offset is ±5 mv, with a temperature coefficient of +0.3 mv per deg C.

On and off time adjusted independently

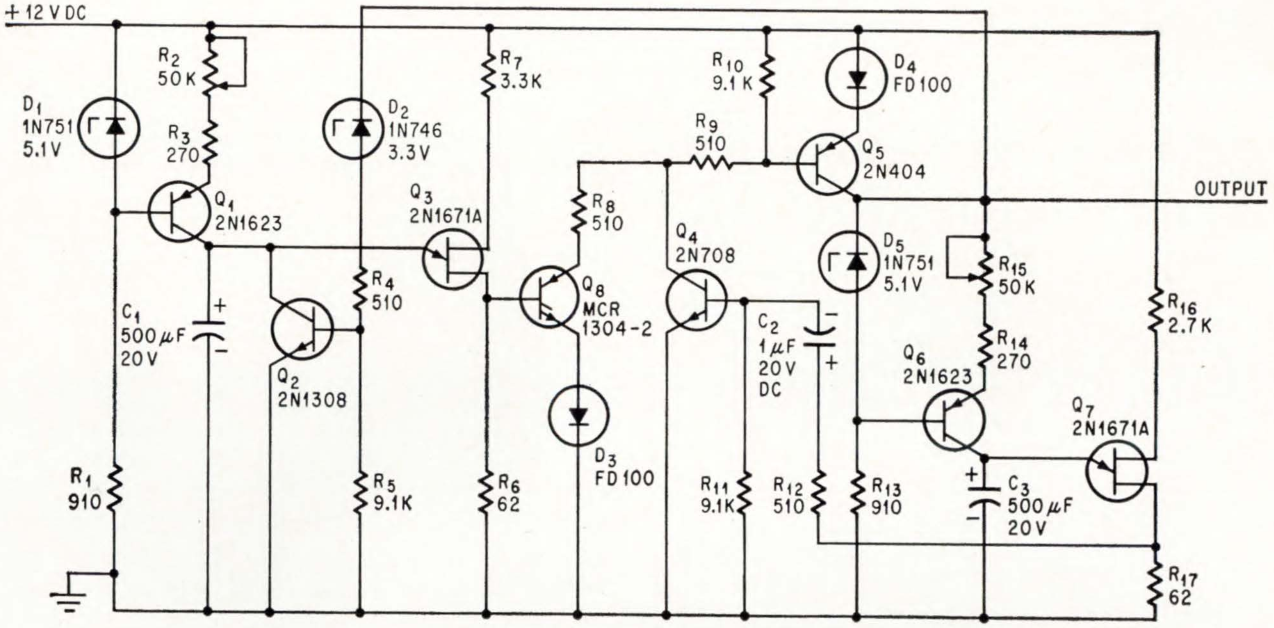
By Algimantas A. Dargis

The Johns Hopkins University, Applied Physics Laboratory, Silver Spring, Md.

Pulse width and interpulse time can be adjusted independently by variable resistors R_{15} and R_2 in the pulse generator circuit shown on next page.

The current generator consisting of R_1, R_2, R_3, D_1 and Q_1 charges C_1, to produce a ramp voltage at the emitter of Q_3. When the ramp voltage reaches the point where the emitter of Q_3 becomes forward-biased, unijunction transistor Q_3 fires, and C_1 discharges through R_6 and the lowered Q_3 emitter-base resistance. The resulting pulse across R_6 fires the silicon controlled rectifier Q_8 that turns on Q_5. Transistor Q_5 then turns on Q_2, completing the discharge of C_1. For the time that Q_2 remains on, C_1 cannot charge.

When Q_5 is on, the current generator consisting of R_{13}, R_{14}, R_{15}, D_5 and Q_6 charges C_3. When the ramp voltage at C_3 reaches the peak point voltage of Q_7, C_3 discharges through R_{17}. Part of the discharge current goes through R_{12} and C_2, providing the drive that momentarily turns on Q_4. In the on condition, Q_4 shorts out Q_8. When Q_4 turns off, Q_8



On time of pulse can be adjusted by variable resistor R_{15}. Off time is controlled by the value of variable resistor R_2.

remains off because it has no gate current. D_3 insures that Q_8 is turned off by Q_4.

With Q_8 turned off, Q_5 and Q_2 lose their base current and are turned off. C_1 starts charging again and the cycle repeats itself. The output of the pulse generator is taken from the collector of Q_5.

The stability of unijunction devices means that a stable pulse repetition rate can be obtained. Also a variation of better than 100 to 1 in on time to off time can be obtained with little interaction between settings. For example, with on time set at 0.25 seconds, off time was varied from 0.25 to 40 seconds, and the change in on time was less than $\pm 1\%$. For an on-time setting of 40 seconds, the corresponding change in off time was less than $\pm 5\%$. The circuit can be simplified by replacing both current generators with potentiometers, but the resolution of the settings is reduced.

Sensistor produces long, reliable pulses

By L.L. Kleinberg

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The thermal monostable multivibrator is capable of producing accurate pulse periods of 15 seconds to 2 minutes with a Sensistor. Texas Instruments Inc., manufactures the Sensistor—a silicon resistor whose resistance varies with temperature, power and time. Large tantalum capacitors ordinarily used to obtain such long pulse periods generally exhibit a tendency to change value with age. The sensistor has negligible leakage current and predictable temperature variation characteristics.

The circuit on pg. 52, top, is an equivalent circuit of the thermal monostable multivibrator. To simplify the analysis, assume R_5 is smaller than $\beta_1 R_1$. With this assumption, the base voltage of Q_1 will be constant and the expression for I_1 may then be written

$$I_1 = \frac{E_1}{R_1}\left[\frac{R_1}{R_1+R_2} + \frac{R_2 \epsilon^{-\gamma t}}{R_1+R_2}\right] \qquad (1)$$

where $\gamma = \dfrac{(R_1+R_2)}{R_1 R_2 C}$

E_1 is the voltage from the emitter of Q_1 to ground.

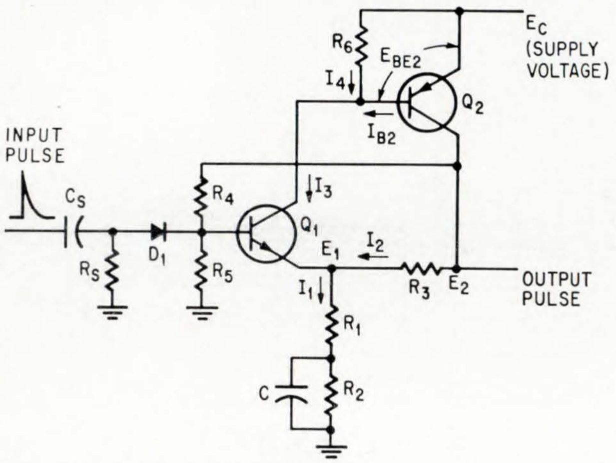
Here it is noted that if R_5 is not much smaller than $\beta_1 R_1$ the input voltage becomes significantly loaded by the capacitor C in the emitter circuit of Q_1. The expression for voltage E_1 would then be mathematically complicated. With $R_5 \leqq 0.1\ \beta_1 R_1$, the expression for E_1 may be written as

$$E_1 = \frac{E_2 R_5}{R_4 + R_5} - E_{BE1}$$

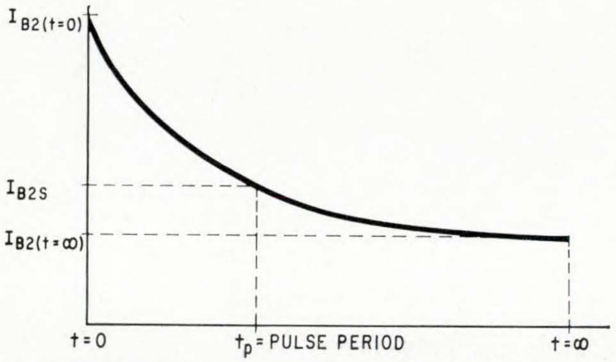
where E_{BE1} is the base-emitter voltage of Q_1. From the circuit diagram it can be seen that

$$I_2 = \frac{(E_2 - E_1)}{R_3} \tag{2}$$

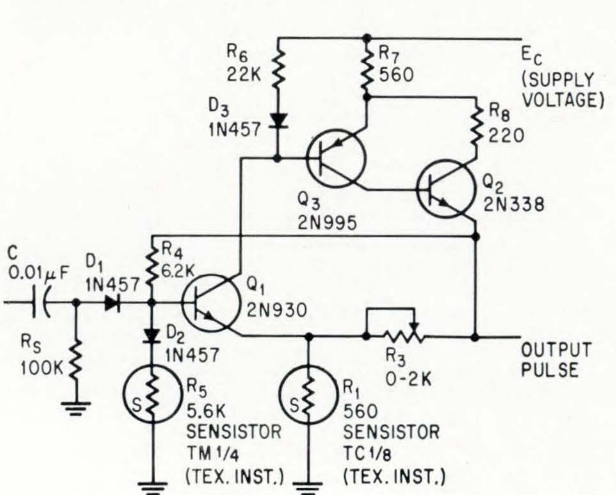
where E_2 is the voltage at the collector of Q_2 to ground, $E_2 = E_C - V_{CE2\ (SAT)}$. ($V_{CE2\ (SAT)}$ is the collector to emitter saturation voltage of Q_2.)



Equivalent circuit diagram of thermal monostable multivibrator can be used for mathematical analysis.



The base current I_{B2s} can no longer maintain Q_2 in saturation at t_p and the pulse period ends.



Thermal monostable multivibrator

$$I_3 = I_1 - I_2 \tag{3}$$

$$I_{B2} = I_3 - \frac{E_{BE2}}{R_6} \tag{4}$$

where E_{BE2} is the base-emitter voltage drop of Q_2 (approximately 0.7 volts).

$$I_{B2} = \frac{E_1}{R_1}\left[\frac{R_1}{R_1 + R_2} + \frac{R_2 \epsilon^{-\gamma t}}{R_1 + R_2}\right] - \frac{E_2 - E_1}{R_3} - \frac{E_{BE2}}{R_6}$$

Two important values of I_{B2} enter into the design considerations. These are the values of I_{B2} at t = o, the first instant of the switching cycle, and t = ∞, the time at which I_{B2} reaches its asymptote. (See curve for Q_2 base current as a function of time.)

$$I_{B2\ (t=o)} = \frac{E_1}{R_1} - \frac{(E_2 - E_1)}{R_3} - \frac{E_{BE2}}{R_6} \tag{6}$$

$$I_{B2\ (t=\infty)} = \frac{E_1}{R_1 + R_2} - \frac{(E_2 - E_1)}{R_3} - \frac{E_{BE2}}{R_6} \tag{7}$$

The turn-off point (end of the period) is reached when the base current of Q_2 can no longer maintain Q_2 in saturation, i.e., when

$$I_{B2s} = \frac{(E_2 - E_1)}{\beta_2 R_3} \tag{8}$$

To calculate the period, R_3 must be known. If the amplifiers are considered ideal, it may be assumed that $I_1 = I_2$. The maximum value of I_1 must saturate Q_2, and the minimum value of I_1 must take Q_2 out of saturation. Once R_3 is chosen, the following equation may be used to determine the period:

$$(I_{B2\ (t=o)} - I_{B2\ (t=\infty)})\ \epsilon^{-\gamma t} = (I_{B2s} - I_{B2\ (t=\infty)}) \tag{9}$$

In the circuit shown below, R_1 is a type TC ⅛, 560-ohm Sensistor—having a 54 second thermal time constant and a resistance multiplying factor of 1.6 for a dissipation of 200 milliwatts. R_3 is a 2 K potentiometer. Because the calculation for the period depends upon more accurate information than is available (transistor β), the circuit is initially designed to latch on for a large value of R_3 (approximately 3 R_1), then R_3 is reduced in value until the desired pulse period is achieved.

The period depends upon the beta characteristics of the transistors and the variation of the Sensistor's resistance with temperature. Current amplifier Q_3 reduces the effects of variation in the current gain (β_2) of transistor Q_2. This circuit was designed and tested over a temperature range of 25°C to 55°C. The period was adjusted for 28 seconds. The circuit was maintained at a constant temperature for 15 minutes. The pulse period variation was within 1.5 seconds of the initial setting.

A circuit of this type is being used in a satellite as a timer that turns on the B+ of a travelling wave tube 30 seconds after the filament power is applied.

Part 2 Applications

Field-effect transistors

Designing with low-noise MOS FETs: a little different but no harder

Devices are being applied in many different circuits. Here are nine designs in the communications field

By Georg G. Luettgenau and Sanford H. Barnes

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The insulated-gate metal-oxide-semiconductor field-effect transistor (MOS FET) lends itself to a variety of circuit applications. Although the MOS device has been commercially available less than a year, it has already been successfully used in audio amplifiers, r-f amplifiers, mixers, product detectors, oscillators and for many other applications.

To acquaint the circuit designer with MOS FET circuitry, several typical circuits are presented in this article.

In designing an audio amplifier stage using MOS field-effect transistors, it is important to remember that the transconductance of an FET decreases with the square root of the drain current. The output impedance, on the other hand, rises inversely with drain current. The voltage gain, which is given by $g_m \times r_d$, is therefore highest when the drain current is at a minimum. It is possible to operate a MOS transistor on a few microamperes. For example, in the single-stage amplifier circuit shown at right, the battery current is only six mA.

The voltage amplification A_v for this circuit is given by:

$$A_v = \frac{(R_L)(r_{dt})(g_{mt})(I_{Dt}/I_D)^{1/2}}{[(r_{dt})(I_{Dt})/I_D] + R_L} \qquad (1)$$

where r_{dt} = test drain resistance
g_{mt} = test transconductance
I_{Dt} = test drain current, as specified on the manufacturer's data sheet.

R_L = load resistance
I_D = actual drain current

For a field-effect transistor with a drain resistance of 50,000 ohms and a transconductance of 1,700 micromhos at a drain current of one milliampere, the voltage gain for the circuit is 213.

When several of these amplifiers are cascaded, because of the Miller effect the input terminals of each amplifier are shunted by a capacitance equal to:

$$C_{\mathrm{Miller}} = C_{dg}(1 + A_v). \tag{2}$$

The drain-to-gate capacitance C_{dg} is typically 0.2 picofarads for high-quality MOS transistors. The cut-off frequency f_{co} of each one of several identical cascaded audio amplifiers is given by:

$$f_{co} = \frac{1}{2\pi R_L C_{dg}(1 + A_v)} \tag{3}$$

Source follower

In a typical source-follower circuit (transistor equivalent of the vacuum-tube cathode-follower circuit) the input impedance Z_{in} is capacitive if the load is real, and is given by:

$$Z_{\mathrm{in}} = \frac{1}{j\omega[C_{gd} + (1 - A_V)C_{gs}]} \tag{4}$$

At low frequencies, Z_{in} becomes high, approaching 10^{14} ohms.

The voltage gain A_V is given by

$$A_v = \frac{1}{1 + \dfrac{1}{(Z_L)[(g_m) + (1/r_d) + (j\omega C_{gs})]}} \tag{5}$$

where g_m = transconductance measured at the operating point
r_d = drain resistance measured at the operating point.

The neutralized common-source amplifier at the right delivers the highest theoretical and practical power gain. Neutralization is accomplished if:

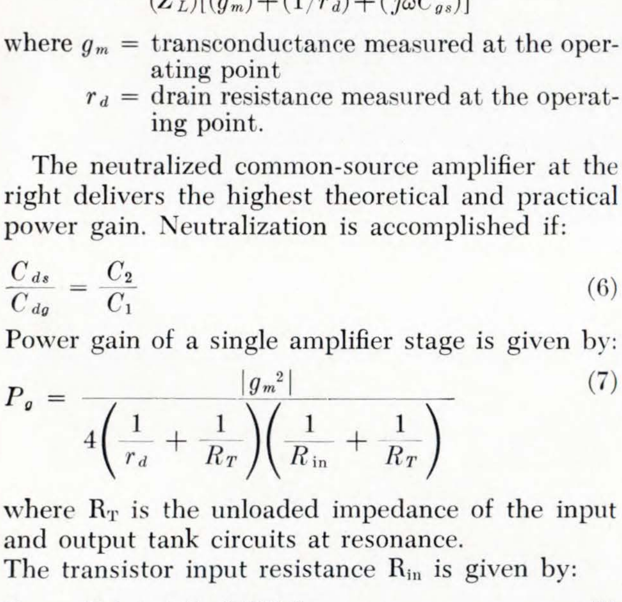
$$\frac{C_{ds}}{C_{dg}} = \frac{C_2}{C_1} \tag{6}$$

Power gain of a single amplifier stage is given by:

$$P_g = \frac{|g_m^2|}{4\left(\dfrac{1}{r_d} + \dfrac{1}{R_T}\right)\left(\dfrac{1}{R_{\mathrm{in}}} + \dfrac{1}{R_T}\right)} \tag{7}$$

where R_T is the unloaded impedance of the input and output tank circuits at resonance.
The transistor input resistance R_{in} is given by:

$$R_{\mathrm{in}} = R_o' + 1/(\omega C_g)^2 R_o' \tag{8}$$



Low-current audio amplifier stage that uses metal-oxide-semiconductor field-effect transistor operated with only six-microampere battery current provides a voltage gain of more than 200.

where R_o' = loss resistance (approximately 250 ohms for the DPT 200)

C_g = capacitance between gate metal and channel (approximately 0.8 picofarad)

For high-frequency operation, the transconductance measured at low frequency ($g_{m\,(LF)}$ must be converted to its high-frequency value $g_{m\,(HF)}$. This is accomplished by:

$$g_{m\,(HF)} = G_{m\,(LF)}/(1 + j\omega C_g R_o') \tag{9}$$

The high-frequency transconductance may also be obtained from the relationship between frequency and transconductance:

$$g_{m\,(HF)} = g_{m\,(LF)}/\sqrt{1 + (f/f_{cogm})^2} \tag{10}$$

where f = operating frequency
f_{cogm} = transconductance cut-off frequency
$= \frac{1}{2}\pi(R_o')(C_g)$ (11)

If several identical amplifiers are cascaded, the power gain per stage reduces to

$$P_g = \frac{|g_m|^2}{\left(\dfrac{1}{r_d} + \dfrac{1}{R_T} + \dfrac{1}{R_{\mathrm{in}}}\right)^2} \tag{12}$$

With high-Q circuits a typical power gain of 20 decibels at 100 megacycles per second can be obtained. The theoretical high-frequency noise figure $F_{o\,(HF)}$ is

$$F_{o\,(HF)} = 1 + \frac{(K)(C_g + C_{dg})\omega}{g_m} \tag{13}$$

where K is a device constant determined by the transistor geometry. A typical value is 2. Measurements for this circuit indicate a noise figure of 3 to 4 decibels at 100 megacycles per second.

Unneutralized common-source amplifier

In the unneutralized common-source amplifier shown at right, the resonance resistance R_{TL} for the loaded tank circuit is given by:

$$R_{TL} = 1/[(1/R_{\mathrm{in}}) + (1/R_T)] \tag{14}$$

The drain terminal of the MOS field-effect transistor is connected to a tap on the output tank to provide a load resistance R_L of:

$$R_L = r_d/[\omega g_m C_{dg} R_T - 2] \tag{15}$$

The power gain per stage for each of several identical unneutralized amplifiers is:

$$P_g = g_m^2 R_{TL} r_d/[(g_m \omega C_{dg} R_{TL} r_d) - 2] \tag{16}$$

At high frequencies (two megacycles or above), equation 16 reduces to:

$$P_g \approx g_m/\omega C_{dg} \tag{17}$$

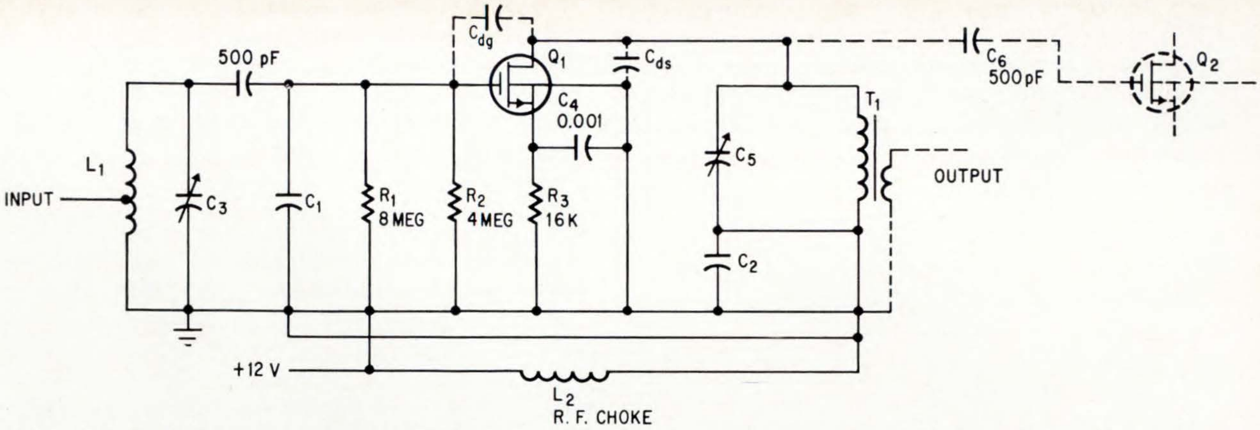
Common-gate amplifier

The following equations apply from the audio region up to 100 megacycles per second.

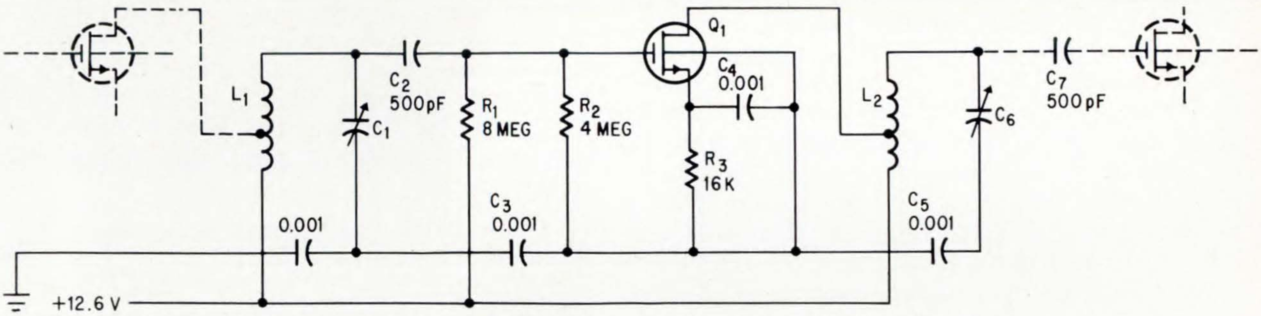
The maximum theoretical power gain is given by:

$$P_{g\,(\max)} = g_m r_d \tag{18}$$

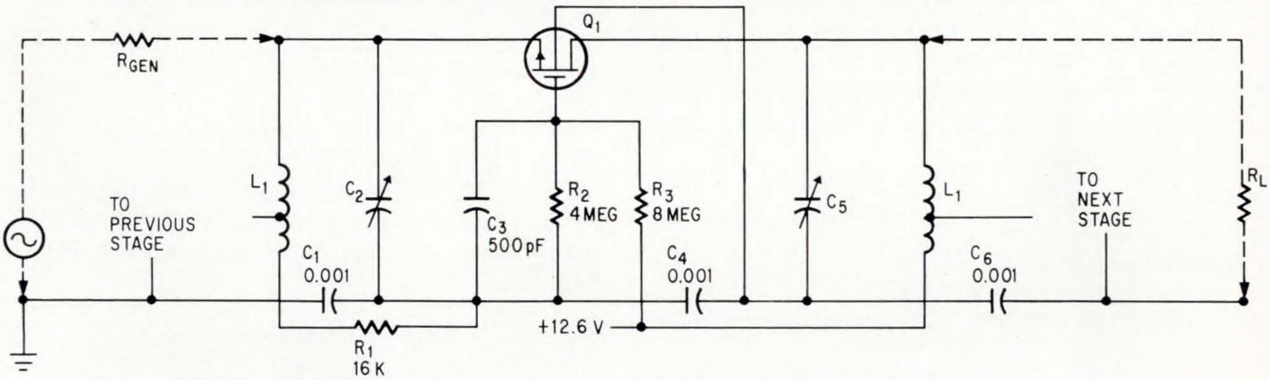
Practically, however, the power gain is given by:



Neutralized common-source amplifier designed with a MOS FET delivers power gain of 20 decibels at 100 megacycles.



Unneutralized common-source amplifier uses MOS FET. Low C_{dg} is needed for high power gains.



MOS FET common-gate amplifier is similar to the grounded-grid vacuum-tube amplifier. Power gains of 15 decibels can be obtained at 200 megacycles per second.

$$P_g = \frac{g_m}{\left(\frac{1}{R_T} + \frac{1}{r_d}\right)\left(1 + \sqrt{1 - \frac{1}{1 + \frac{r_d}{R_T}}}\right)^2} \qquad (19)$$

where R_T is the unloaded impedance of the output tank circuit. The optimum generator resistance for obtaining the power gain calculated from equation 19 is given by:

$$R_{gen\ (opt)} = \frac{1}{g_m}\sqrt{1 + \frac{R_T}{r_d}}, \qquad (20)$$

and the optimum load resistance is given by:

$$R_{L\ (opt)} = \frac{1}{\sqrt{\frac{1}{R_T^2} + \frac{1}{R_T r_d}}}. \qquad (21)$$

The load resistance (the input impedance of a following common-source amplifier or mixer stage) is sometimes much higher than R_T. In this case, the power gain reduces to

$$P_g = \frac{g_m}{\left(\frac{1}{r_d} + \frac{1}{R_T} + \frac{1}{R_L}\right)^2 R_L\left[1 - \frac{1}{1 + \frac{r_d}{R_T} + \frac{r_d}{R_L}}\right]}. \qquad (22)$$

The optimum generator resistance for this case is given by

$$R_{gen} = \frac{1}{gm\left[1 - \frac{1}{1 + \frac{r_d}{R_T} + \frac{r_d}{R_L}}\right]}. \qquad (23)$$

Cascode amplifier

The power gain of the cascode amplifier shown below is slightly higher than that of a a neutralized common-source stage. If the output capacitance of the previous common-source stage is equal to the input capacitance of the common-gate stage, the interstage matching coil inductance is given by

$$L_m = \frac{2G_{\text{in}}}{\omega[G_{\text{in}}^2 + (\omega C_{ds})^2]} \tag{24}$$

where G_{in} is the real part of the input admittance of the common-gate stage and is expressed by

$$G_{\text{in}} = g_m\left(1 - \frac{1}{1 + \frac{r_d}{R_L}}\right) \tag{25}$$

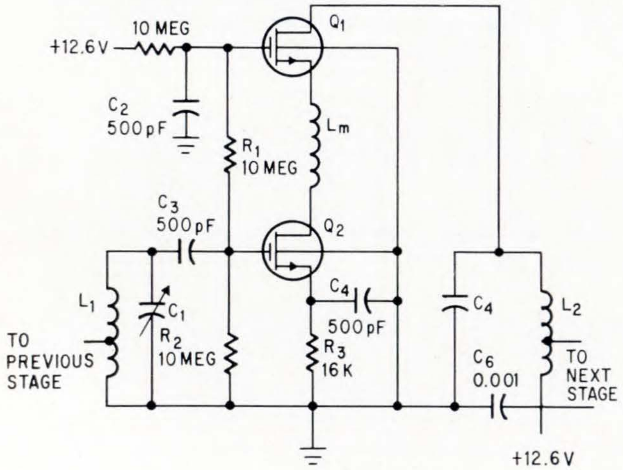
The load resistance R_L consists of the input impedance R_{in} of the following stage in parallel with the drain tank-circuit impedance. The substrate of the common gate stage must be ground to r-f voltage or there will be a substantial amount of feedback from the drain to the source through the substrate, causing instability and oscillations. The d-c potential at the substrate is not critical so long as it is negative with respect to the source. With a negative potential at the substrate, there will be a fairly wide depletion region around the source terminal and under the channel, resulting in effective decoupling of substrate from conduction region.

The mixer

The bias voltage V_b, the signal voltage E_{sig} and the local oscillator voltage E_{osc} are applied to the gate. To avoid interaction between the various tuned circuits a balanced oscillator input is used. The drain current is:

$$I_d = K[(V_b - V_{St}) + E_{sig} \sin(\omega_{sig}t) + E_{osc} \sin(\omega_{osc}t)]^2 \tag{26}$$

where $K = (C)(\mu)/2(L)^2 \approx 10^{-3}$
V_{st} = gate turn-off voltage
C = capacitance between metal gate electrode and channel electrode
μ = electron mobility in the surface inversion layer
L = channel length under gate



Gain of cascode amplifier is greater than that of neutralized common-source stage. The circuit is designed for amplification in the radio-frequency range.

The drain current consists of a d-c component; components with frequencies ω_{sig} and ω_{osc}; second harmonics, 2 ω_{sig} and 2 ω_{osc}; sum frequency ($\omega_{sig} + \omega_{osc}$); and the desired i-f frequency component. This component of the drain current is given by:

$$I = K\,E_{sig}E_{osc} \tag{27}$$

Compared with the conventional transistor mixer, with respect to intermodulation and interference from oscillator harmonics, the MOS transistor mixer is superior. As shown by equation 26, only the second harmonics and frequencies representing sum-and-difference components of incoming signals are generated. No intermodulation by-products of the form $(1 + n)\,\omega_1 - n\omega_2$ or $(1 + n)\,\omega_2 - n\omega_1$ are present as in conventional mixers. The gate voltage excursion, however, should be limited to a range over which the transconductance rises linearly with gate voltage. For the particular FET used, the peak drain current is limited to one milliampere. Therefore, the bias point is chosen as 0.38 milliampere. The maximum permissible voltage swing at the gate is

$$E_{\text{gate (pp)}} = \sqrt{I_{d\,(\text{max})} I_{d\,(\text{test})}}\left(\frac{2}{g_{m\,(\text{test})}}\right) \tag{28}$$

where g_m (test) is the transconductance specified by the manufacturer at the drain current $I_{d(test)}$.

The mixer transconductance is:

$$g_{m\,(\text{mix})} = \frac{d(I_{IF})}{d(E_{sig})} = K\,E_{osc} \tag{29}$$

where E_{osc} is the peak oscillator voltage. In the mixer circuit shown, half the voltage across L drives the gate. If the signal voltage is small, the oscillator voltage swings over the entire permissible gate voltage range, and the mixer transconductance becomes:

$$g_{m\,(\text{mix})} = \sqrt{\frac{I_{d\,(\text{max})}}{I_{d\,(\text{test})}}}\;\frac{g_{m\,(\text{test})}}{4} \tag{30}$$

From equation 29 it is apparent that the mixer transconductance is directly proportional to the oscillator voltage. Because of this it can be used for automatic gain control. By reducing the local oscillator output, the mixer gain can be reduced to zero. When E_{OSC} is small, E_{sig} may occupy the entire range of the permissible gate voltage. This is desirable, since maximum gain reduction is needed if the signal amplitude is very large.

Product detector

A typical product detector circuit of a single-sideband receiver is shown at right. The square-law relationship between transconductance and drain current makes the FET ideal for product detector use, an essential circuit function in single-sideband receivers. There is no need to make the beat frequency oscillator (carrier injection oscillator) amplitude many times larger than the signal; this is necessary with diode and conventional transistor circuits. As in the case of the audio amplifier, the demodulator gain is highest when the drain current is low.

The maximum permissible peak-to-peak beat frequency oscillator (BFO) voltage is:

$$E_{BFO\ (\max)} = \sqrt{\left(\tfrac{2}{3}\right)(I_d)(I_{d\ (\text{test})})}\left(\frac{4}{g_{m\ (\text{test})}}\right). \qquad (31)$$

The signal voltage may be as low as 100 microvolts. The maximum demodulator voltage is half the audio voltage since the voltage gain is half that obtained from equation 1.

Crystal oscillator

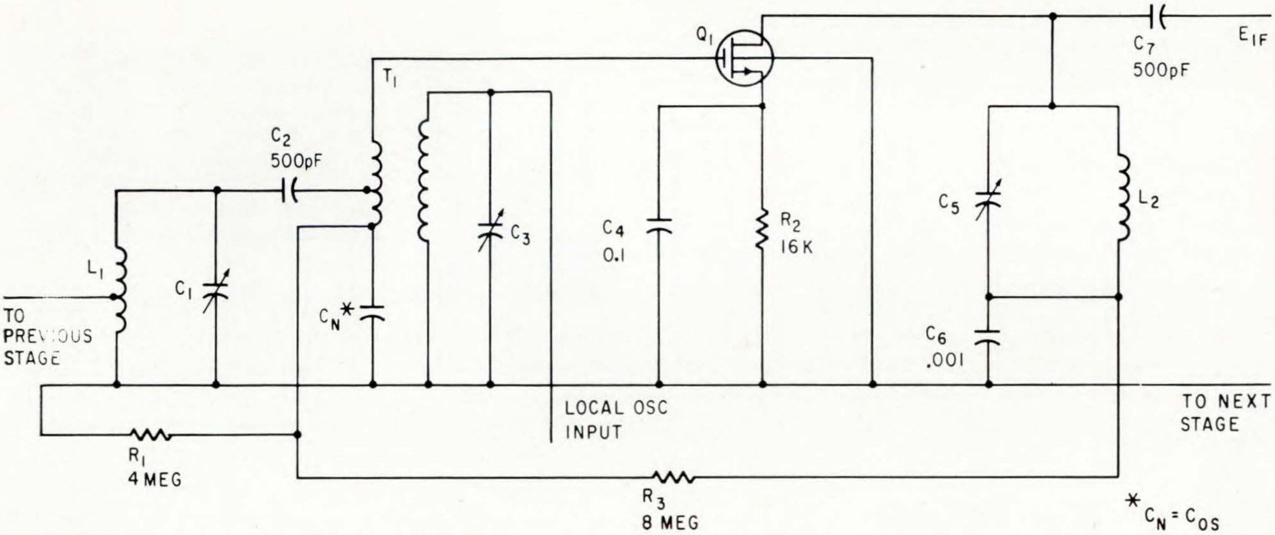
A typical oscillator circuit is shown below. For fundamental and third overtone crystals:

$$R_{\text{in}} \gg \frac{1}{(\omega C_{\text{in}})^2 R_S} \qquad (32)$$

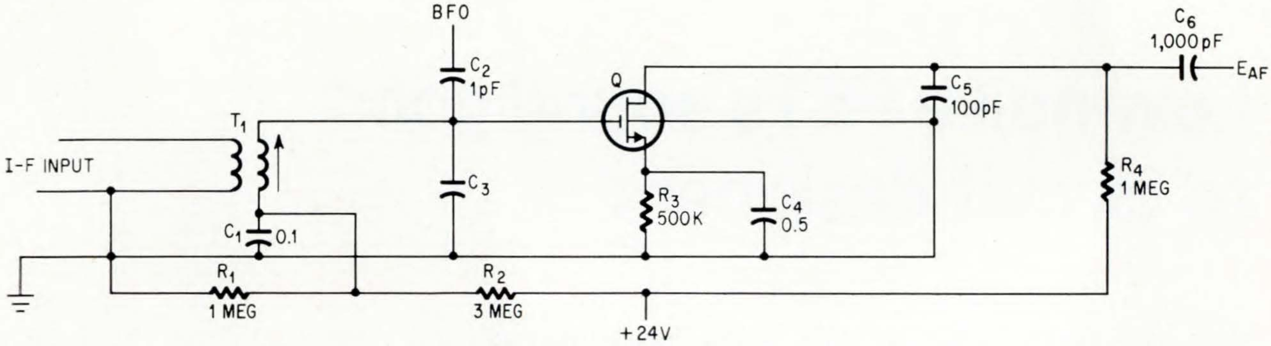
and

$$R_S \ll \frac{1}{\omega C_{\text{in}}} \qquad (33)$$

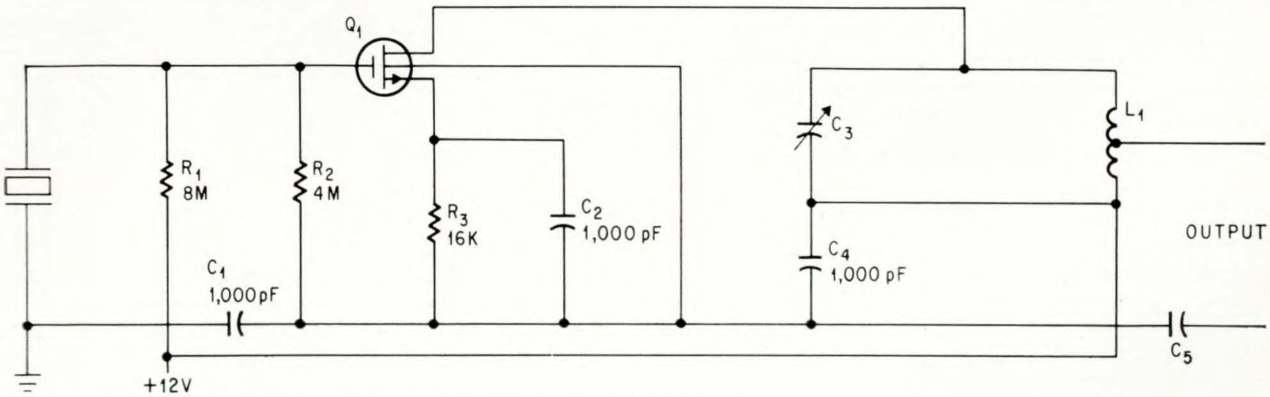
where $C_{in} = C_{gs} + C_{(holder)} + C_{(stray)}$ and R_S is



Mixer circuit containing MOS FET is superior to conventional transistor mixer circuit in controlling oscillator harmonics.



Product detector stage for single-sideband receiver uses MOS FET



Crystal oscillator circuit needs only a very small supply voltage to function. In this case only a 100-microvolt signal is needed to maintain oscillations.

crystal series resistance. Oscillations will occur if the loaded drain tank circuit has a resistance at resonance of

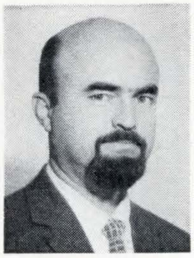
$$R_T \geqq \frac{1}{\dfrac{C_{dg}\,g_m}{2\omega R_S (C_{\text{in}})^2} - \left(\dfrac{1}{r_d}\right)}. \qquad (34)$$

Usually the circuit will oscillate vigorously. The amplitude is reduced by decreasing g_m, by increasing R_3 or by reducing the resistance values of the gate divider R_1, R_2. The last method reduces the influence of variations in R_S for various crystals.

The insulated-gate MOS field-effect transistor is particularly useful in high-impedance audio and low-power r-f circuitry. Continued development should increase its frequency and power-handling capabilities to the levels of conventional transistors. Although the discussion has been limited to communications in this article, MOS switching devices are also growing in popularity.

The authors

Georg G. Luettgenau has been director of advanced circuits development since 1962. After coming to the United States from Germany in 1959, he joined the company's applications department.



Sanford H. Barnes has been manager of transistor development at TRW since 1962. Before joining the company 10 years ago, he was with the Hughes Aircraft Co. He holds five patents on semiconductor device designs and processes.

Field-effect transistors

Low-noise FETs sound good to circuit designers

Added interest in new field-effect transistors spurs new ways to design for low noise in amplifiers

By Bruce Smith

Crystalonics, Inc. Cambridge, Mass.

Circuit designers, intrigued by the low-noise capability of the field-effect transistor, are finding a variety of applications for this semiconductor device. Among the most important are audio and radio-frequency amplifiers.

The heightened interest in new field-effect transistors has prompted manufacturers to reconsider their methods of specifying noise.[1]

An ideal amplifier does not add any noise to the signal. But in any practical amplifier, the noise at the load contains contributions by both the source and the amplifier, itself. Noise factor, therefore, may be expressed as the ratio of the total noise power appearing at the load to the noise power at the load which is due solely to the source resistance, or:

$$F = P_{NO}/(G \times P_{NI}) \quad (1)$$

where F = noise factor
P_{NO} = noise power out (amplified noise from source plus amplifier contributed noise)
P_{IN} = noise power in (source noise)
G = power gain

If P_{SO} = output signal power, then

$$G = P_{SO}/P_{SI} \quad (2)$$

Thus, noise factor F may be expressed (combining 1 and 2) as:

$$F = (P_{SI}/P_{NI})/(P_{SO}/P_{NO}) \quad (3)$$

This, in turn, may be converted to noise figure NF. Noise figure NF is given by:

$$NF = 10 \log_{10} [(P_{SI}/P_{NI})/(P_{SO}/P_{NO})] \quad (4)$$
$$= 10 \log_{10} (P_{SI}/P_{NI}) - 10 \log_{10} (P_{SO}/P_{NO})$$

Noise components

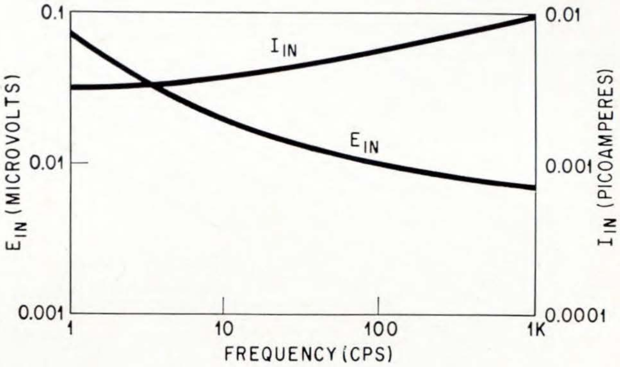
Transistor noise has two components, one that is independent of the source impedance and another that is not. These two noise components, respectively, are known as voltage noise and current noise. Voltage and current noise characteristics are shown at the right for the 2N3089A, a junction field-effect transistor. If the source resistance is zero ohms, the only noise present at the input is the voltage noise. When the source resistance is very high, the current noise becomes more significant than the voltage noise. An important characteristic of the field-effect transistor is that it has very low current noise with high input impedance.

Field-effect transistor noise can be only 1% of the source noise produced by an ideal resistor. It is nearly impossible to accurately determine the noise-figure contribution of the FET, because the noise of the source resistance cannot be measured within 1%.

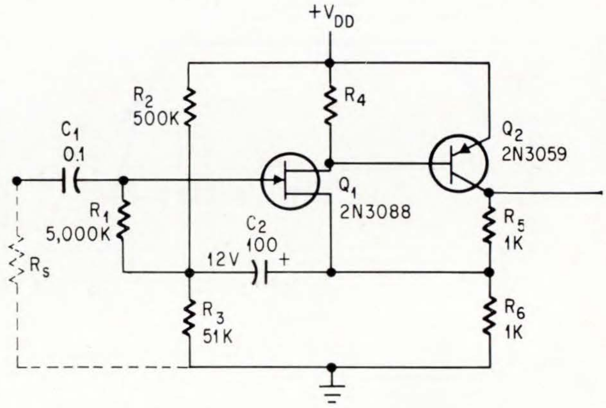
The measurement of noise and its methods of representation were recently discussed in Electronics.[1] For this reason, a reactive source impedance is used to determine the noise characteristics of the transistor. This impedance is usually provided by a capacitor with an impedance equal to that of the source resistor ordinarily used at the specified frequency. The capacitor ideally does not generate any noise of its own. The only noise present at the input is the internal transistor noise itself. Knowing the impedance of the capacitor at that frequency, one can substitute into the noise-figure equation the source-resistor (Johnson) noise. $N_R = \sqrt{4KTBR}$ where K is Boltzman's constant or 1.372×10^{-23} joules per °K, T is the temperature in degrees Kelvin (approximately 300° for room temperature), B is the bandwidth in cycles and R is the value of impedance in ohms.

One way of designing high-impedance low-noise field-effect transistor circuits is to use a source-follower (common-drain) configuration. However, source-follower circuits lack the gain needed to provide high output signal-to-noise ratios.

Another approach is to use a bootstrap circuit like the one shown above. Although this type of



Both voltage and current noise characteristics are needed to define the noise performance of the field-effect transistor. Characteristics shown are for a 2N3089A.



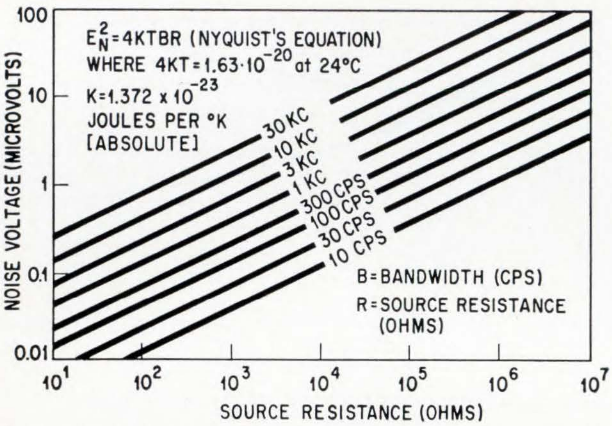
SPOT NOISE FIGURES

FREQUENCY (CPS)	R_S (OHMS)	NF (DB)
10	20 MEG	6.0
100	2 MEG	2.5
1,000	200 K	1.3
10,000	20 K	1.1

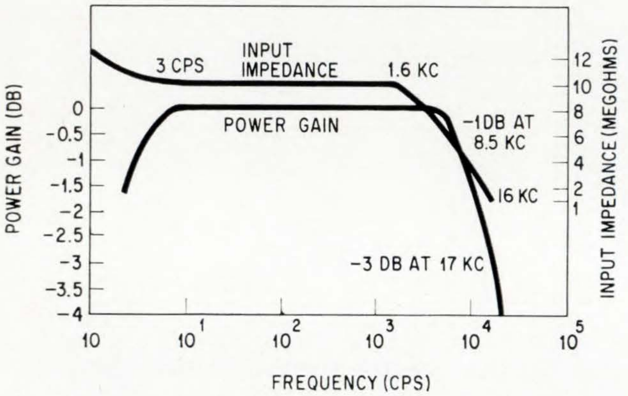
Two-stage amplifier has no provision for low-noise operation. Circuit operates with high collector current, which contributes to over-all noise level.

The author

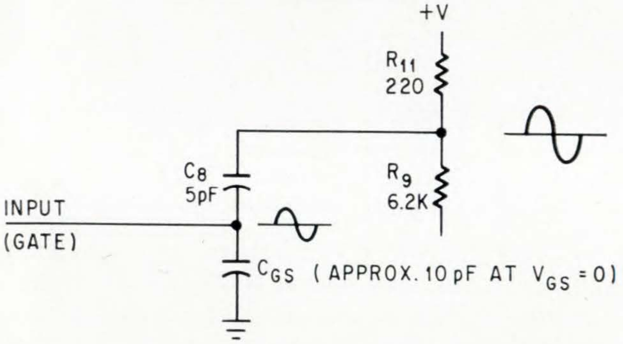
Bruce Smith joined Crystalonics in August as chief applications engineer. His duties include device evaluation and customer assistance He was previously an applications engineer for the Applied Electronics Corp. of N.J.



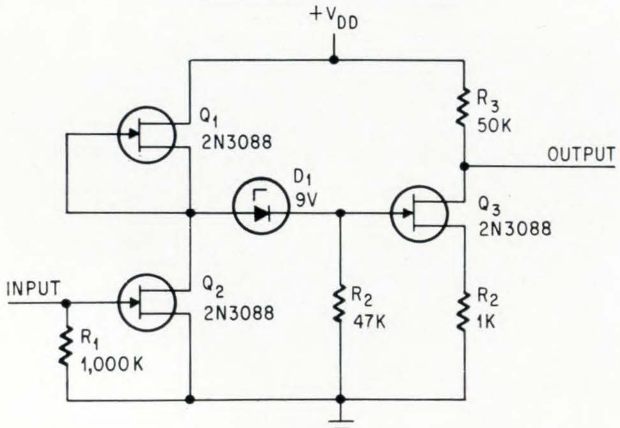
Thermal (Johnson) noise characteristic curves



Input impedance and power gain remain constant from 10 cps to above 15,000 cps.



Capacitance-dividing effect in the circuit on page 61



Field-effect transistor cascode amplifier offers high voltage gain and low noise.

circuit provides enough gain to increase the signal-to-noise ratio, its noise figures are not especially low. Typical figures are given with the circuit. High noise figures may be produced with this circuit if the field-effect transistor operates far from pinchoff, since this type of operation results in substantially reduced g_m and signal-to-noise ratio. In addition, the relatively high collector current makes a major contribution to the over-all noise level. The circuit does have high input impedance at low frequencies, but this drops off from 180 megohms at 10 cycles per second to 3 megohms at 10 kilocycles per second. The source impedance is shown as R_S on the diagram.

Cascode operation

An improved circuit for providing high-impedance, low-noise operation is shown below. Here, two field-effect transistors are operated in cascode to provide maximum voltage gain and temperature stability with a low voltage supply (V_{DD}). Another field-effect transistor, Q_3, serves as the load resistance. The voltage gain for this configuration is:

$$V_G = [(g_{m1})/(1+g_{m1})]\,[(r_{d1})\,(r_{d2})/(r_{d1}+r_{d2})] \qquad (5)$$

where g_{m1} = transconductance of Q_1
r_{d1}, r_{d2} = dynamic drain resistance of Q_1 and Q_2, respectively

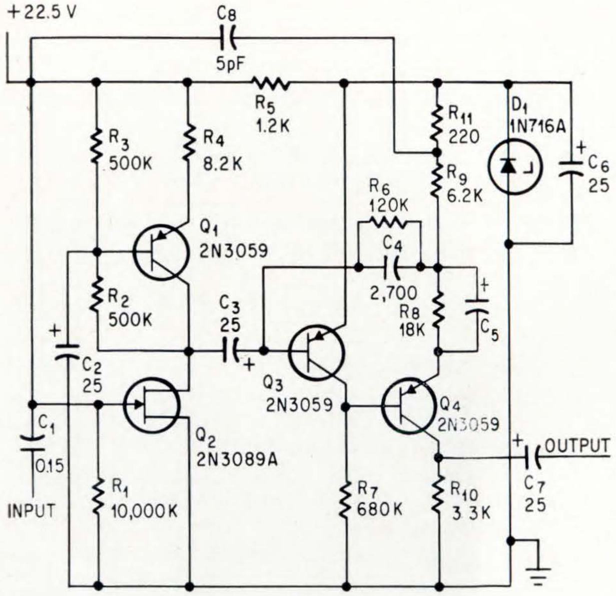
This circuit has good stability provided that Q_1 and Q_2 have similar temperature coefficients. The Q_1, Q_2 combination provides voltage gain of 40 db and extremely low noise performance in audio use.

The same circuit can be modified to use only one field-effect transistor, followed by a low input impedance second stage as shown on p. 61. In this circuit, Q_1 of the previous circuit is replaced by a low-cost pnp transistor which acts as a constant-current source. Although there is some reduction in stability, this is more than offset by the savings in over-all cost. The base-to-emitter junction of Q_3 presents a low impedance to the previous stage. Actually, the emitter of Q_3 has inherently high resistance but current feedback to this stage reduces the base-to-emitter resistance to 0.1 or 0.2 ohms. The current gain of Q_3 is set by the ratio of resistors R_6 and R_9; for the component values shown the gain is 20. The current gain of the last stage is 5. The total voltage gain for the entire amplifier circuit is 500.

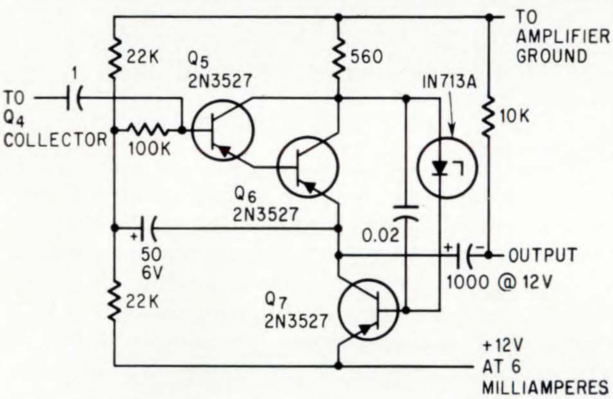
In this circuit, the direct current flowing through the second stage is only 10 microamperes. This value must be kept low to minimize the shot-noise current developed across the transistor junction. Shot-noise current increases with collector current as shown by the Schottky equation:

$$I_{NS} = \sqrt{2(q)\,(I_{EV})\,(B)} \qquad (6)$$

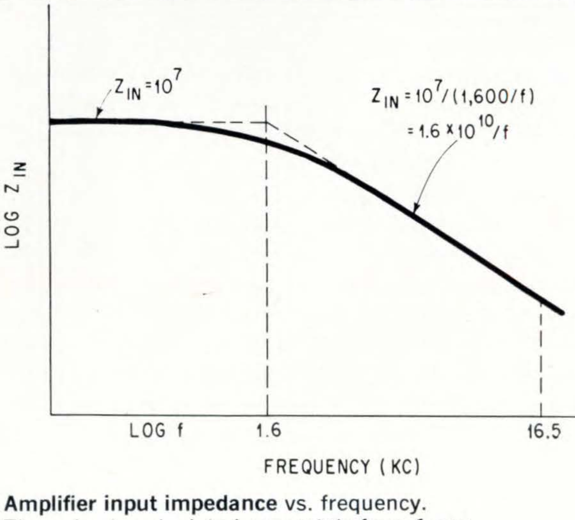
where I_{NS} = shot-noise current
q = 1.602 × 10^{-19} coulombs
$I_{EV} = I_C/h_{fe}$ provided $I_B \gg I_{CBO}$
B = bandwidth



Low-noise amplifier has voltage gain of 500. Only one FET is used in this circuit to reduce its cost. If an output impedance other than 33,000 ohms is required, an output impedance conversion stage is needed.



Output circuit for impedance conversion. This circuit, when added to the output of the amplifier circuit above, provides output impedance of less than 10 ohms. The 1-microfarad input capacitor of this circuit replaces C_7 of the circuit above.



Amplifier input impedance vs. frequency. The noise is calculated separately from 1 cps to 1.6 Kc and from 1.6 Kc to 16.5 Kc.

I_C, I_B = collector and base currents
h_{fe} = small-signal current gain
I_{CBO} = collector-to-base cutoff current

As shown on p. 60, the circuit creates a capacitor-divider effect at the input to decrease the effective gate-to-source capacitance. Positive feedback to increase the input impedance is accomplished by the network consisting of R_{11} and C_8. The value of C_8 may be raised if necessary to nullify any increases in the input impedance caused by cable capacitance. If C_8 is increased and the amplifier is open-circuited, or if the input capacitance is removed, oscillations will occur.

High-frequency noise contributed by the amplifier itself is very low. However, thermal noise (also known as Johnson noise) at high frequencies originating from the source is high. Thermal noise levels corresponding to various source resistances and bandwidths are shown at the top of page 60.

The output impedance for this circuit approaches the value of R_{10}. The frequency response of the amplifier is essentially flat from 1 cps to 16.5 kcps as shown on page 60. The dropoff in input impedance as frequency increases is also plotted.

The noise performance of the circuit is illustrated on page 62 for various bandwidths. Also shown are the output signals for rms input signals of 2 and 10 microvolts rms, respectively, with a 16.5 Kc bandwidth.

The set of curves on page 59 may be used with those on page 60 to calculate the thermal noise at the input of the amplifier over the bandwidth.

Calculating noise

Thermal noise is expressed as follows:

$$E_n^2 = 1.6 \times 10^{-20} (R) (\Delta F) \qquad (7)$$

where E_n = thermal noise voltage (volts)
R = input resistance (ohms)
ΔF = bandwidth (cps)

Considering the thermal noise occurring in the low-frequency end (0 to 1,600 cps) of the band separately from the noise in the remainder of the band (1,600 cps to 16.5 Kc), and then adding the two noise values will yield more accurate results than using equation 7 for the entire bandwidth.

For the range from 0 cps to 1,600 cps for a 10^7 ohm source impedance, the thermal noise voltage is calculated as follows:

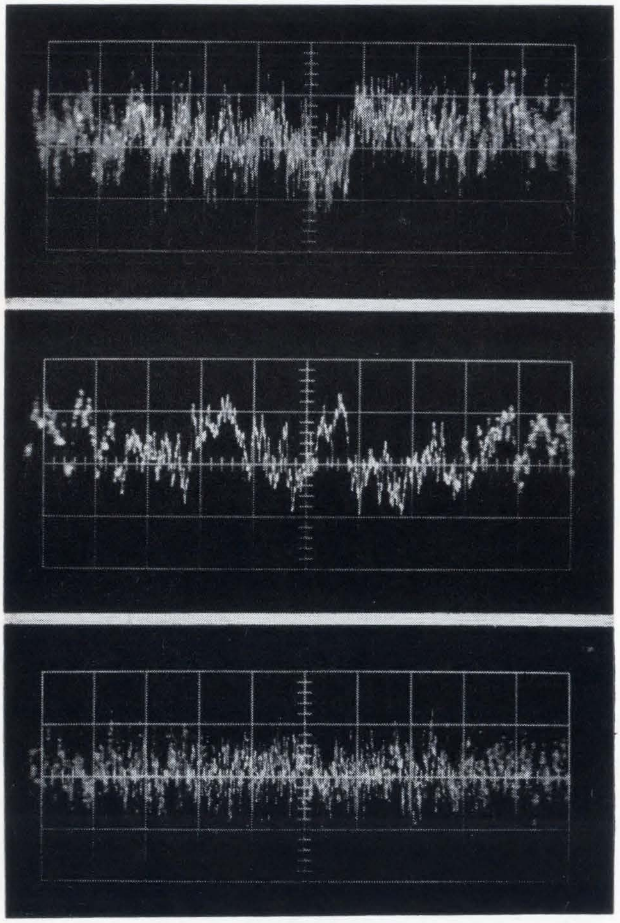
$$E_n^2 = 1.6 \times 10^{-20} (10^7) (1.6 \times 10^3)$$
$$= 256 \times 10^{-12} \text{ sq. volts rms}$$

For the range from 1,600 cps to 16.5 Kc., the thermal noise voltage may be expressed in integral form as:

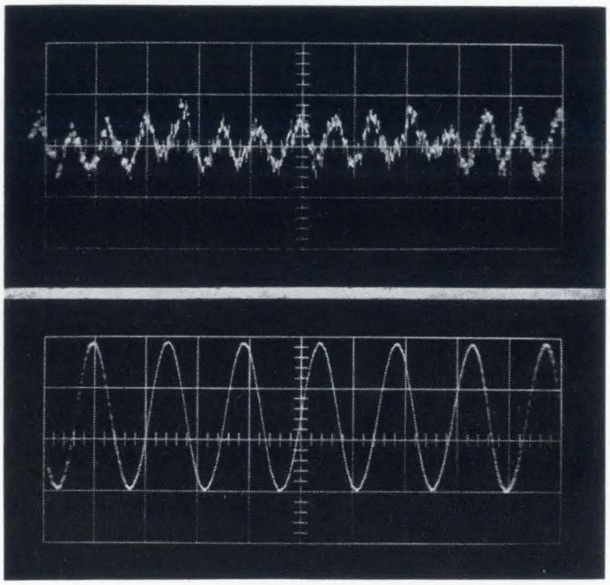
$$E_n^2 = 1.6 \times 10^{-20} \int_{f_1}^{f_2} Z df \qquad (8)$$

where f_2 = upper frequency limit = 16,500 cps
f_1 = lower frequency limit = 1,600 cps
$Z = (10^7)(1{,}600/f) = 1.6 \times 10^{10}/f$. The expression for Z is obtained from the figure at the left.

Amplifier output characteristics



Output noise with the input shorted. Each vertical box represents two microvolts peak-to-peak. Top shows bandwidth from 1 to 16,500 cps. Middle shows bandwidth from 1 to 1,500 cps. Bottom is bandwidth from 400 to 16,500 cps.



Output signals for bandwidth from 1 to 16,500 cps. and 1-megohm source resistance. Top shows 1-millivolt output for 2-microvolt rms input. Bottom shows 5-millivolt output for 10-microvolt input.

Therefore

$$E_n^2 = 1.6 \times 10^{-20}\,(1.6\times 10^{10}) \int_{1,600}^{16,500} \frac{df}{f}$$
$$= 2.56 \times 10^{-10}\,(\ln 16{,}500 - \ln 1{,}600)$$
$$= 608 \times 10^{-12} \text{ sq. volts rms}$$

The total thermal noise voltage for the bandwidth from 0 to 16,500 cps is determined as follows:

$$E_n = \sqrt{\sigma E_n^2} \quad (9)$$
$$= \sqrt{(256 + 608) \times 10^{-12}}$$
$$= 29.4 \text{ microvolts}$$

The measured peak-to-peak output noise voltage for the amplifier was 43.5 volts. Since the amplifier gain is 500, the input noise voltage is 87 microvolts peak-to-peak or 30.8 volts rms.

The integrated noise figure NF is given by:

$$NF = 20 \log_{10} [E_{n(\text{in})}/E_n] \quad (10)$$

For the total amplifier noise voltage of 29.4 microvolts and the input noise voltage of 30.8 microvolts:

$$NF = 20 \log_{10} [30.8/29.4] = 0.4 \text{ db}$$

If a 1.0 megohm source resistance is used instead of the 10^7 ohm resistance, NF is calculated to be 0.5 db.

Output stage

An output stage with a voltage gain of one may be added to the amplifier circuit to provide impedance transformation. This circuit, called a White follower circuit, is named after the man who designed a similar circuit, introduced in 1944, which used vacuum tubes. The emitter-follower type circuit is capable of providing very low output impedances.

The output stage incorporates a Darlington driver and a bootstrapped input to provide high input impedance to accommodate the amplifier. The output impedance of the stage is less than 10 ohms; its input impedance is approximately one megohm.

If the output stage is added to the amplifier, the one-microfarad capacitor shown at the input of the stage replaces C_7 of the amplifier. In a typical application, the output stage delivers a 1.5-volt rms signal to a 600-ohm load.

The field-effect transistor is a low-noise device but it is only one of many components in a circuit. Hybrid audio circuitry (FET combined with conventional transistors) which takes advantage of the low-noise capability of the FET is simple to design. From the standpoint of cost this approach has an edge over FET-only audio circuitry. And for low noise, it surpasses conventional junction-transistor circuitry.

Reference

1. Joel M. Cohen, "How to measure FET noise," Electronics, Nov. 30, pp. 62-63.

Using feedback in FET circuit to reduce input capacitance

Technique for junction FET allows design of circuit with only 0.4 picofarad input capacitance even though input capacitance of transistor is about 30 picofarads

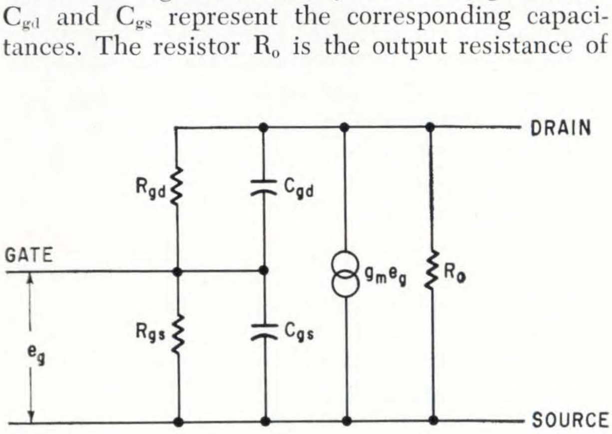
By Bryan Down
Ferranti, Ltd., Oldham, England

High input impedance and low-noise performance for a field-effect transistor (FET) can be achieved only when the input capacitance is held to a minimum. This can be done with feedback, which allows the design of circuits with only 0.4-picofarad input capacitance even though the input capacitance of the FET itself is about 30 picofarads.

The major reason for minimizing input capacitance is that input impedance is determined largely by the transistor gate capacitance at frequencies greater than a few cycles per second.

Another reason for holding input capacitance as low as possible, particularly in designing wide-band amplifiers, is that input capacitance reduces frequency response.

In the junction FET equivalent circuit shown below, resistors R_{gd} and R_{gs} represent the reverse bias resistances for the diodes created by the gate-to-drain and gate-to-source junctions. Capacitances C_{gd} and C_{gs} represent the corresponding capacitances. The resistor R_o is the output resistance of the FET and g_m is the transconductance of the device. A chart of typical values is given below.



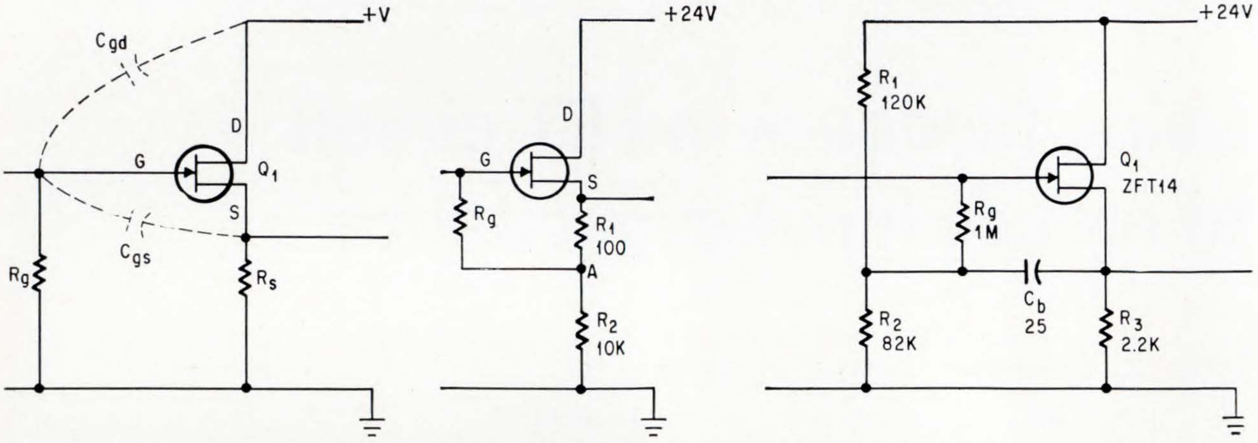
Simple equivalent circuit for the junction field-effect transistor has fewer components than its metal-oxide seminconductor counterpart.

Capacitance C_{gd} is smaller than C_{gs} under normal conditions because of the large reverse bias at the drain side of the gate-channel junction. If both gates of a four-terminal (two-gate) junction FET are joined, typical values for C_{gd} and C_{gs} are 5 picofarads and 25 picofarads, respectively. The two-gate structure, which is commonly used for junction FETs is shown on page 65. The second gate, as the drawing indicates, is actually the substrate. Three-lead devices are shown in the circuit diagrams appearing in this article. However, the transistor symbols also apply to a four-lead device with control and substrate gates externally tied together.

Typical characteristic values for n-channel transistor ZFT14

Ambient Temperature 25° C	Values
R_{gd}, R_{gs}	300 Megohms
C_{gd}, C_{gs}	15 pF
R_o	25 Megohms
g_m	3 mA/V
Zero-gate-voltage drain current I_{DO}	6 Milliamperes
Pinch off voltage V_P	−5 Volts
Maximum drain-to-gate voltage V_{DG} (max)	25 Volts

Three types of source-follower circuit



Simplified version of the source-follower (common-drain) circuit at left uses a junction field-effect transistor. Resistor R_s provides negative feedback. Circuit at center offers better stability than the one at the left because it can use smaller values of R_g. Another version of the source follower is shown at right. It allows higher input impedances by using potential-divider biasing.

Input capacitance for the junction FET is very low if the device is operated with one gate tied to the source and the signal applied to the other gate. Unfortunately this type of operation reduces the transconductance by about 30%, which is more than can be tolerated in some applications. The gate capacitance for this type of operation is about 10 picofarads and comprises most of the input capacitance.

FET circuit design

The bias voltage of the basic grounded-drain (source-follower) circuit shown above is developed across R_s and applied through R_g to the gate.

Negative feedback is provided by R_s, which considerably decreases the gate-to-source capacitance. The stage voltage gain M is given by:

$$M = (g_m)(R_s)/(1 + g_m R_s) \qquad (1)$$

Because of the feedback, the effective gate-to-source capacitance is:

$$C'_{gs} = C_{gs}\,(1\text{-}M) \qquad (2)$$

If M approaches unity, C'_{gs} approaches zero and the input capacitance of the stage is determined almost entirely by C_{gd}.

The input resistance R_{in} is determined by R_g since it is in parallel with the input circuit of the FET. For very high input resistance stages, values of 10 or 20 megohms may be used for R_g. In this circuit, gate leakage current flows through R_g, making the circuit sensitive to temperature.

In a typical source-follower circuit shown above, the effective input resistance is given by:

$$R_{in} = R_g/(1\text{-}A) \qquad (3)$$

where A is the voltage gain between point A in the circuit and the input. This circuit is superior to the one previously discussed because smaller values of R_g may be used, thus increasing the stability of the operating point. The input resistance and the input capacitance of the circuit for various values of R_g are given below:

R_g (megohms)	R_{in} (megohms)	C_{in} (pF)
0.056	1.0	5.6
1.0	15	5.6
10	150	5.6

Another approach to source-follower design is the use of a potential-divider network for biasing. In this type of circuit, shown above, the gate resistance R_g reduces the shunting effect of R_1 and R_2 on the input impedance. Resistor R_g is bootstrapped by C_b. Capacitor C_b should have a small reactance value at the lowest frequency at which the amplifier operates. For an R_g of one megohm, the input resistance for the circuit is six megohms and the input capacitance is seven picofarads.

In the last two circuits described, values of input resistance much greater than 10 megohms can be achieved only with gate-bias resistors that have values of the order of megohms. This is often undesirable because the gate-leakage current restricts the temperature range of stable operation.

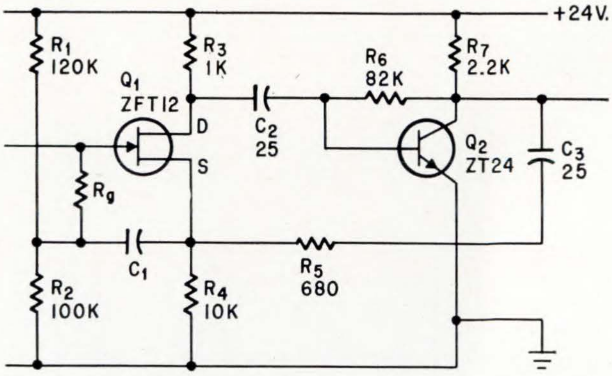
In some applications, input impedance levels of 50 megohms or higher are required over a very low frequency range. Thus the input impedance is determined almost entirely by the input resistance. For such applications the two-stage circuit shown on p. 65 is preferable to the ones previously discussed. In this circuit, increases in input resistance are achieved by negative feedback.

The voltage gain of the common-source FET stage is well below unity. Its output is fed to a high-gain amplifier stage that uses a bipolar transistor. Nearly all the output is fed back to the first stage to increase the input impedance.

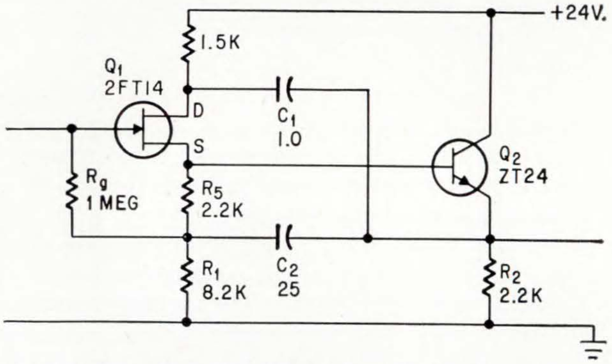
The circuit has an over-all voltage gain of unity; its input impedance varies with R_g as shown below:

R_g (megohms)	R_{in} (megohms)	C_{in} (pF)
1.0	65	4.5
10	500	4.5

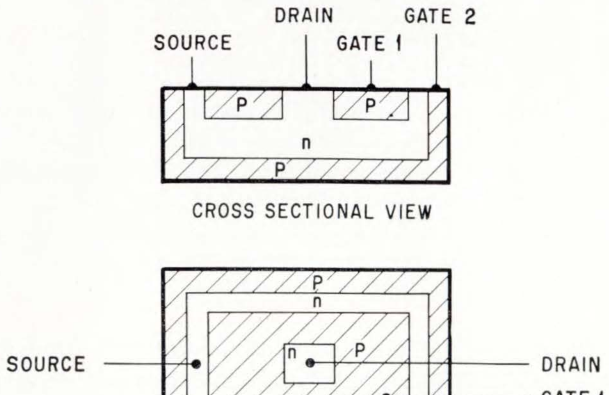
The importance of reducing the effects of gate capacitance has been shown, and the circuits already described nearly eliminate the effect of the gate-to-source capacitance C_{gs}. However, in a wideband amplifier stage, absolute minimum input capacitance is desirable since the upper limit of the frequency response is determined entirely by two factors: the input capictance and the internal resistance of the signal source.



Two-stage amplifier has feedback from Q_2 to Q_1 and offers a higher circuit input impedance than the three circuits shown on page 64.



Wideband amplifier circuit is designed for very low input capacitance. Transistor Q_1 functions as a source follower.



Two views of the junction field-effect transistor shows the construction of the device. Epitaxial techniques are used to form the channel and gate on the p-type substrate, which acts as a second gate.

The effect of the gate-to-drain capacitance, C_{gd}, can be reduced in a way similar to that used for C_{gs}, that is, by the reduction of the signal voltage appearing across it. The circuit shown at the left reduces the effect of C_{gd} to such a level that the input capacitance of the stage is almost entirely determined by the circuit layout and wiring capacitance.

The common-source FET stage (first stage) has a small drain load and, with the output taken from the source, functions as a source follower. The output is applied to a common-collector stage using a bipolar transistor.

To reduce the effect of C_{gd}, the emitter-follower output stage is returned through C_1 to the drain of Q_1 so that the drain is driven in phase with the gate input. For best results, the amplitude of the feedback voltage must be as near as possible to the gate voltage. This is achieved by bootstrapping bias resistor R_s. The effective value of R_s is therefore increased and the gain for the first stage is also increased. As a result, the signal voltage fed back to the drain is larger and the bootstrapping is more effective.

In addition, the increased gain of the first stage further decreases the effect of C_{gs} and reduces C_{in} more.

The total gate capacitance for Q_1 is typically 30 picofarads before the techniques for reducing this value are used. The effect of C_1 and C_2 on the circuit is given by this chart:

Circuit arrangement	Effect	C_{in} (pF)
C_1 and C_2 omitted	Effective C_{gs} reduced, C_{gd} unaffected	5.3
C_1 omitted, C_2 in place	Effective C_{gs} reduced further, C_{gd} unaffected	3.5
C_1 in place, C_2 omitted	Effective C_{gd} reduced	2.0
C_1 and C_2 in place	Effective C_{gs} and C_{gd} both reduced	0.4

As a result of the techniques described, the over-all input capacitance of the amplifier is reduced to 0.4 picofarad, representing a considerable improvement over the 30 picofarad gate capacitance of the FET itself. With an R_g of one megohm, R_{in} is 5 megohms and the amplifier voltage gain is 0.98.

The author

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Understanding and using the MOS FET

Device parameters are represented by capacitors, resistors, diodes and a constant-current generator

By David M. Griswold

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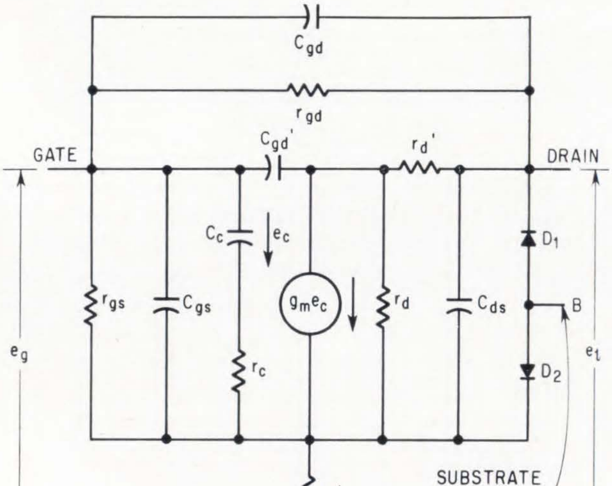
Electronically speaking, the metal-oxide-semiconductor field-effect transistor is represented by 14 components: six resistors, five capacitors, two diodes and a constant-current generator. One way to understand the MOS FET is by analogy with an equivalent circuit using these 14 components. For this purpose, an n-channel MOS FET of the 3N98 type is represented by the 14 components.

Components of the equivalent circuit

The resistances r_{gs} and r_{gd} represent the leakage resistance paths from gate to source and from gate to drain. The resistances of these paths are a function of actual length across the transistor surface. For the 3N98 type of MOS FET, their total combined resistance in parallel typically is between 10^{14} and 10^{15} ohms.



Basic common-source equivalent circuit for MOS FET with operation in the pinch-off region

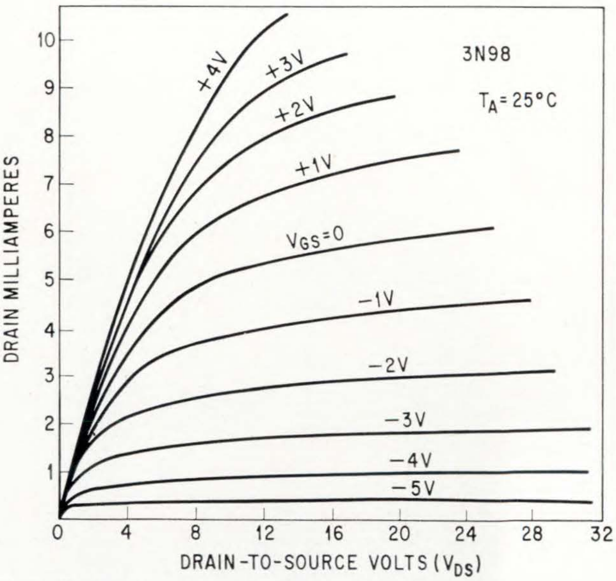
The series network formed by c_c and r_c is a lumped approximation of the distributed network formed between the active channel—the portion of the channel under the gate—and the gate electrode, with the silicon-dioxide insulating layer serving as the dielectric. The capacitance c_c is the sum of the small capacitors distributed over the active channel area.

The capacitance c_c charges and discharges through the channel resistance r_c. The channel resistance, in turn, is composed of innumerable series and parallel resistors between the source, or drain, and the points in the channel where the individual channel-to-gate capacitances take effect. The voltage across c_c helps determine how c_c is charged and discharged$_d$. The voltage across r_c produces only internal heating, which serves no useful purpose. The high-frequency performance of the MOS FET depends primarily upon the time constant determined by r_c c_c. The 3N98 has an equivalent c_c of about four picofarads and a typical r_c in the vicinity of 100 ohms.

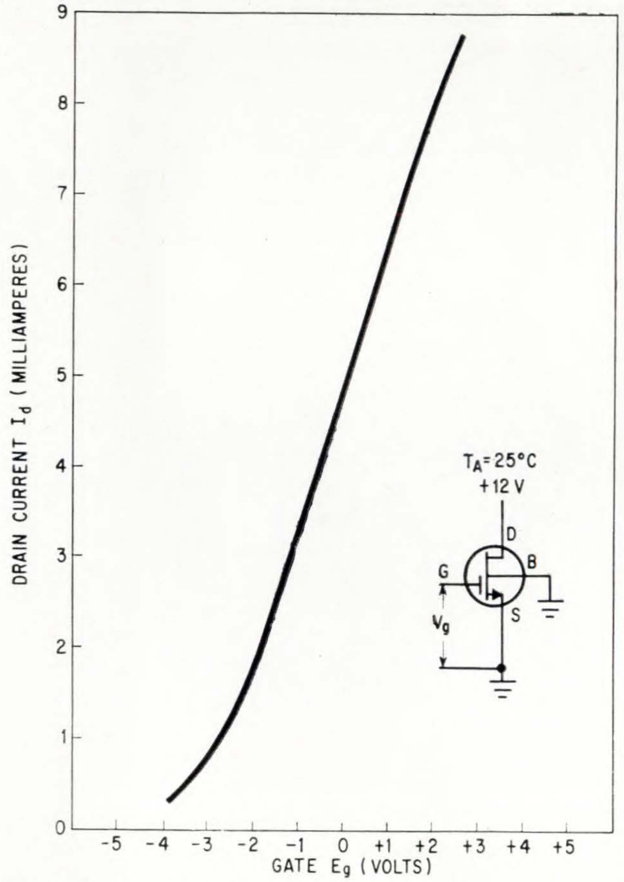
Current generator

The constant-current generator $g_m e_c$ is included in the equivalent circuit because, in the pinch-off region, the drain current is nearly constant with changes in drain-to-source voltage. At low frequencies the intrinsic and extrinsic values of g_m are practically the same, and are equal to the slope of an I_d/E_g transfer-characteristic curve such as the one for 3N98 shown on the next page.

The resistance r_d in parallel with the current generator $g_m e_c$ represents the dynamic output resistance of the transistor. In the pinch-off region, r_d is several orders of magnitude larger than any parasitic resistances. The parasitic resistances appear in series with the source and at the drain. This value may be determined by measuring the slope of the output characteristic curves. As shown on p. 67 by the typical output characteristic curves for an n-channel depletion transistor, r_d



Family of drain characteristics for the 3N98



Transconductance characteristic for the 3N98 with 12 volts supplied to the drain

increases as the channel is further depleted by negative gate voltage. Conversely, r_d decreases significantly at low drain-to-source voltages. Because the channel conduction of an insulated-gate transistor may also be enhanced, r_d may be reduced to a much lower value than is possible with junction-

(*Continued on page* 70)

How the MOS FET works as amplifier

Amplifier circuits

Field-effect transistors are used in three basic configurations in single stage amplifiers common-source, common-gate and common-drain. These are diagramed in this article. Each configuration has certain advantages over the others in particular applications.

The common-source arrangement, which is the most frequently used, is characterized by high input impedance, medium-to-high output impedance, and voltage gain greater than unity. In this mode of operation; the input signal is applied between gate and source, and the output signal is taken between drain and source. The common-source voltage gain without feedback, A, may be determined by the following equation:

$$A = \frac{g_m r_d R_L}{r_d + R_L} \qquad (1)$$

where g_m is the gate-to-drain transconductance, r_d is the drain resistance, and R_L is the effective load resistance. An unbypassed source resistor may be employed to produce negative feedback proportional to the output current. The common-source voltage gain A′ with an unbypassed source resistor is:

$$A' = \frac{g_m\, r_d\, R_L}{r_d + (g_m\, r_d + 1)\, R_S + R_L} \qquad (2)$$

where R_S is the unbypassed source resistance. The common-source output impedance, Z_o is increased by the unbypassed source resistor, as given by:

$$Z_o = r_d + (g_m\, r_d + 1)\, R_S \qquad (3)$$

Common-drain circuit

The common-drain arrangement is frequently referred to as a source-follower. In this circuit, the input impedance is higher than for the common-source configuration, the output impedance is low, there is no polarity reversal between input and output, the voltage gain is always less than unity, and distortion is low.

The source-follower is used in applications that require reduced input capacitance or high-to-low impedance transformation, or in applications with large input signals. The input signal is injected between the gate and drain, and the output is taken between the source and drain. The circuit inherently has 100% negative-voltage feedback; its gain A′ is given by:

$$A' = \frac{R_S}{\left(\frac{\mu + 1}{\mu}\right) R_S + \frac{1}{g_m}} \qquad (4)$$

Because the amplification factor μ is usually much greater than unity for an MOS transistor, this equation can be simplified to:

$$A' \approx \frac{g_m\, R_S}{1 + g_m\, R_S} \qquad (5)$$

If the transistor g_m is 2,000 micromhos and R_S is 500 ohms, the stage gain A is 0.5. With the same value of R_S and a transistor g_m of 10,000 micromhos, the stage gain increases only to 0.83.

With the resistor R_G connected to ground, the input resistance R_i of the stage is equal to R_G. If R_G is returned to the source terminal, the input resistance R_i' may be determined from:

$$R_i' = \frac{R_G}{(1 - A')} \qquad (6)$$

where A′ is the voltage amplification of the stage with feedback. For example, if R_G is 1 megohm and A′ is 0.5, R_i' is 2 megohms.

If the load is resistive, the effective input capacitance C_i' of the source-follower is reduced by the inherent voltage feedback and is given by

$$C_i' = C_{gd} + (1 - A')\, C_{gs} \qquad (7)$$

For example, with a 3N98 MOS FET having a C_{gd} of 0.3 picofarads, a C_{gs} of 5 picofarads and with A′ equal to 0.5, C_i' is reduced to 2.8 picofarads.

The source-follower output resistance R_o' is given by

$$R_o' = \frac{r_d\, R_S}{(g_m\, r_d + 1)\, R_S + r_d} \qquad (8)$$

where r_d is the transistor drain-to-source resistance in ohms. With a MOS FET having a g_m of 2,000 μmhos, r_d of 7,500 ohms and R_S of 500 ohms, R_o' is equal to 241 ohms.

The source-follower output capacitance C_o' may be expressed as follows:

$$C_o' = C_{ds} + C_{gs}\, [(1 - A')/A'] \qquad (9)$$

If A′ is assumed as 0.5, C_o' reduces to the sum of C_{ds} and C_{gs} (1.5 + 5.0 = 6.5 picofarads). This figure is typical for a 3N98 used with a total external source resistance of 500 ohms. If the same MOS FET is used with an external source resistance of 2,000 ohms, A′ has a value of 0.8 and C_o' drops to 2.87 picofarads.

Common-gate circuit

The common-gate circuit is used to transform from a low to a high impedance. The input impedance of this configuration has approximately the same value as the output impedance of the source-follower circuit. The common-gate circuit is also desirable for high-frequency applications because its relatively low voltage gain makes neutralization unnecessary in most instances. The general expression for common-gate voltage gain, A, is given by

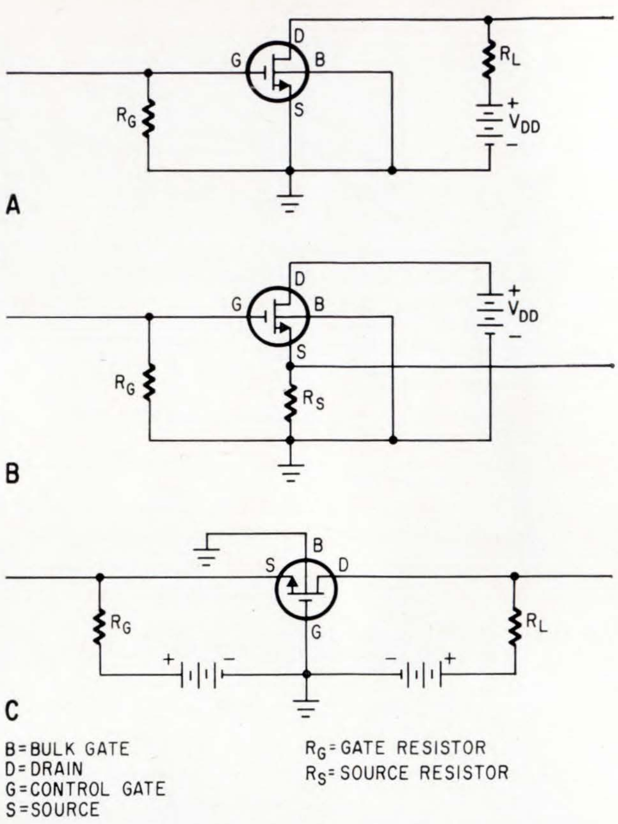
$$A = \frac{(g_m\, r_d + 1)\, R_L}{(g_m\, r_d + 1)\, R_G + r_d + R_L} \qquad (10)$$

where R_G is the resistance of the input signal source. If g_m = 2,000 μmhos, r_d =7,500 ohms, R_L = 2,000 ohms and R_G = 500 ohms, the common-gate voltage gain is 1.8. Doubling the value of R_G, reduces the voltage gain to 1.25.

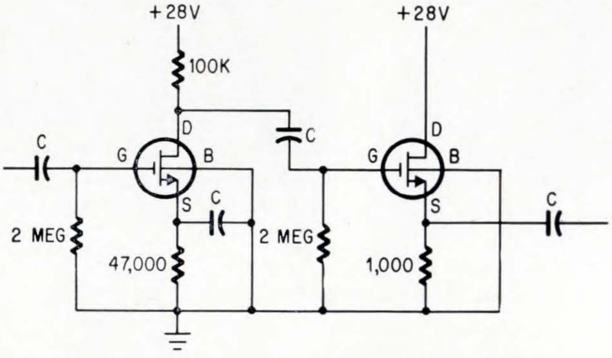
The MOS field-effect transistor can also be used in several two-stage cascade arrangements, either with other MOS transistors or combined with bipolar transistors or vacuum tubes. A pair of 3N98's with a load impedance of 1,000 ohms will produce an over-all voltage gain of

Equivalent circuit components

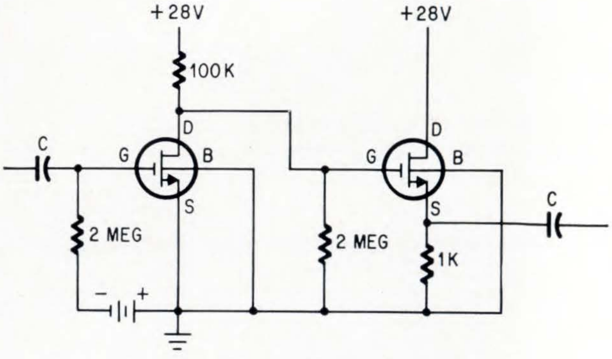
Symbol	Name	Value (for type 3N98)
C_C	Intrinsic channel capacitance	4.0 picofarad
C_{ds}	Drain-to-source capacitance	2.0 picofarad
C_{gd}	Extrinsic gate-to-drain capacitance	0.1 picofarad
C_{gs}	Total gate-to-source capacitance	5 picofarad
$g_m e_c$	Intrinsic current generator	5 milliamps
r_c	Channel charging resistance	100 ohms
r_d	Active drain resistance (function of applied voltage)	10,000 ohms
r_d'	Unmodulated drain resistance (function of device geometry)	300 ohms
r_{gd}	Gate-to-drain resistance	2 x 10^6 ohms
r_{gs}	Gate-to-source resistance	1 x 10^{15} ohms
r_s'	Source resistance	< 1 ohm
D_1	Drain-to-substrate diode	—
D_2	Source-to-substrate diode	—
e_g	Input gate voltage	—
e_1	Drain-to-source output voltage	—



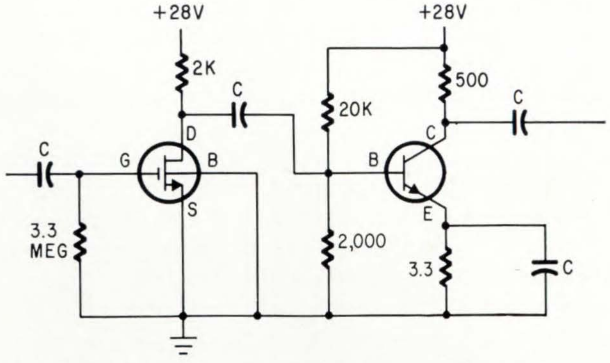
The three basic amplifier configurations for a FET; (A) common-source operation, (B) source-follower operation, (C) common-gate operation



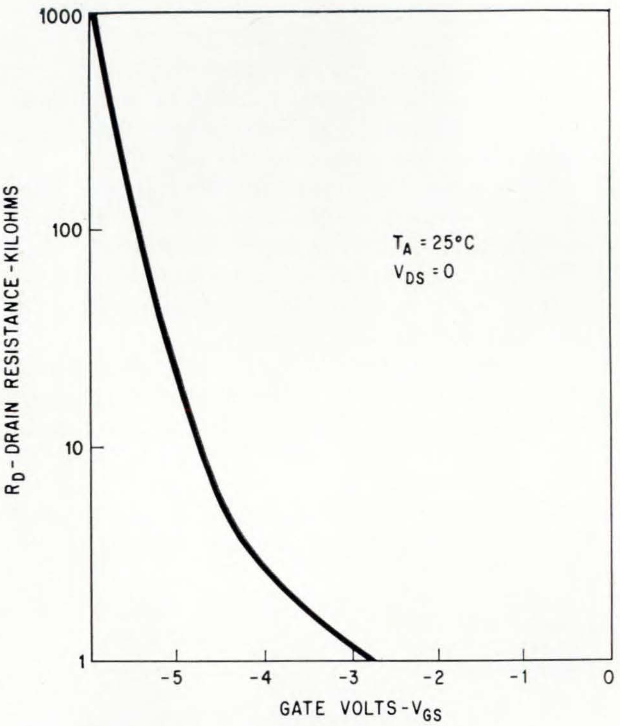
Two-stage amplifier has over-all voltage gain of 10 provided by a pair of 3N98 transistors



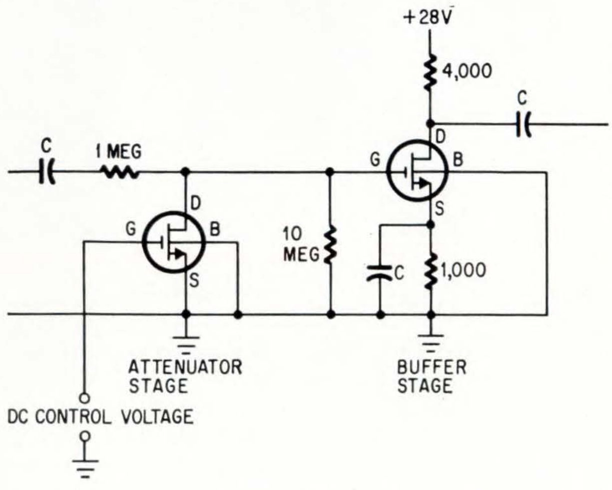
Directly coupled amplifier eliminates coupling capacitors but requires additional bias supply



Hybrid amplifier. An npn conventional transistor is coupled with the n-channel FET.



Drain resistance characteristic shows basically linear relationship between gate voltage and drain resistance



Field-effect transistor circuit can attenuate input signals from 60 to 70 db

approximately 10 in the low-output impedance circuit shown on page 68.

The first stage has a voltage gain of about 20. The reduction of the first-stage drain current to the 100-microampere level permits the relatively large 100,000-ohm d-c load resistance to be used without an excessive drop in the quiescent drain-to-source voltage. The high input impedance presented by the second MOS FET in turn prevents undesirable loading of the first stage. The low output impedance from the pair is then obtained by operating the second stage as a source-follower having a voltage gain of 0.5.

Direct coupling

The circuit on page 68 shows the use of direct coupling between two MOS FETs. This circuit is similar to the one just discussed in that the first stage is operated at a reduced level of drain current for a voltage gain of about 20 and the second stage is designed as a source-follower to allow for low output impedance. However, because all coupling capacitors have been removed, an additional bias battery must be used with the first-stage gate to accomplish what the bypassed source resistor did in the previous circuit. The main drawback associated with the missing source resistor is that the temperature stability of the stage is reduced and closer control of ambient conditions is required. Circuits of this type are interesting microelectronic systems designers in the use of MOS devices in integrated circuits.

In the direct-coupled circuit the drain voltage of the first stage is applied directly to the second-stage gate; however, its effect is partially cancelled by the increased voltage drop across the 1,000-ohm source resistor as a result of the enhanced second-stage drain current.

For example, if the quiescent drain current of the second state is six milliamperes (at $V_{GS} = 0$), the second-stage gate has − 6 volts opposing + 12 volts, or a net positive potential of 6 volts. This potential enhances the drain-current flow, and causes a greater voltage drop across the second-stage source resistor so that the gate is balanced at about half the original difference, or 3 volts for a unit in which:

$$g_m = \frac{1}{R_S}.$$

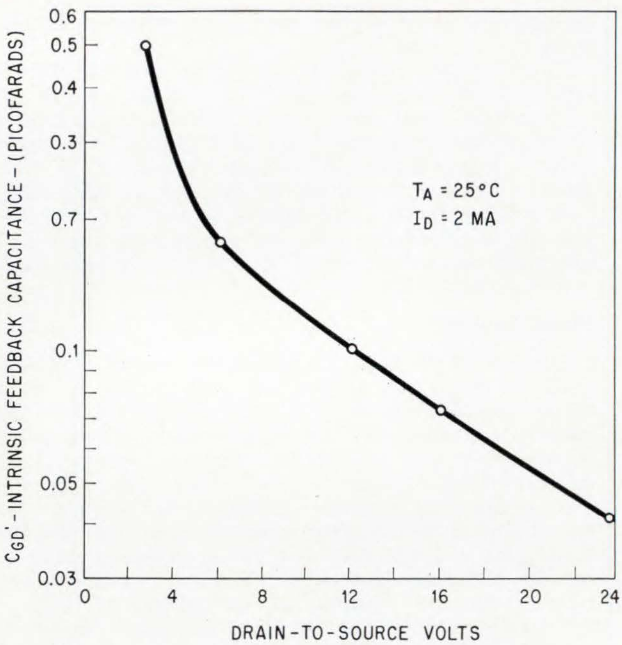
The circuit shown above, containing an n-channel field effect transistor and an npn junction transistor, uses the MOS FET to drive the low input impedance of an npn power transistor. In this combination, the MOS FET is a high-to-low impedance transformer. Even though the low input impedance of the conventional power transistor limits the voltage gain obtained from the first stage, the first-stage power gain can be very high because of the large impedance ratio obtained from the transistor.

Attenuator

The usefulness of an MOS FET as a voltage-controlled attenuator is illustrated by the drain-resistance characteristic shown at the left. Variation of the transistor's gate voltage causes the drain-to-source resistance to increase or decrease, but the curve is linear at low voltages. The primary advantages of the MOS FET in voltage-controlled attenuator circuits are its low gate-power requirements and wide dynamic range.

A simple L-pad arrangement, in which the transistor serves as the variable resistance in the low side of the attenuator is shown at the left. In this circuit, the maximum attenuation is normally between 60 and 70 decibels and the minimum signal reduction is 1 or 2 db. Proper performance of this circuit is possible only when the attenuator unit is followed by a high-impedance load such as a common-source MOS FET amplifier.

In another version of the L-pad attenuator, the MOS FET is placed in the series arm. In this case, the shunt arm must have low impedance if the maximum attenuation figure of 60 to 70 db is desired. The minimum attenuation normally would be 1 to 6 db.



Feedback capacitance characteristic for the 3N98 becomes linear above drain-to-source voltage of 6 volts

gate transistors. At low drain-to-source voltages the output resistance for the MOS FET may be increased from a few hundred ohms to as high as several thousand megohms by making the gate voltage more negative.

Back-to-back diodes

Diode D_1 represents the junction formed between the heavily diffused drain region and the semiconductor substrate; D_2 is the junction formed between the heavily diffused source region and the substrate. D_1 and D_2 are back-to-back diodes in parallel with the channel. In many amplifier applications, the anodes of D_1 and D_2 are connected externally to the source by connecting the fourth lead to the source lead. As a result, D_1 is reverse-biased and D_2 is, in effect, short-circuited. However, a distributed bulk resistance is associated with these substrate diodes; therefore D_2 is not completely shorted out. In low-frequency applications, however, this resistance is negligible; at high frequencies, the diodes contribute an equivalent series RC network that affects the output admittance.

Resistances r_d' and r_s' represent those portions of the source-to-drain channel that are not controlled by the transistor's gate. In the 3N98 the major portion of r_d' results from an intentional offset of the insulated gate away from the drain. This offset results in a greatly diminished feedback capacitance $\mathbf{C_{gd}}$ and a high source-to-drain breakdown voltage. Resistance r_s' is a result of bulk resistance or contact resistance in the source and/or of unmodulated channel resistance caused by misalignment of the gate. In the common-source configuration, r_s' represents both heat loss and degeneration since it produces some negative feedback, r_d' represents only a heat-loss element in series with the external load impedance.

Capacitances $\mathbf{C_{gd}}$, $\mathbf{C_{ds}}$, and $\mathbf{C_{gs}}$ are the physical case and interlead capacitances between the gate and drain, gate and source, and drain and source. Capacitances $\mathbf{C_{gd}}$ and $\mathbf{C_{gs}}$ also include any capacitances not dependent on voltage such as that contributed by the physical overlap of the insulated gate over the source or drain. Capacitance C_{ds} includes the capacitances for D_1 and D_2.

Capacitance C_{gd}' represents the intrinsic gate-to-drain capacitance, which decreases as the channel voltage approaches the pinch-off region. This decrease in capacitance is desirable and especially noticeable in an offset-gate transistor. It is illustrated by the curve at the left.

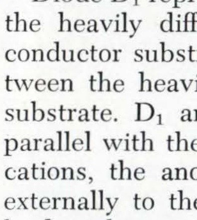
Although the equivalent-circuit diagram does not show it, the 3N98 FET silicon substrate role is not completely passive. To some degree, the substrate forms a junction with the active channel and therefore may be used as a second control electrode. The degree of control depends primarily on the channel length and the doping level of the substrate. The 3N98 typically exhibits a substrate-to-drain transconductance between 400 and 1,000 micromhos.

Fourth lead

The substrate gate of the 3N98 is made accessible by a fourth lead. When a negative bias is applied between this lead and the source lead, the drain current is decreased. However, the use of the substrate as a gate may introduce two characteristics of the conventional silicon junction at that gate—temperature-sensitive saturation current and low impedance—when a positive bias is applied between the substrate gate and the source. Because the substrate-gate trans-conductance of the 3N98 is not controlled during manufacturing, the substrate-gate lead usually should be placed at a-c ground potential and connected to a d-c voltage which minimizes the potential difference between the substrate gate and the insulated gate.

The equivalent circuit is useful in understanding how the MOS FET functions. However, admittance parameters are often used in actual circuit design using either MOS FETs or conventional-junction FETs. In fact, several of the equivalent circuit elements shown on commercial data sheets can only be determined by making Y-parameter measurements at several frequencies.

The author



David M. Griswold is a senior engineer in the Radio Corp. of America's consumer applications department. He has also served as manager of RCA's rating laboratory and manager of test and reliability engineering. He is chairman of the Joint Electronic Devices Engineering Council's Committee on Consumer Product Devices.

The field-effect transistor as high-frequency amplifier

At 250 megacycles, the FET has less cross-modulation than nuvistor tubes or conventional transistors

By Paul E. Kolk and Irwin A. Maloff
KMC Corp., Long Valley, N.J.

High-frequency field-effect transistors with figures of merit between 700 and 900 megacycles can be used to design FET amplifiers that operate at 200 Mc and higher. This capability makes the field-effect transistor competitive with conventional high-frequency transistors and nuvistor tubes[1] for radio-frequency amplifier, mixer and converter applications. Power gain for a single transistor stage at 200 Mc with commercially available FETs is approximately 12 decibels.

Figure of merit

The figure of merit of conventional transistors is the maximum frequency of oscillation (f_{max}) and is the frequency at which the power gain falls off to unity or zero db. This is directly related to the current gain-bandwidth (f_T) and inversely related to the base resistance feedback capacitance product ($r_{bb}'c_c$) as follows:

$$f_{max} = \sqrt{\frac{f_T}{25 r_{bb}' c_c}}$$

A similar figure of merit (f_{comax}) exists for field-effect transistors. It is expressed as:

$$f_{co\ (max)} = \frac{g_m}{2\pi C_{fb}}$$

where
$f_{co\ (max)}$ = frequency in Mc at which the power gain is unity,
g_m = transconductance in mhos
c_{fb} = drain-to-gate capacitance in farads

For a typical high-frequency field-effect transistor (type number K1001) of the insulated-gate, metal-/oxide-semiconductor variety, $g_m = 4000$ micromhos and $C_{fb} = 0.7$ microfarads. Therefore:

$$f_{co\ (max)} = \frac{4000 \times 10^{-6}}{2\pi\ (.7 \times 10^{-6})} = 910 \text{ Mc}$$

As with conventional transistors, the maximum usable frequency for a field-effect transistor as an amplifier is considerably below $f_{co(max)}$. However, a transistor with an $f_{co(max)}$ above 900 Mc is more than adequate for amplifier service at 200 Mc and performs well even at 250 Mc.

Maximum available gain

The maximum available power gain (MAG) for a transistor stage is seldom achieved in practical circuits since it can be approached only when feedback is negligible. However, the circuit designer can come within 0.5 to 1.0 db of the MAG calcu-

The authors

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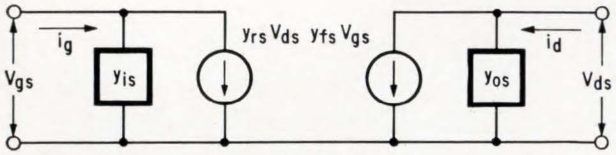
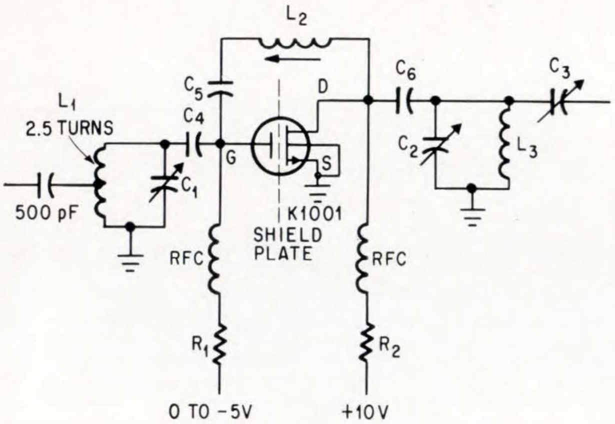
lated from the admittance parameters and still obtain stable operation.

Characteristics of such nuvistor tubes as the 6CW4 are normally specified as measured in a neutralized circuit. Most conventional transistors are also specified this way. Neutralization is the technique of nullifying feedback from output to input, usually accomplished by placing a capacitor between the drain and the gate. A few manufacturers publish both neutralized and unneutralized gain figures. Amplifier circuits are often both neutralized and mismatched to achieve neutralized stable gain (NSG). In an unneutralized circuit, stabilized gain (USG) is obtained only by input or output mismatching or a combination of both.

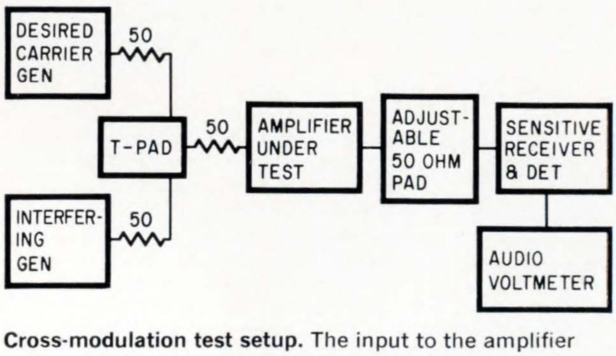


Admittance-parameter equivalent circuit for a field-effect transistor



COMPONENT VALUES			
C_1	0.9–7 pF	L_1	5 TURNS, $\frac{5}{8}$" x $\frac{1}{2}$" NO. 20 WIRE, 0.29μH
C_2	0.9–7 pF	L_2	MILLER TYPE 20A107RBI OR EQUIV. 0.125–0.079μH
C_3	0.9–7 pF	L_3	5 TURNS, $\frac{5}{8}$" x $\frac{1}{2}$" NO. 20 WIRE
C_4	500 pF		
C_5	500 pF	R_1	6,800 OHMS
C_6	500 pF	R_2	2,200 OHMS

200-megacycle neutralized amplifier. Component values are given in the chart.



Cross-modulation test setup. The input to the amplifier under test is a broadband untuned signal.

Admittance parameters

The admittance parameters at any frequency are useful in characterizing the field-effect transistor as a four-pole "black box".[2] The gain is calculated at 250 Mc to assure that these or higher gains will be achieved at 200 Mc.

The admittance parameters in millimhos for a typical type K1001 measured at 250 Mc are:

Common-source input admittance $(Y_{is}) = (0.84 + j\,5.8)$

Common-source output admittance $(Y_{os}) = (0.52 + j\,3.2)$

Common-source forward transadmittance $(Y_{fs}) = (-4 + j\,2.6)$

Common-source reverse transadmittance $(Y_{rs}) = -(0.2 + j\,0.58)$

From the admittance parameters:

Parallel input resistance $(R_{inp}) = 10^3/0.84 = 1200$ ohms

Parallel input capacitive reactance $= X_{Cinp} = 1/j\omega C_{inp} = 10^3/5.8 = 172$ ohms, Parallel input capacitance $= C_{inp} = 4$ picofarads

Parallel output resistance $(R_{op}) = 10^3/0.52 = 1920$ ohms

Parallel output capacitive reactance $= (X_{cop}) = 1/j\omega C_{op} = 10^3/3.2 = 313$ ohms, Parallel output capacitance $= C_{op} = 1.5$ picofarads

Forward transconductance $(y_{fs}) = g_m = 4.86$ millimhos

Feedback reactance $= X_{Cfb} = 1/j\omega C_{fb} = 10^3/5.8 = 172$ ohms, Feedback capacitance $= C_{fb} = 0.4$ picofarads

The subscript s stands for common source; p for parallel.

Calculating MAG and NSG

The expression for MAG is:

$$MAG = [(g_m)^2 R_{inp} R_{outp}]/4 = [(4.86)^2 (1200) (1920) \times 10^{-6}]/4 = 12.9 \text{ (equivalent to approximately 11 db)}$$

If calculated for 200 Mc instead of 250 Mc, MAG is equal to 13 db. In the typical 200-Mc amplifier circuit shown at left, the actual gain was measured as 12 db with a drain-to-source voltage of 10 volts and a drain current of 5 milliamperes.

The neutralized stable gain[4] at 250 Mc is given by:

$$NSG = 2kg_m X_{Cfb}$$

where X_{Cfb} = feedback reactance $= 1/\omega C_{fb} = 1/2\pi\,(250)\,(.24) = 2900$ ohms

$g_m = y_{fs} = 4.86$ millimhos

k = arbitrary skew factor[5] = 0.2 (determined by shape of amplifier bandpass characteristic)

The lower the value of k, the greater the stability.

k should not exceed 0.4 for fixed-gain stages or 0.2 for AGC stages

$$NSG = 0.4\,(4.86)\,(2900) \times 10^{-3} = 5.6 = \text{approximately } 8 \text{ db}$$

In addition to neutralizing the C_{fb} of 0.4 pf, it is also necessary to take into account variations between individual transistors. Therefore, additional neutralization is required. The amount of variation, typically, can be in the order of 0.2 picofarads.

Cross modulation and distortion

Cross modulation is the transfer of undesired modulation from one carrier to another. Modulation distortion is produced by harmonics of the modulation impressed on a desired carrier.

Both cross modulation and modulation distortion can be represented by the odd terms in a series expansion of the expression for the transistor output current in terms of the input voltage. Modulation distortion (V_1) can be attributed to the nonlinearities of the transconductance of the device. Modulation distortion[3] is given by:

$V_1 = 8\,V_{is}/3m$

where

V_{is} = rms value of interfering signal voltage to produce 1% cross modulation distortion
m = % modulation

Cross modulation is measured by the arrangement shown below. The input to the amplifier under test is a broadband untuned signal from a 50-ohm resistive source. The frequency of the undesired signal is sufficiently distant from the frequency of the desired signal so that the system selectivity prevents cross modulation in the sensitive receiver.

Devices should be compared for cross-modulation levels in equivalent systems. For a meaningful comparison the interfering signal voltage, the input impedance of the device and the source impedance driving the device must be known. The power of the interfering signal P_{int} may be determined by
$P_{int} = V_{is}^2/R$
where
V_{is} = Interfering signal to produce 1% cross modulation and R is the parallel combination of source resistor R_s and transistor input resistance R_{in}.

A comparison of cross modulation versus AGC for a 6CW4 nuvistor, a field-effect transistor type K1001, and a silicon npn 2N2857 uhf transistor is shown at right. The table at right compares the pertinent characteristics of these devices at 200 Mc. The data illustrates the superiority of the FET over both the tube and the junction transistor in limiting cross modulation.

Circuit design and construction

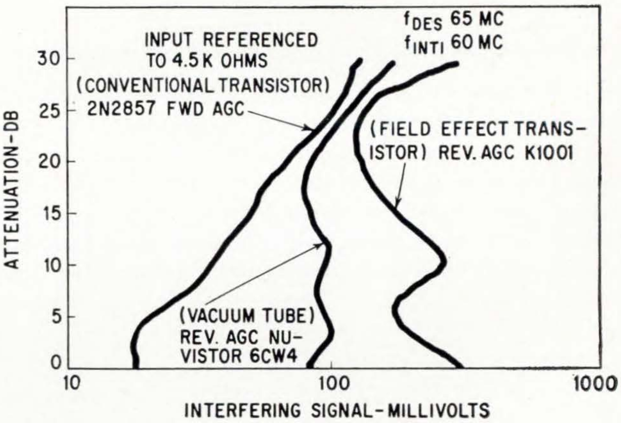
The measured circuit gain for the 200-Mc amplifier shown on page 72 is 13 db, which agrees closely with the calculated gain. The bandwidth is 12 Mc.

Conventional tube circuit-design techniques may be used in designing field-effect-transistor circuits. As in tube and conventional transistor circuit design, the same techniques in selecting low-loss high-frequency components apply. Input circuits must be designed to minimize losses for good noise figure and power gain. Lead lengths should be minimized and high unloaded Q is desired.

The input tank circuit L_1-C_1 is resonant at 200 Mc. The amplifier is neutralized by shunt inductance L_2 between the drain and gate. Capacitor C_5 and L_2 are mounted on the gate side of the shielding plate which isolates the input and output of the amplifier.

Noise-figure measurement

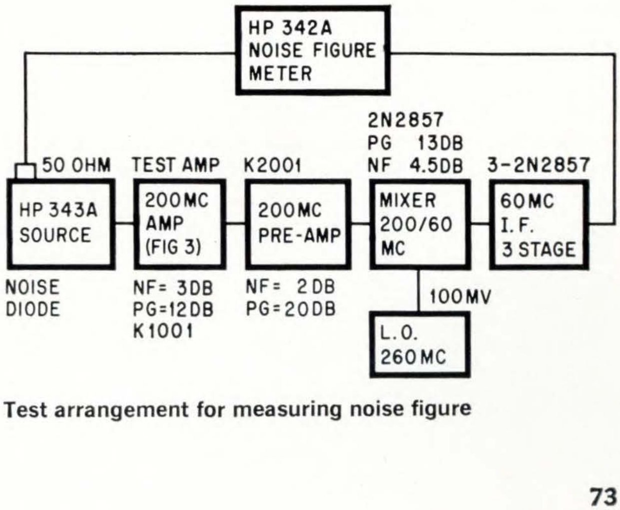
The noise-figure measurement test setup is



Cross-modulation characteristics for a junction transistor (2N2857), a tube (6CW4), and a field-effect transistor (K1001)

TYPE AND NUMBER	FIELD EFFECT TRANSISTOR K1001	NUVISTOR 6CW4	JUNCTION TRANSISTOR 2N2857
R_{OUT} (OHMS)	1900	3000	7500
C_{OUT} (pF)	1.5	1.7	1.5
R_{IN} (OHMS)	1200	1000	300
C_{IN} (pF)	4.0	8.5	5.0
Gm (MILLIMHOS)	5.0	9.5	47.0
MAG (DB)	13	15	22
C_{FB} (pF)	0.4	0.9	0.5
NF (DB)	3.0	5.0	3.0

Cross-modulation comparison chart



Test arrangement for measuring noise figure

shown at right. It includes a Hewlett Packard 342A noise figure meter and 343A noise diode.

Low-frequency noise ($1/_f$) measurements were made for K1001 transistors using a Quan-Tech Laboratories model 311 field-effect transistor noise set. Measurements were made at 100, 1000 and 10,000 cps with a one-cps bandwidth. The d-c bias was set at $V_{ds} = 10$ volts and $I_{ds} = 1$ ma. The results are shown below:

$g_m = 2000$; voltage gain = 20 db

Frequency (cps):	E_N*:
100	0.60
1,000	0.16
10,000	0.06

* Microvolts per root-cycle (square root of bandwidth in cps).

The field-effect transistor operated at 200 Mc is superior to conventional transistors in cross-modulation performance. The FET and the conventional high-frequency transistor appear to be on a par as far as noise figure is concerned but the conventional unit holds an edge in power gain.

Because it is a majority carrier device, the field-effect transistor, unlike the conventional transistor, can be operated at extremely low temperatures. For example, with 200-Mc operation at the temperature of liquid nitrogen, the FET's power gain increases approximately 4 db and its noise figure drops about 2 db.

Although the discussion in this article has been limited to the use of the FET as an amplifier at 200 Mc, FET amplifiers that can operate up to 300 Mc have been built. However, selected transistors must be employed in constructing a 300-Mc amplifier.

References

1. G.C. Hermelin, "A Nuvistor Low-Noise Tuner," REA Electronics Pioneer No. 22, Spring, 1961.
2. P.E. Kolk, Application Note, RCA, Somerville, N.J., SMA23, "Design of VHF and UHF Circuits Using the Admittance Parameters."
3. B.D. Dammers, "Application of Electronic Valves in Radio Receivers and Amplifiers" Book IV, N.V. Philips Gloeilampen-fabrieken-Eindhoven (Netherlands), pp. 308-328.
4. David D. Holmes and T.O. Stanley, "Transistors I," RCA Laboratories, Princeton 1956, p. 403.
5. Ibid, pp. 406, 413.

Field-effect transistors

An FET micropower amplifier

This circuit provides a voltage gain of 1,000 and requires less than 100 microwatts to function

By James S. Sherwin Sr.

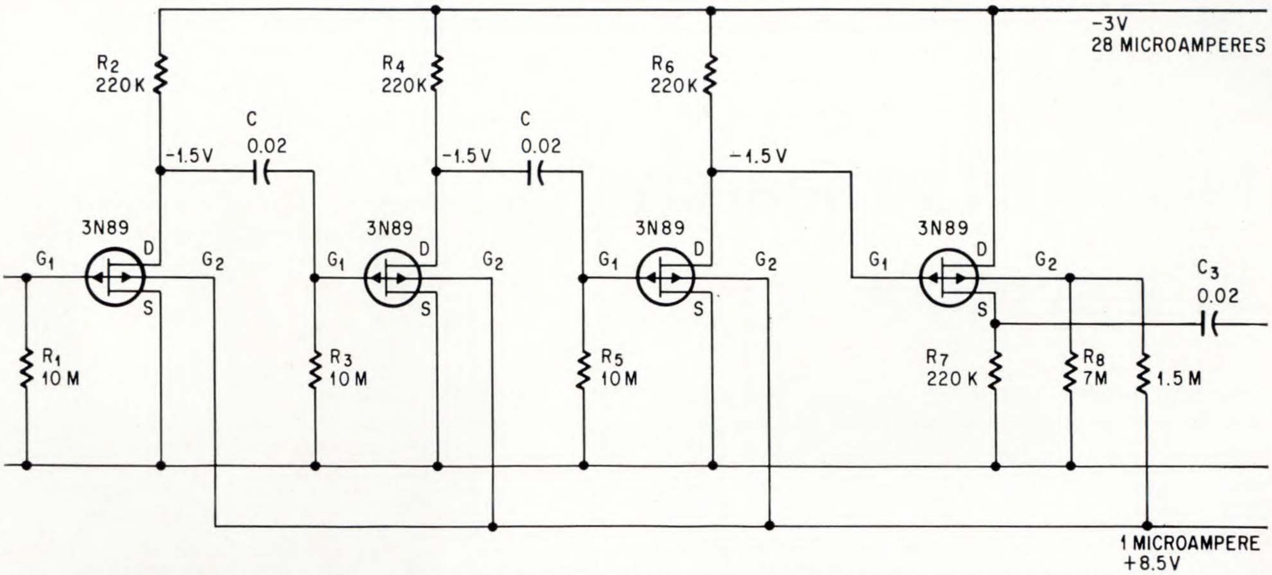
Siliconix, Inc., Sunnyvale, Calif.

Amplifier circuits with high gain and high input impedance operating at extremely low power levels, can be designed with FETs. For example, a four-stage amplifier can be designed that has a voltage gain of 60 decibels and a power drain of less than 100 microwatts. This amplifier can control crystal transducers and is useful in various space applications where supply power is limited. The amplifier employs four 3N89 four-terminal transistors, three of which can be diffused into a single silicon substrate in an integrated-circuit design.

The amplifier uses three stages of voltage gain and a source-follower output stage. Each FET is biased by placing a positive voltage on the substrate gate to supply a drain current of seven microamperes. The transconductance at this current is 50 to 100 micromhos.

Tetrode FET used

The 3N89 tetrode FET was chosen because it



Low-level amplifier provides voltage gain of 60 db over a range of 1 to 30,000 cps. Three of the four 3N89 transistors used are matched. The output stage transistor Q_4 need not be matched to the other transistors. The maximum output voltage is 0.5 volt rms.

exhibits a higher ratio of transconductance to drain current at low values of drain current than does the triode FET; also, the control gate is available for biasing without the need for bias-network resistors and bypass capacitors.

Biasing is simple and consumes less than 10 microwatts, mainly in the output stage. Each FET is operated for a stage gain of less than 10 with zero bias on the signal gate so that the circuit is simplified by elimination of source bias resistors.

In this design, the maximum signal level at the gate of the final stage of amplification is 50 millivolts rms, which is insufficient to cause the FET input resistance to decrease because of forward biasing by the signal. Control-gate bias is applied equally to each FET in the three voltage-gain stages. Because voltage dividers are not required to bias the second gate, the circuit can be relatively simple and power loss in the biasing networks can be eliminated.

Three matched devices used

To enable the use of a common-bias circuit, the three FETs have matched second-gate characteristics so that the drain currents of all three transistors are equal at the given second-gate bias. Also, the 3N89's are selected for low values of drain current at gate-drain reach-through voltage—the voltage at which the spreading depletion region extends from gate to drain. In this way, input impedance is kept high when the FET is biased down to seven microamperes. The output FET Q_4 need not be matched to the other transistors, because a separate voltage-divider network is used to provide its bias voltage.

10-megohm input impedance

The amplifier input impedance of 10 megohms for this circuit is determined by the input-stage gate-return resistor. The output impedance is 10 to 20 kilohms and is a function of the $1/g_{fs}$ ratio for the output transistor. The amplifier cannot actually be loaded with 10 kilohms, of course, because it is not capable of delivering full output to such a load. The maximum output voltage is 0.5 volt rms, limited by the 3-volt supply.

The minimum over-all voltage gain is 1,000 at 25°C, and frequency response is one to 30 kilocycles per second with the circuit values shown in the circuit above.

Low-frequency response

For this four-stage amplifier circuit, low-frequency response is limited only by the coupling capacitors and the gate resistors. High-frequency response is limited by the FET input, output and circuit capacitances paralleling the drain-load resistors. A high-frequency RC time constant of four microseconds is produced by the 3N89 input and output capacitances of 8 and 2 picofarads including Miller effect capacitance, together with the stray capacitance of about 5 picofarads. The amplifier noise figure at one kilocycle is three decibels for generator impedances of 10 to 20 megohms. The power drain is 21 microwatts per stage plus 8.5 additional microwatts in the output-stage biasing network. The total power required is thus only 92.5 μwatts.

Applications for circuit

The use of this circuit in space vehicles is particularly promising because of the low battery current drain and because of its compatibility with integrated circuit design requirements.

The author

James S. Sherwin Sr. is a senior applications engineer at Siliconix. He is involved in circuit design, device evaluation and customer assistance.

MOS FET in search of a symbol

Manufacturers of insulated-gate metal-oxide-semiconductor field-effect transistors agree that the standard FET symbol is all right for junction field-effect transistors, but that it won't do for the MOS FET. And that's about all on which they do agree.

Five different basic sets of circuit symbols currently are in use for the MOS FET. These are shown at the right. Whether any of these symbols will survive as the standard is open to conjecture.

The first two sets have one important advantage over the remaining three sets: They are able to distinguish between n-channel and p-channel devices if the bulk gate lead is eliminated. When the lower three sets are modified to represent a three-lead device, it is impossible to tell whether an n-channel or p-channel device is being described.

The top two symbols at the right are preferred by the semiconductor division of the Fairchild Camera & Instrument Corp.; General Micro-Electronics, Inc., and the Semiconductor-Components division of Texas Instruments, Inc.

The second set suggested by TRW Semiconductors, Inc., a division of Thompson Ramo Wooldridge, Inc., is similar to the first set except that the lines representing the source and drain are slanted instead of being parallel. Drawing the source and drain lines at an angle makes the symbol look more like the conventional junction transistor than the junction field-effect transistor.

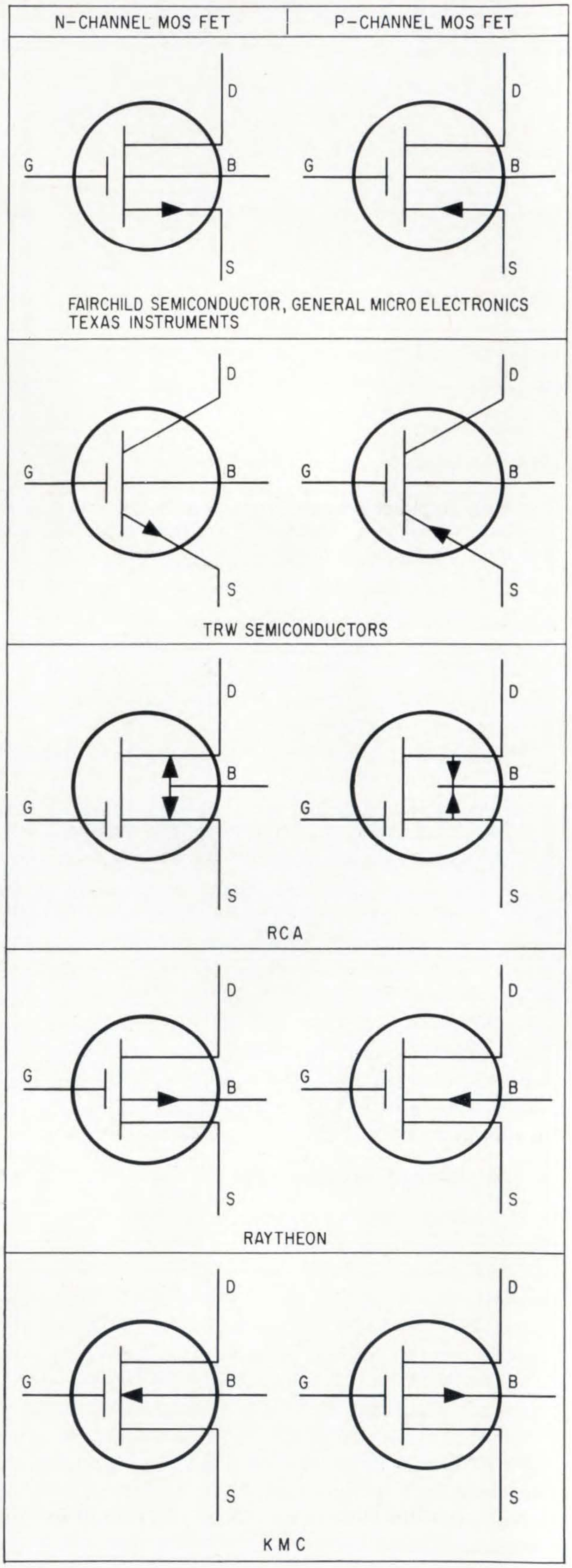
The symbols proposed by the Electronic Components & Devices division of the Radio Corp. of America have the gate located directly opposite the source. However, this is done to depict the physical construction of the device, which is built with the gate offset toward the source, rather than to provide a method of distinguishing between source and drain.

One drawback of this set if the gate is not offset and of the symbols proposed by the KMC Corp. is that the source lead cannot be distinguished from the drain lead unless labeled.

The symbols proposed by Raytheon Co. engineers eliminate this problem, but only for the four-lead device—by moving the bulk gate line closer to the source than to the drain.

The Institute of Electrical and Electronics Engineers committee that sets up standards on graphical symbols for semiconductor devices meets in January, and will consider proposed symbols for the insulated-gate MOS FET at that time.

Four-terminal MOS FET symbols



All five sets of symbols shown above are currently being used to represent insulated-gate MOS FETs. The symbols depict four-lead devices. By eliminating the portion of the symbol concerned with the bulk gate, the symbols apply to three lead transistors.

Digital television: shrinking bulky bandwidths

Its flexibility and relative immunity to distortion have long been known. Now a new approach solves the bandwith dilemma, providing an effective tool for command and control or extended space-probe observations

By J. M. Knight, J. K. Fadely, G. L. Raga and B. C. King

Electro-Mechanical Research, Inc., Sarasota, Fla.

The advantages of digital television have long been recognized, but engineering problems and costs have blocked its development and acceptance. Digital tv allows pictures to be processed by computers already in place for other digital jobs. The system isn't subject to the distortions that affect analog receiver is simpler and less expensive.

Commercial tv, which uses analog transmission, isn't expected to be replaced by digital techniques, primarily because the analog system came first and the consumer market is geared to its use. Also, the analog receiver is simpler and less expensive.

The major obstacle to digital tv is its bandwidth. For a comparable picture, the bandwidth of a digital system has to be eight to 12 times wider than an analog system. Therefore, major efforts are being made to narrow that bandwidth. Since a tv signal has a lot of redundancy—because often much of the picture doesn't change—one of the efforts to narrow the bandwidth involves removing all superfluous information and transmitting only the data needed to define the motion in the picture.

Digital tv has three immediate applications:

- **Transmitting secret military messages.** Digital signals can be put into a complex code easily to prevent the enemy from understanding an intercepted signal.
- **Closed-circuit tv on telephone lines.** The bandwidth can be narrowed for transmitting images over phone lines.
- **Televising from outer space.** The earth-based receiver can receive weak signals and regenerate them into noise-free and accurate pictures.

The system described in this article is a general type that demonstrates a two-to-one compression.

Digital television (dtv) reduces video information to binary numbers that can be manipulated easily, thus making possible several elegant and practical methods for removing redundancy. The system can transmit moving or still pictures, with or without compression, and with either high or limited resolution. Commercial tv—which operates at 30 frames a second and has a 525-line resolution —has been digitized to five or six bits.

Moving-picture dtv of reasonable quality can be obtained with a 10-frame-per-second, 250-line resolution, four-bit system. Minimum usable moving pictures are obtained at three-to-five frames per second with 125-line resolution and three-bit encoding. The development of dtv for the transmission of still pictures requires a compromise between resolution and picture quantization. Resolutions vary from 125 to 3,000 lines per frame and usable quantization from two to seven bits. The higher quantizations are used for reconnaissance, radiometric and photometric work.

Dual approach

There are two forms of digital tv. The most common is a system in which the television camera is operated in normal analog mode and the video signal passes through an analog-to-digital converter. This type is called pulse code modulation (pcm) television. In the second, the television camera scan beam is digitally indexed asynchronously under control of a digital timing system. Video from a television camera operated in this way is also processed by an analog-to-digital converter. However, this system is better than the first system because the frame rate can be varied continuously by varying the clock that controls digital timing. Also, resolution can be changed by altering the countdown points on horizontal and vertical sweep-generation counters. And, the television scanning beam need not be indexed at a constant speed, but can dwell upon picture elements.

Design of a dtv system depends on resolution, quantization and frame rate. These quantities correspond roughly to vertical resolution, signal-to-noise ratio and frame rate in analog tv. Quantization means that in digital tv the video at each picture element is allowed to assume only discrete values with the difference between the actual video and the nearest discrete level being termed quantization noise. An acceptable picture results from a resolution of 512-by-512 picture elements and six-bit quantization, corresponding to 64 discrete video levels. A 30-cycle frame rate should yield motion equal to commercial tv. Interlacing the dtv scan makes it as flicker-free as commercial tv.

No more wow

Pictures from a dtv system can be processed directly by computers and transmitted through digital data-handling systems designed for other uses. The digitized picture can be sent through a transmission system that contains many repeater amplifiers. The recording and reproduction of the digitized picture can be accomplished without the usual wow and flutter inherent in analog recording techniques. A dtv system that is designed to scan asynchronously also offers flexibility, and the decision to trade off resolution for frame rate can be accomplished by flipping a switch.

Digital picture encoding matches the accuracy of the pictorial sensor. This is important not only when the sensor is used to provide a picture of events, but also when it is used for radiometric measurements of brightness. When the picture is in digital form it is readily processed by many crypto-encoding techniques.

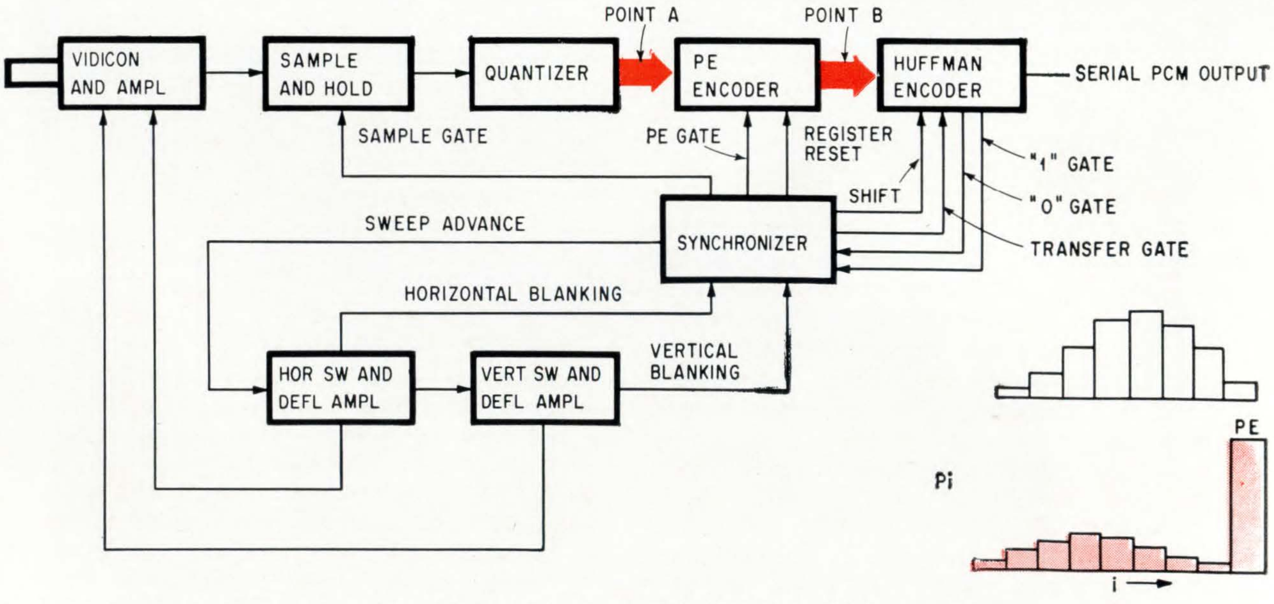
Getting it down to size

Digital television systems can be divided into two categories: those that use compression techniques and those that don't. Systems without compression often store digital data for slow-speed readout to allow transmission over narrow bandwidth communication links.

Compression systems either preserve or destroy information. A preserving system is one that uses completely reversible compression operations between the transmitter analog-to-digital converter and the receiver digital-to-analog converter. Such a system retains all information about the analog signal except a small amount that is lost through analog-to-digital conversion.

Many attempts at tv compression use reduction in resolution, quantization and frame rate. One experimenter, S. Deutsch of Polytechnic Institute of Brooklyn, N. Y., reduced the number of picture elements to approximately 45,000, corresponding to the number seen on an inexpensive home receiver with a 2-megacycle bandwidth and poor interlacing. He was able to reduce the frame rate from 30 per second to 0.375 per second with a special scan and a kinescope phosphor that reduced flicker and retained some image motion. The resulting 10-kilocycle bandwidth requirement represents a remarkable compression.

Compression systems can be classified into three categories: approximation, statistical and hybrid. The approximation systems attempt to represent the actual video by an approximation waveform whose transmission requires less bandwidth, or power, or average bits per picture element. The



Previous element coding system is used for tv picture compression. Eight-level histogram (top, in lower right corner) shows gray-level distribution at point A before encoding. Bottom histogram shows how addition of previous element reduces redundancy as observed at point B.

Each white dot in the picture at the right represents a picture element from the original (left) that is unlike its previous neighboring element. The black areas indicate the amount of picture redundancy.

statistical compression systems attempt to produce and transmit a reduced redundancy digital signal that can be reversibly decoded into an exact replica of the original digital signal. Hybrid systems separate the video into high- and low-frequency components, applying perhaps an approximation technique to the low-frequency component and statistics to the high-frequency component.

Even moderate compression offers economic and technical advantages. The cost saving can be demonstrated by considering a system with a compression ratio of only two to one, a compression that has been achieved: A 200-mile tropospheric scatter link costs about $4 million: by adding a $400,000 compression system, the same link can handle twice the video traffic.

And there is also saving for the subscriber: If line time costs $100 an hour, two-to-one compression saves the uses $50 a hour; thus the $400,000 cost of the compression system can be recouped in about a year of full-time service.

For a space probe, where the time to transmit pictures is fixed, the compression system can be a technical advantage because twice as many pictures can be sent in a mission.

How to compress

A previous element coding (pec) system, developed on the basis of statistical compression, uses element-to-element pictorial redundancy combined with an efficient coding scheme to produce a digital bit stream output averaging two bits per picture element where the original video went in at four bits per picture element, providing fair resolution.

Television compression is achieved this way: At point A in the diagram on page 78, it is possible to accumulate first-order statistics on the video levels appearing. For example, given an eight-level source (three-bit encoding), an eight-bar histogram of the video statistics could be made as shown. Since the distribution is not flat, the entropy of this distribution is less than three bits.

Entropy H, a measure of the flatness of distribution in bits per message, is given by

$$H = - \sum_{i=1}^{i=n} P_i^{\log_2} P_i$$

where n is the number of messages (eight), i is the number of the particular message (here taken as one to eight in the histogram) and P_i is the probability of its occurrence.

All the video levels are accounted for in the histogram. It is an observed fact, however, that 70% or 80% of these video levels are exactly like their previous neighboring element. A second encoder, called a previous element (pe) encoder, has been devised that will emit a ninth signal, called a previous element (pe) signal, whenever a given picture element is equal to its immediately preceding neighbor. Those elements, unlike a previous neighboring element, are unchanged by the coder.

The girl's photograph (above, left) illustrates how transitions can be recorded for picture elements that are unlike their previous neighboring element. Each white dot (above, right) represents a picture element in the original picture that is unlike its

Other digital tv systems

The immediate impact of digital television (dtv) is on military systems used for conferences and briefings, management or command and control.

The military security required to prevent enemy exploitation of intercepted signals is easily accomplished by encoding digital signals.

Several companies are known to be active in dtv:

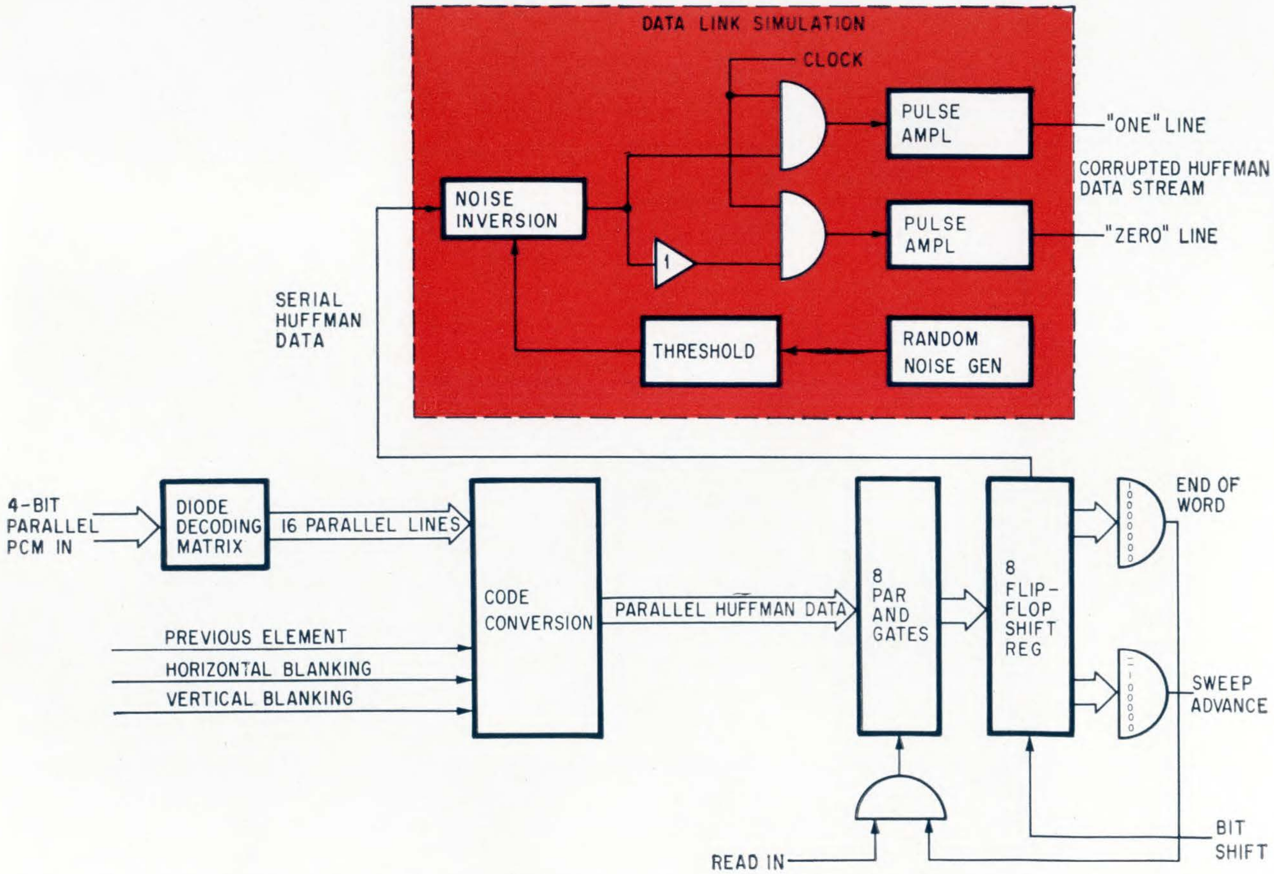
- The Ball Brothers Research Corp.—The Digilink system, said to be in operation by government agencies, uses an analog-to-digital converter to change a video signal into a binary pulse train using a modified delta modulation system. Commercial color tv can be transmitted with good quality using a rate of 30 megabits. Biternary transmission bandwidth is 7.5 megacycles.
- The Philco Corp.—Favoring delta modulation, this company has suggested a number of techniques, including a two-bit modulation system that allows two positive and two negative step sizes, giving small steps for gradual change and larger steps for rapid change. Five-megacycle video is sampled at 10 megabits with two-bit precision, resulting in 20-megabit rate.
- The Radio Corp. of America—Analog color television signals are converted to binary digital signals, scrambled in an encoder, transmitted and reconverted to analog for normal display. A bandwidth compressor reduces channel requirements to 10 megacycles. The system is compatible with National Television System Committee standards.
- The Raytheon Co.—A delta-square modulation system is used to produce fair pictures at sample rates as low as 7 megacycles although the system is designed for 10 megacycles. The system is compatible with current studio equipment and tv channels. Voice information is interspersed between normal synchronizing pulses.

previous neighboring element. However, each black spot represents a picture element in the original picture that is like its previous neighbor. Thus, the large amount of black area at the right provides a concept of the amount of picture redundancy.

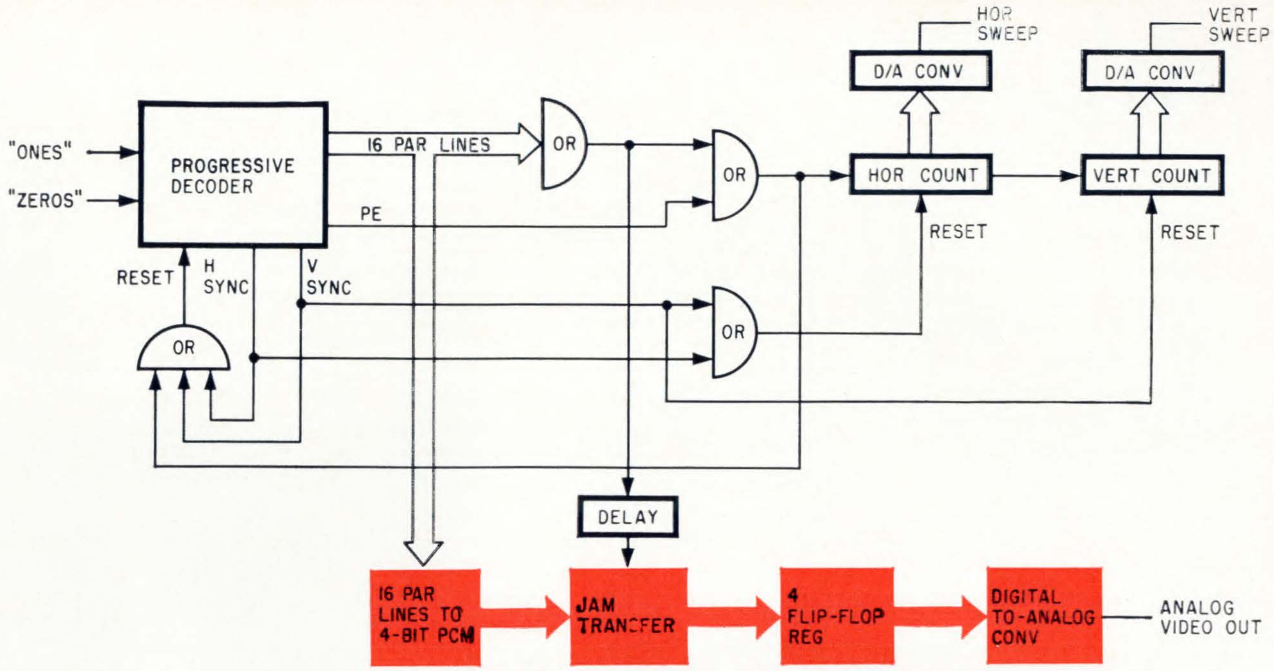
If first-order statistics are taken at point B [diagram on p. 78], a histogram similar to the previous one will be obtained. This histogram is markedly nonflat and its entropy is not only less than three bits, but is also less than the entropy of the one above it. This operation of pe encoding essentially takes 70% or 80% of the events in the first histogram and stacks them into the pe column of the second histogram.

The pe operation has reduced the statistical entropy of the original tv source by taking into account horizontal picture correlations one picture element apart. The reduction of statistical entropy by reversible processes (original picture is completely defined by the pe and non-pe signals) is true compression of the original source. At this point the battle is only half won. The statistical entropy given by the first equation must be realized by coding the pe and non-pe signals with an efficient code, such that the coded entropy H_c—or average code-word length—given by

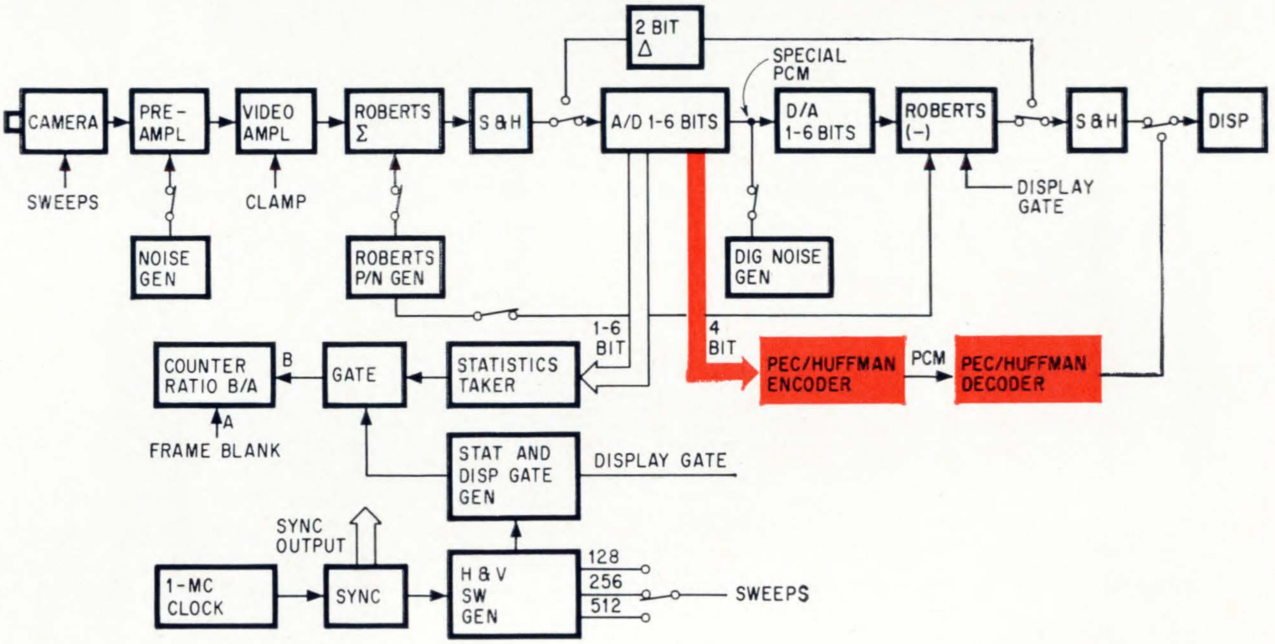
$$H_c = \sum_{i=1}^{n} P_i \, l_i$$



Huffman encoder accepts four-bit pulse code modulation data, previous element signal and horizontal and vertical blanking. The serial Huffman code is routed through a simulated noisy data link shown in color.



Huffman decoder operates a display system (in color) besides performing its basic function.



Experimental digital television system is used to investigate digital tv and compression techniques. Basic Huffman elements are in color.

is minimized. The length of the i^{th} code word is l_i, whose probability of occurrence is p_i. A coding system that accomplishes this effect was discovered by D. A. Huffman. It is based on a decision to assign the shorter code words to the more probable signals, reducing the average word length. It also has the convenient prefix property such that, since no short code word is a prefix of a longer one, no code word synchronization bits are required to separate code words in the Huffman stream.

Basically, the Huffman coding scheme consists of ranking the messages to be sent in order of decreasing probability of occurrence. The two least probable messages are coded with either a 1 or 0. Then there is a grouping of the probabilities of the coded messages. Finally, the messages are reranked in a new sequence following an order of decreasing probabilities. This procedure is continued until the probability of the last grouping equals unity.

The basic pe coder is shown on page 82. This device accepts data from the analog-to-digital encoder in the form of four-bit parallel pcm words. The data is stored for one element time in the pe encoder and is then compared with the present element as generated by the analog-digital (a/d) encoder. A digital comparator circuit decides whether the present element is identical to the previous element. If so, the pe line is set to go.

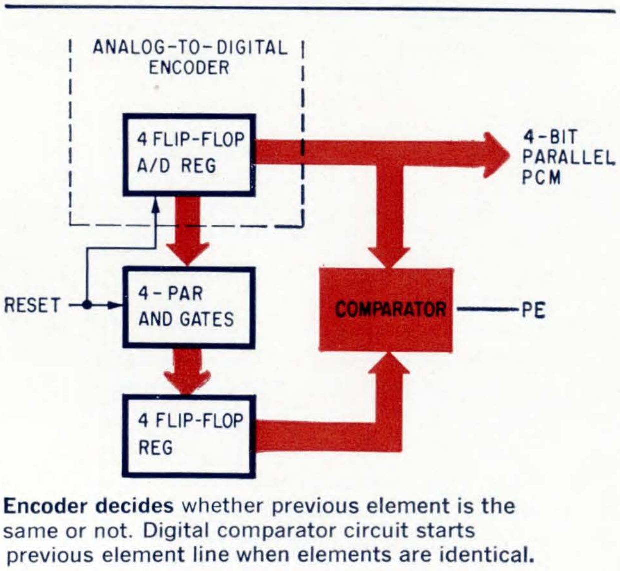
Huffman encoder

Into the Huffman encoder (p. 80) are fed the four-bit pcm data, the previous element signal, horizontal blanking and vertical blanking. This data is converted into the Huffman code shown in the table. The proper Huffman code word, with an extra one bit tacked on the end, is shifted in parallel into an eight flip-flop shift register by the joint occurrence of a read-in pulse from the system synchronizer and an end-of-word signal from the encoder. This modified Huffman word is necessary for housekeeping in the shift register. An AND gate that recognizes the occurrence of a logical one in the last flip-flop and logical zeros in the other seven flip-flops generates the end-of-word command.

If the extra one were not added, it would be more difficult to locate the end of the Huffman word. A similar gate can be used to detect the occurrence of a one in the third flip-flop and zeros in the fourth through eighth stages. This would signal the impending end of a word and could be used to initiate the sweep advance to generate the next element for completely asynchronous operation. The serial Huffman code word is then shifted out of the register and passed through a simulated noisy data link. This data link has provisions for generating accurately known error rates to allow evaluation of their effect on the compressed data.

PE	1	PE	1 1
1	0 1 1 1 1	1	0 1 1 1 1 1
2	0 1 1 1 0	2	0 1 1 1 0 1
3	0 1 1 0 1	3	0 1 1 0 1 1
4	0 1 1 0 0	4	0 1 1 0 0 1
5	0 1 0 1 1	5	0 1 0 1 1 1
6	0 1 0 1 0	6	0 1 0 1 0 1
7	0 1 0 0 1	7	0 1 0 0 1 1
8	0 1 0 0 0	8	0 1 0 0 0 1
9	0 0 1 1 1	9	0 0 1 1 1 1
10	0 0 1 1 0	10	0 0 1 1 0 1
11	0 0 1 0 1	11	0 0 1 0 1 1
12	0 0 1 0 0	12	0 0 1 0 0 1
13	0 0 0 1 1	13	0 0 0 1 1 1
14	0 0 0 1 0	14	0 0 0 1 0 1
15	0 0 0 0 1	15	0 0 0 0 1 1
16	0 0 0 0 0 1	16	0 0 0 0 0 1 1
VS	0 0 0 0 0 0 1	VS	0 0 0 0 0 0 1 1
HS	0 0 0 0 0 0 0	HS	0 0 0 0 0 0 0 1

Huffman code (left) assigns shortest digital word to most probable event. Modified code (right) is necessary for digital housekeeping.



Encoder decides whether previous element is the same or not. Digital comparator circuit starts previous element line when elements are identical.

Buffer storage

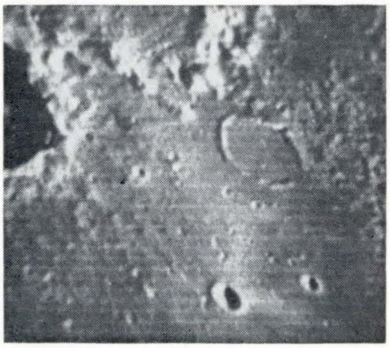
A practical compression system requires some type of buffer storage because it receives and sends information at different rates. In this system, a variable number of bits are transmitted for each element. A buffer store capable of smoothing the transmitted data rate would be large and complex. Thus, asynchronous operation of the camera is highly desirable. It allows the data to be transmitted at a uniform rate and new information is generated by the camera upon command of the Huffman encoder. A digitally scanned vidicon is capable of asynchronous operation. The frame rate has a little jitter but in most cases, especially single-frame transmission, this is completely unnoticable.

Huffman decoder

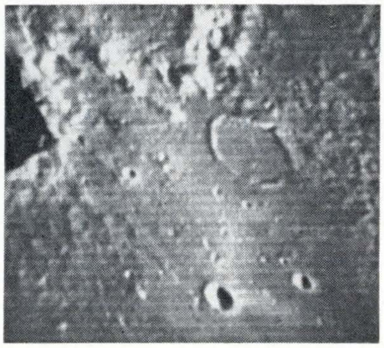
The decoder (p. 81) accepts the serial Huffman data from the encoder on two parallel lines. There is a pulse on the one line for a logical one and a pulse on the zero line for a logical zero. This is necessary because in the experimental implementation the serial Huffman code gallops; that is, the words, formed every 10 microseconds, may be as short as 1 μsec or as long as 7 μsec. In practice, this galloping is prevented by using a buffer store or by operating the scanning device asynchronously to provide a nongalloping bit stream to the decoder transmission link. Upon identification of a Huffman word, all flip-flops in a progressive decoder (not shown) are reset to zero state. If the first bit is a one, the decoder recognizes the Huffman code for a pe. This causes the flip-flops to be reset to zero. The process of selection continues until the Huffman code word is decoded. The output consists of 19 lines with a logical one on the line that refers to the decoded word. Sixteen of these lines represent amplitude levels. These are converted into four binary bits by the code-conversion circuit. If the element is not a pe, these four bits are transferred into a flip-flop register, where they are decoded and displayed. During the time the element is decoded the horizontal sweep is advanced. If the decoded word is a pe, the horizontal sweep is advanced and the previously displayed element is again displayed.

The reception of horizontal-synchronization or vertical-synchronization words causes the appropriate sweep counters to be reset. This rudimentary synchronization system is sufficient for low

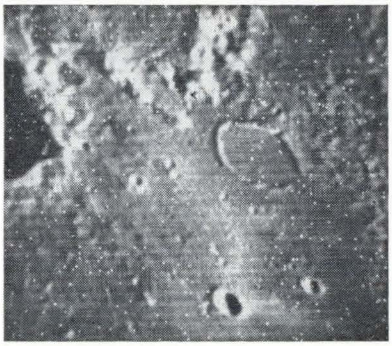
This lunar scene is the picture from which compressed digital television pictures were made. Comparative bit error performance of 16-level pulse code modulation (pcm) and 16-level previous element coding (pec) Huffman systems shows the pictorial difference, but the cost for pulse code modulation is four bits per picture element whereas Huffman previous element coding costs only two bits.



pcm with no errors

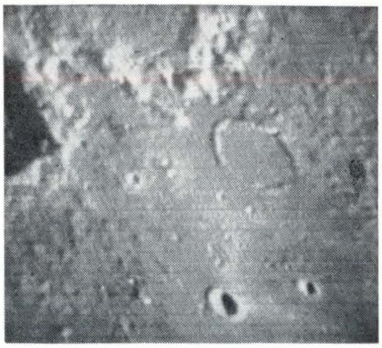


pcm with bit error probability of 10^{-4}



pcm, 10^{-2}

pec with no errors



pec with bit error probability of 10^{-4}

pec, 10^{-2}

error rates. However, at higher error rates there is a high probability that data words will be corrupted into synchronization words, causing the lines and raster to retrace at the wrong time.

An operational system must use pseudo-random sequences for the synchronization words, which is common in pcm telemetry. Synchonization systems have been designed that allow satisfactory operation up to bit error rates of 10^{-2} without an exorbitant increase in the number of bits transmitted.

Experimental equipment

A flexible laboratory tool called Edits (experimental digital television system) has been made to investigate digital television parameters. The equipment on page 81 also acts as a source of analog and digital video signals for the operation and comparison of various compression techniques; it provides the four-bit digital words that are the input to the Huffman encoder. The output from the Huffman decoder is displayed on a modified X-Y oscilloscope where it is photographed. Edits also contains a random noise generator, a variable threshold and a bit-inverter circuit. These circuits allow simulation of a symmetric binary data link and the evaluation of various error rates on the received picture.

A series of half-tone reproductions illustrates the response through the Huffman system compared with pictures received through a conventional four-bit pcm system for various error rates. For photographic purposes, hard wire synchronization of the horizontal and vertical retrace is used. In practice, frame, field and line signals are preceded by moderately long code words to establblish synchronization. Examination of the photographs shows the characteristic salt-and-pepper effect of pcm digital noise. This pattern occurs because a single error in a digital word can cause a change in intensity of up to half-scale in the element in which it occurs without affecting adjoining elements.

Noise in the Huffman pictures shows up as streaks. The streaks are caused by propagation of a digital error over several elements. If an element of level 8 is transmitted and is erroneously received as level 16, the receiver continues displaying succeeding pe's as level 16 instead of the correct level 8 until the next new element is transmitted and received correctly. Because of this streaking, the Huffman system requires approximately an order of magnitude lower error rate than the pcm system for the same quality of received photographs.

The Huffman system transmitted these 16-level digital pictures at an average of approximately two bits per picture element for a compression of approximately two to one. This system compares favorably with certain types of information-destroying compression schemes and has the advantage that it is completely reversible and no information is destroyed.

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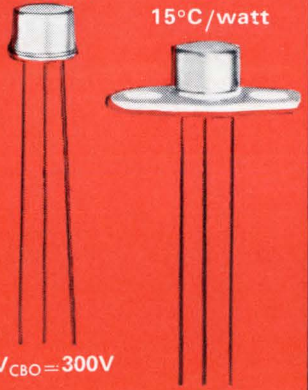
High-Voltage Regulators Inverters • Deflection Circuits • Operational Amplifiers • High-Impedance, Low-Signal Readout Drivers	2N3440 40256 15°C/watt  $V_{CBO}=300V$	 $V_{CEV}=160V$	 $V_{CEV}=160V$

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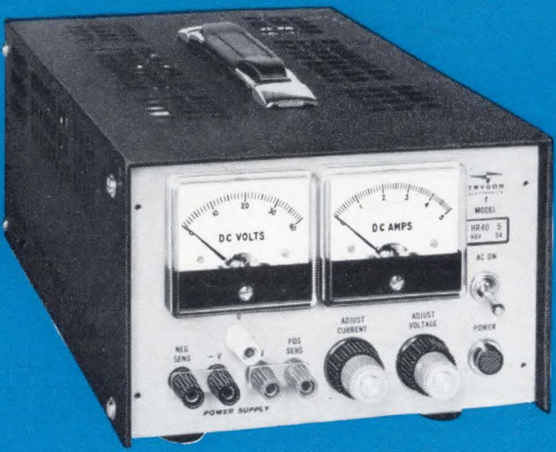

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Radar in bad weather: a beacon or a curse

Used correctly, radar can guide a ship through dense fog. Used incorrectly, it offers only false security

By W. J. Evanzia
Avionics Editor

Norwegian tanker Stolt Dagali flounders off New Jersey after being split in two by the Israeli liner Shalom. The collision occured in fog and heavy seas. The Shalom's captain said his radar was operating.

Early on Nov. 26, the new white-hulled Israeli liner Shalom was steaming down the New Jersey coast for a Thanksgiving cruise of the Caribbean. Fog was thick and the sea was choppy. The radar was operating, according to the Shalom's captain. Suddenly the liner's bow sliced into the side of the Norwegian tanker Stolt Dagali, splitting her in half. The rear section of the tanker sank within minutes and 19 lives were lost.

Seek reasons. With radar presumably guiding the Shalom through the fog, how could the accident have occurred? Isn't radar good enough? Or is it being used incorrectly?

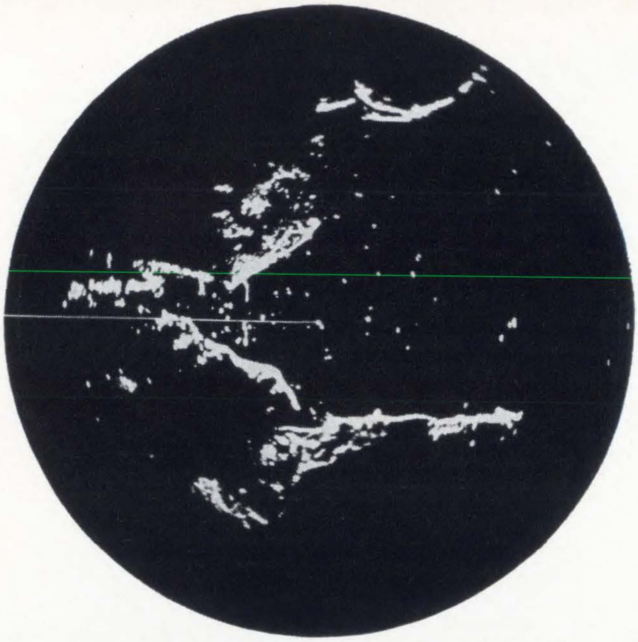
While declining to comment on this collision, spokesmen for both the Navy and Coast Guard say human error plays a significant role in most ship collisions. They concede, however, that certain weather conditions restrict radar's effectiveness. But they add quickly that proper interpretation of a radar signal, even in bad weather, generally tends to offset these restrictions—but only up to a point.

I. Radar on the ships

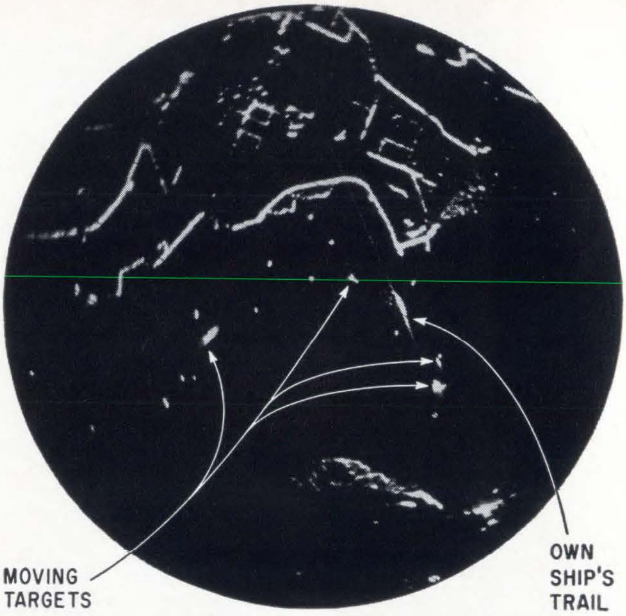
The Shalom carries two radar sets, both three-centimeter instruments made by Decca Radar, Ltd., of England.

The Stolt Dagali, whose captain declined to say whether his radar was operating at the time of the crash, carries a 10-centimeter radar made by the Raytheon Co.

In the past two years, the Coast Guard has investigated 44 major ship collisions; 25 of these occurred



Radar scope's-eye view of ship entering mouth of river. This relative-motion presentation offers viewer scene he would see if he were standing on bow of ship.



True-motion radar presentation offers the observer a bird's-eye view as if from above the ship. In this case the ship and all targets move across the screen. Light trails indicate moving targets.

during poor visibility. In every case, the Coast Guard says, one or both ships involved carried good radar equipment.

Makers of radar equipment don't agree as to which frequency is best for marine applications. For example, 3-centimeter radar is more affected by bad weather than 10-centimeter radar; but 3-centimeter radar gives sharper pictures of targets. However, producers say their new instruments have overcome these limitations.

Best display. Also, users of radar aren't in agreement on the best kind of presentation. In general, the choice is between true-motion and relative-motion displays. Most deck officers are used to observing situations on a relative scale, because the situation is the same as in visual sightings, where bearings are made in relation to the bow of the ship. In a relative-motion presentation, the ship's image remains in the center of the radar screen and the targets appear as short-lived blips at various distances. To determine the course and speed of the target, the radar viewer must plot a sequence of blips.

In a true-motion radar, on the other hand, the picture on the scope appears as if the viewer were looking down from an airplane. Unlike relative-motion radar, the true-motion screen shows both the tracking and target ships in motion.

The true-motion radar presentation also provides image persistence, in which the image continues on the screen for 15 to 20 seconds; when the sweeper rotates around the screen, the most recent blip is brighter than the last previous blip. In this way an indication of target motion is introduced.

II. Shalom's equipment

The Shalom's radar—called the TM-969 and one of the most sophisticated produced—is a true-motion radar. The set operates in five modes:

- Relative motion, ship's head-up display. In this mode the ship's bow is 0° and readings are relative to that point.
- Relative motion, stabilized north-up display. In this mode the target bearings are made with respect to true north.
- Off-center relative-motion display. In this mode the display can be shifted from the center of the scope.
- True-motion presentation with log-speed input. In this mode, data on the ship's speed is automatically fed into the display.
- True-motion presentation with manual speed input. In this mode the speed is manually fed into the display.

Redundant units. The operator can switch from one mode to another without adjusting the set. The Shalom's radar installation is so versatile that it is possible to operate the two radars as redundant units. For example, the transmitter of one can be used with the receiver of the other.

The system's minimum range is about 30 yards and the receiver can discriminate between targets 30 yards apart.

The Stolt Dagali's radar is a Raytheon 1402. The display console is a relative-motion type. Most radars of this type have a maximum range of about 40 miles and a minimum range of about 50 yards.

III. Plotting a course.

Most deck officers are accustomed to observing scenes on a relative radar because the scene is the same as in visual sightings from the ship. For example, if a target plot shows that the target is closing on a constant relative bearing, the officer realizes the target is on a collision course with the ship.

However, when rapid target evaluation is needed, true motion has an advantage because the over-all picture of a changing scene can be understood faster without plotting; in this case, less skill is needed.

Storm signals. Weather conditions can combine to make radar nearly useless. Even though a set's minimum range may be 30 yards and its maximum range 60 miles, rough seas, storms and barometric pressure may combine to make close-in detection nearly impossible and long-range detection very difficult.

Changes in barometric pressure, water vapor and temperature alters the atmosphere's index of refraction and causes a change in the radar's horizon.

False targets. Clouds produce echoes that can obscure a target, and choppy seas can give false target indications.

But good training and extensive experience tends to overcome many of these limitations.

There is no requirement that an ocean-going ship carry radar, and many foreign vessels don't have it. Most large United States vessels, however, do have radar installations aboard.

Although the U. S. doesn't require American-flag ships to have radar, it does demand that vessels that have radar must also have certified observers to operate it. Britain has the same rule.

IV. Classes on use of radar

The U. S. Maritime Administration operates radar training schools in New York, San Francisco and New Orleans.

The administration offers two courses: one for certification, and a more advanced course that many shippers urge their men to take.

The one-week certification course gives intensive instruction in the use of all available radar.

The second, more advanced course goes into radar-scope interpretation, collision avoidance, coastal navigation, buoy pick-up and other plotting situations.

Human error. Human error is probably a major reason for collisions. Aside from more and better training, what can be done about it?

Some maritime people suggest automatic control—perfecting the radar to the point where it can guide the ship accurately. Studies in this direction are being undertaken by both Raytheon and Decca. But such a system is still over the horizon.

The major obstacle is technological, and it will probably take years of small advances before such a system can be developed.

Space electronics

Mariner 4 finds its guiding star

After some carefully planned acrobatics in space,
U.S. spaceship seems to be on right track to Mars

To a stargazer on the earth Canopus is the second-brightest star in the night sky, following Sirius.

But to Mariner 4, the United States' spacecraft speeding toward Mars, Canopus is a shimmering needle in a celestial haystack.

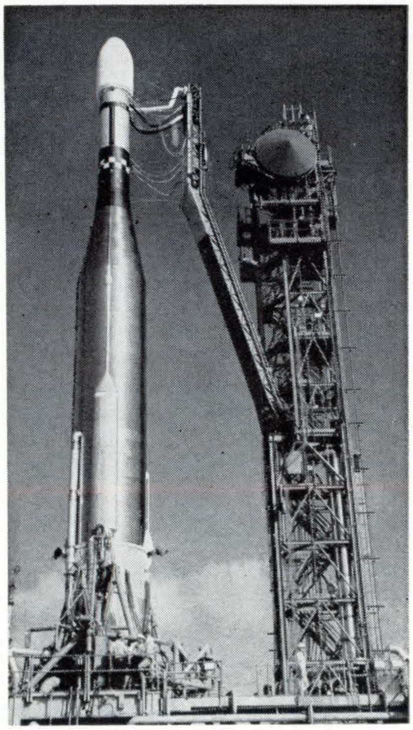
Yet that needle had to be found and grasped electronically if Mariner was to keep its July rendezvous with the Martian outskirts.

Mariner *did* lock onto Canopus, after some carefully planned acrobatics in outer space.

Mariner needed two reference points to establish its trajectory. One, the sun, was easy to find. The other, Canopus, was just a star a little brighter than billions of other heavenly bodies.

I. Problem anticipated

Contrary to early reports, scientists at the Jet Propulsion Laboratory at the University of California, Berkeley, expected a few false starts before Mariner's electronic star-tracker latched onto Canopus' light.



Before launch, Mariner is checked out at Cape Kennedy.

As planned, Mariner quickly locked onto the sun. Then the craft began a 360° roll, and the tracker began to scan the sky for Canopus.

Canopus' approximate light intensity is known, and Mariner's tracker had been calibrated to stop the roll when it encountered any light of about that brilliance.

Four false guides. The sensor first locked onto the star Aldebaran, whose brightness was barely at the fringe of acceptability.

As planned, the sensor let go of Aldebaran and resumed its search. Then it encountered Regulus, reasonably well within the acceptance band. Because of Regulus' position relative to Mariner 4, it would have been abandoned as a guide automatically in about 15 days. However, Mariner would have been far off course by then, so the Jet Propulsion Laboratory broke the lock and reactivated the ship's roll.

Twice again, Mariner erred and locked onto the wrong stars; first Naos and then on a cluster of four stars with strong backlighting. Twice again, earth commands broke the locks and Mariner resumed the search. Finally, on Nov. 30 at 2:59 a.m., Pacific Standard Time, Mariner locked onto Canopus. The spaceship was then 359,850 miles from the earth and traveling 7,400 miles an hour.

The Canopus lock was proven by a small earth-sensor aboard the craft, installed in such a way that it could only see the earth when Mariner was locked onto Canopus. When the sensor was flooded with light from the earth, the control center in California knew Mariner was on the right route to Mars.

II. Tracking the star

The heart of Mariner's star-tracker is the image dissector tube, called Reconotron, manufactured for this probe by the CBS Laboratories in Stamford, Conn., a division of the Columbia Broadcasting System, Inc. Without this device, Mariner would rotate at random on its long axis; this would prevent the transmission of television pictures of the surface of Mars.

The Reconotron's basic components are an optical lens, photo cathode, electron lens, target slot and electron multiplier. The optical lens sees Canopus or another source of light and focuses the image onto the fiber-optics face of the photo cathode. The cathode, excited by the image light, emits an electron stream whose magnitude is proportional to the image intensity.

At the same time, an oscillating potential of 1,000 cycles per second is imposed across the electron lens, and the beam is swept back and forth across the target plate. Only when the beam passes over the target slot does it excite the electron multiplier. The multiplier's output, therefore, is pulsating.

The tracker's circuit was designed and built by the Barnes Engineering Co. of Stamford.

Demodulator. The 1,000-cycle oscillator that drives the electron lens also serves as a reference for a demodulator. The demodulator samples the pulse output of the electron multiplier and compares its frequency with the oscillator's. If the frequencies aren't in phase, the demodulator puts out a positive or negative error signal. If the frequencies are in phase, the output is zero.

Unless the image is centered on the photo cathode so that the undeflected electron beam passes directly through the target slot, the output of the multiplier is a train of uneven pulses, because the swing of the beam to either side of the slot describes unequal arcs.

Under these conditions, the multiplier's output signal is two pulses close together followed by a pause, two more pulses and another pause, and so on. The length of the pause depends on how far the image is off center. The error signal is plus or minus depending on which direction the multiplier pulses are out of phase with the oscillator. This error signal actuates roll-control gas jets to bring the star image to the center of the photo cathode.

Another error signal. The pulsed output from the image-dissector tube is fed into an integrator that measures it against a fixed reference voltage. The integrator produces an error signal proportional to the deviation between the pulsed input and the fixed reference. The error signal also controls a voltage supply that establishes a potential across the electron multiplier in the image-dissector tube.

If the pulses get too high, the multiplier voltage is increased to inhibit electron amplification, thereby reducing the pulse height. This prevents system overload from overly bright objects such as the sun; but more important, the voltage input to the electron multiplier serves as a measure of the brightness of the acquired star. The voltage level relative to Canopus' brilliance was established as the signal for the craft to stop its search roll and to lock onto a star.

Mariner's star-tracker weighs five pounds, compared with the seven-pound earth tracker used in previous Mariner shots. The star-tracker system requires 1.5 watts compared with 7.0 watts. It has no moving parts, and uses 24 transistors instead of 55.

G. W. Meisenholder, engineering group supervisor of the JPL's Guidance and Control division, says "The electronics of the system are only about four times as complicated as a pocket transistor radio."

Go-it-alone circuits advocated for Apollo spaceship's computer

MIT lab says exhaustive testing can select units so reliable that redundancy won't be necessary

Scientists at the Massachusetts Institute of Technology are putting their money on integrated circuits —but the way they've stacked the cards, they don't consider it a gamble.

They're building a computer to operate the guidance and navigation functions of the three-man Apollo moon probe. They are so sure of the computer's reliability that the design doesn't provide for redundancy or for mid-flight repairs.

Their reasoning: Once you get integrated circuits that are good, they'll keep on working fine; the only trouble is in getting perfect integrated circuits for the instrument in the first place.

I. Inferior circuits

A team at MIT's instrumentation laboratory has been examining standard planar integrated circuits, and has come up with this conclusion: Manufacturers' quality control, in many instances, leaves much to be desired [Electronics, Nov. 30, p. 17].

To try for perfect integrated circuits, the team set up elaborate screening techniques to weed out inferior circuits. The results of the investigation were reported last month at a conference in Washington.

Good integrated circuits offer excellent reliability, the MIT scientists said. And the best and cheapest way to maintain that reliability is to use standardized circuits—in this case a three-input NOR gate. In this way, the circuits can be bought in volume and tested in large numbers, and the production methods can be perfected to the point where reliability can be predicted with high confidence.

II. Expanding the computer's role

The MIT team—Eldon C. Hall, deputy associate director of the lab; L. David Hanley, assistant director; and Mrs. Jayne Partridge, a staff engineer—gave the system such a favorable report that the National Aeronautics and Space Administration expanded the role of the computer for Apollo. Now, it will handle not only navigation and guidance, but also stabilization and control. However, in the remote chance that the computer does fail, the Apollo team will be able to turn to the semiautomatic

Modes of failure for integrated circuits

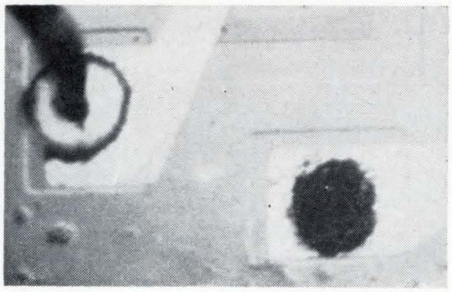


Fig. 1 "Purple plague"—an open bond caused by a gold-aluminum formation

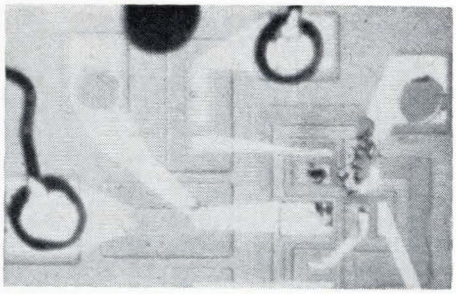


Fig. 2 Poor aluminum adhesion to the silicon dioxide

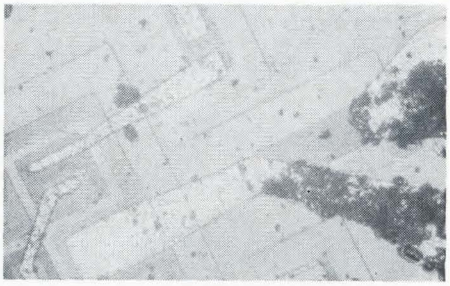


Fig. 4 Corrosion on aluminum conductors causes early failure

Fig. 5 Melting and an open at a scratch. Corrosion is suspected

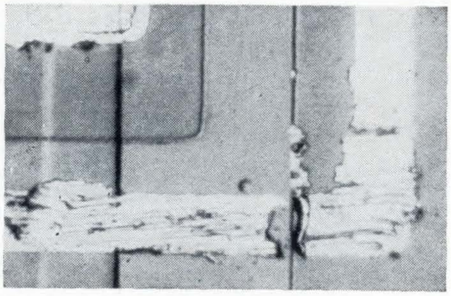


Fig. 7 An open at a scratch over an oxide step, caused by aluminum melting

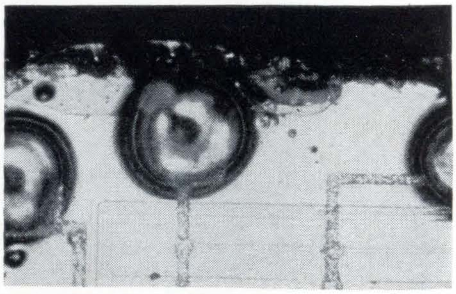


Fig. 8 Excessive chipping and breaking, which exposes raw silicon

and manual system for stabilization and control.

The reliability approach, considered by the MIT group to be particularly appropriate for computers, had its beginning in the Polaris computer program, which was also directed by the MIT lab. In that program, circuits were standardized, but the discrete components used were not put through as exhaustive a screening process.

Hard to sell. "The standardization approach to reliability," says Hall, "is the conservative approach, and it is also one that is hard to sell to engineers. They prefer exotic circuits and variety."

The first design of the computer called for using planar integrated circuits in TO-47 cans, and the competition narrowed down to three vendors. Some of these computers have already been delivered for various Apollo tests. The MIT

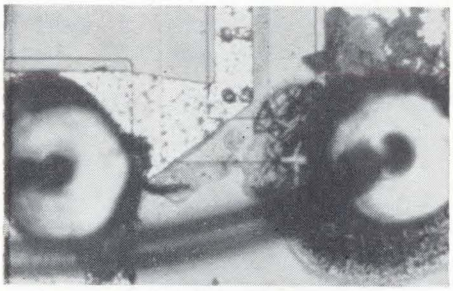


Fig. 3 Example of overbonding that causes failure of circuit

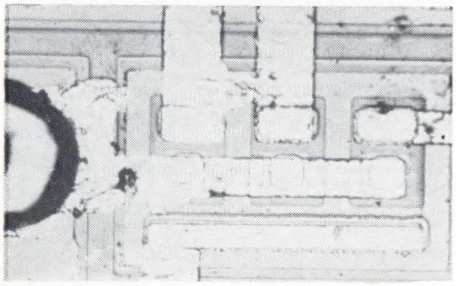


Fig. 6 Shorting due to aluminum scratching and smearing

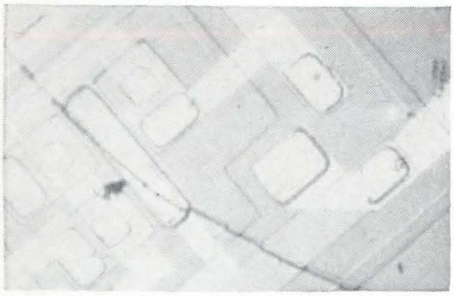


Fig. 9 Chip cracking that caused circuit to fail

team's confidence on integrated circuits was based on the performance of some 200,000 of these circuits. And, added Hall, it became clear that a healthy sprinkling of competitive spirit is necessary for attaining better circuits.

Dual-gate design. In the next stage of the computer's design, which is close to prototype production, the team is working with six companies. And the design has shifted to standardized dual-gate circuits in a single flatpack [Electronics, June 15, p. 25].

In the first stage, the computer was in series with the stabilization and control subsystem; a failure in one would incapacitate the other. But in the second design, the two systems were made independent of each other.

Both the Polaris flight computer and the Apollo computer use the three-input NOR gate as the only logic element. All logic functions are generated by interconnecting this single logic circuit, with no additional logic blocks, resistors or capacitors.

Failures found fast. The three-input NOR gate for Apollo operates at 3 volts and 15 milliwatts, but is rated at 8 volts and 100 milliwatts. Unpowered temperature rating is 150°C. The basic simplicity aids the screening process and provides for quick detection and diagnosing of failures without extensive probing.

The standardization approach depends on detection of failure modes and eliminating or minimizing the failures.

III. The art of production

All the failure modes are "the result of poor process control or the vendor's lack of complete technical knowledge of his process," says the MIT team. "Most problems are quality-control problems," according to Hall. Mrs. Partridge adds: "There is no substitute for good, tight inspection on the line. Sure, the fabrication of these circuits is an art, but so is the whole business of producing semiconductor devices."

Several failure modes have been detected by the team.

▪ An open bond caused by a gold-aluminum formation, commonly called "purple plague," is shown in figure 1. It has been traced back in most cases to uncontrolled bonding procedures. The failures may be triggered by mechanical shock, thermal shock, acceleration or vibration testing.

▪ Open bonds, due to poor aluminum adhesion to the silicon dioxide, are shown in figure 2. These have been found to be triggered in every case by mechanical stresses. The same is true of open bonds that result from underbonding.

▪ The only example found so far of an electrically open bond attributed to overbonding—that is, either excessive temperature, pressure or both—is shown in figure 3. It was detected after baking at 150°C for 168 hours, and it is thought that baking may have contributed to the electrical failure.

▪ Failures in figures 4, 5 and 7 are opens in aluminum interconnections. Figure 4 is an example of early failures. But electrical opens have occurred after more than 6,000 hours of operation at high temperatures. Scratches contribute to such failures, but the main cause of failure is faulty wash-and-dry techniques. In Figure 5, the failure occurred after long operation at room temperature. It is suspected that localized heating accelerated a corrosion mechanism, which in turn generated more local heating as the resistance increased. Figure 7 indicates that scratches contribute to opens even when the corrosion phenomenon is not observed.

▪ Other failure modes include bulk shorts due to secondary breakdown or to uncontrolled pnpn switching, shorting caused by scratching of the chip surface (figure 6) and shorts from the aluminum interconnection to the silicon through the silicon dioxide. This last one is attributed to the poor dielectric strength of the silicon dioxide.

Expose raw silicon. Shorts have been created during parameter testing because of poor pattern layout and bonds made too close to an oxide edge on the surface of the chip. Figure 8 shows an example of excessive chipping and breaking, which exposes raw silicon.

Failure due to cracks in the silicon die, attributable to strains set up during attachment of the die, is shown in figure 9.

Many types of shorts have been caused by internal lead wires and

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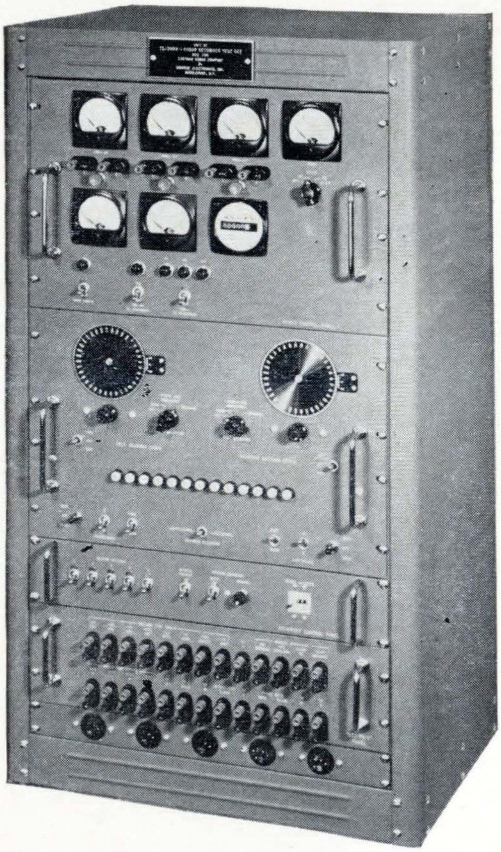

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the method of making contact from the aluminum pads on the chip surface to the posts of the package.

IV. Method of testing

Tests, under use conditions, were conducted on 20,000 to 60,000 units per vendor. This established a continuous vendor-qualification procedure. Vendors were rated with respect to the number of failure modes, frequency, relative seriousness and how rapidly a vendor cure failure causes.

The table below compares the results of circuits provided by three vendors described only as A, B and C. The names of the companies weren't disclosed. Vendor C is no longer a supplier.

Three classes of tests. The tests are divided into three sections:

- Prequalification involves a relatively small sampling in which failures are weeded out by a combination of mechanical, thermal and power stressing. This includes visual inspection and studies of electrical characteristics.
- Screen and burn-in tests, involving all the circuits include baking, spinning in a centrifuge and operating at room temperature; these are called the second and third electrical tests. Total fallout—a part of the screen and burn-in test—includes visual and electrical inspection, lead stressing and pressure checks.
- Extended life test at use conditions. In this case, the failure rate was determined with samples of 6,000 to 18,000 for each vendor. The MIT team noted that the three vendors maintained their respective positions throughout the entire evaluation.

VENDOR	PRE QUALIFICATION % FAILURES	SCREEN & BURN-IN % FAILURES		FAILURE RATES AT USE CONDITIONS 90% CONFIDENCE
		TOTAL	2nd AND 3rd ELECTRICAL	
A	5	1.8	0.3	$0.005\%/10^3$ HRS (0 FAILURES)
B	26	3.8	1.7	$0.3\%/10^3$ HRS (2 FAILURES)
C	58	5.0	2.5	$1.8\%/10^3$ HRS (26 FAILURES)

Results of exhaustive tests of integrated circuits by a Massachusetts Institute of Technology team. Sample checks were made for the prequalification and use-condition parts of the examination, but all circuits were tested for the screen and burn-in section.

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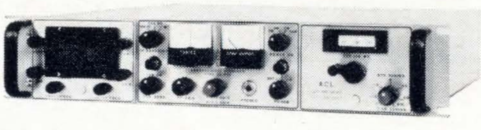

SR-209 Surveillance Receiving System

TR-104 Telemetry Receiving System

□ Or take another member of the family—the TR-104 Telemetry Receiving System. This one receives all standard IRIG signal formats in the 55-2300 mc range with 8 plug-in RF heads. Ten IF bandwidths are available (10 kc to 3.3 mc) and 4 IF bandwidth amplifiers and matching demodulators may be installed at one time, switchable from the front panel. Just 5¼" high, the unit requires a maximum of 35 watts and may be battery-operated in the field.

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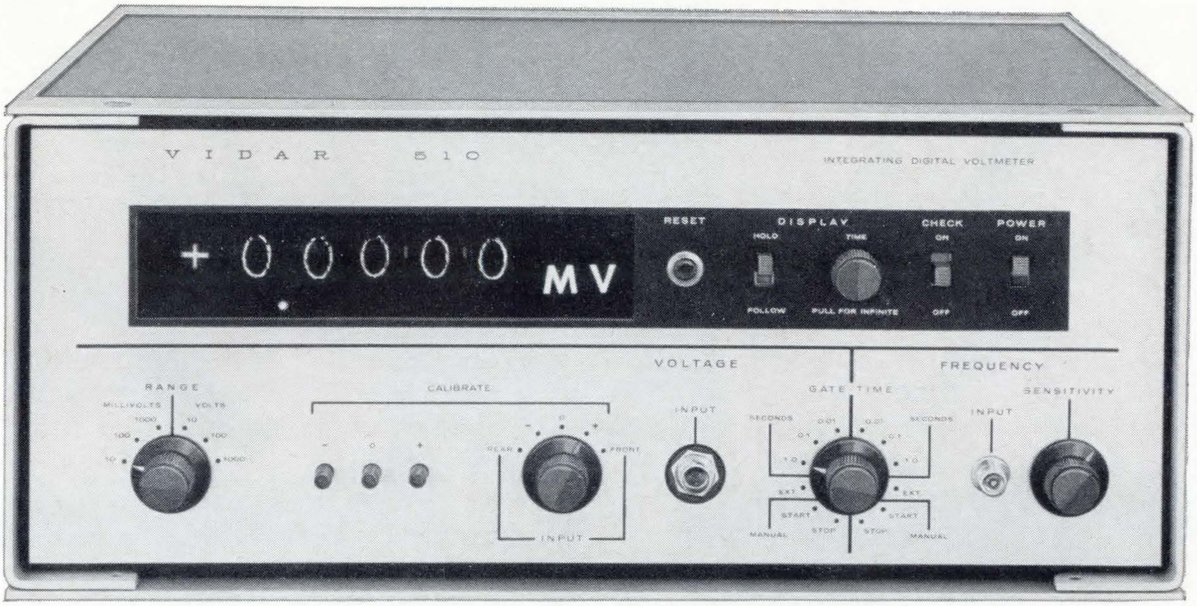

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Frequency counter directly measures to 6.4 Gc

Accurate readings can be obtained by nontechnical personnel in laboratories and testing departments

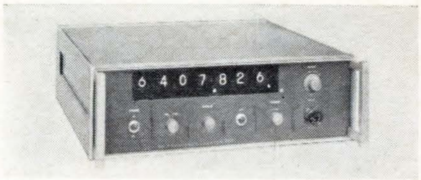
Measurement of frequencies from 0 to 6.4 Gc with high accuracy has been simplified by the model 950 direct frequency counter which presents a number of advantages. For instance, the operator need have no knowledge of the frequency to be measured prior to making the test. And the answer appears on the numerical readout tubes almost instantaneously while binary printout signals in the 1-2-4-8 code are made available automatically for record keeping or computer input. To achieve the same results with a transfer oscillator instrument, the operator must know the approximate frequency to be measured to select the proper harmonic. But when the answer is read out on the dials, it must be manually translated to the records or computer input. Both steps may lead to errors.

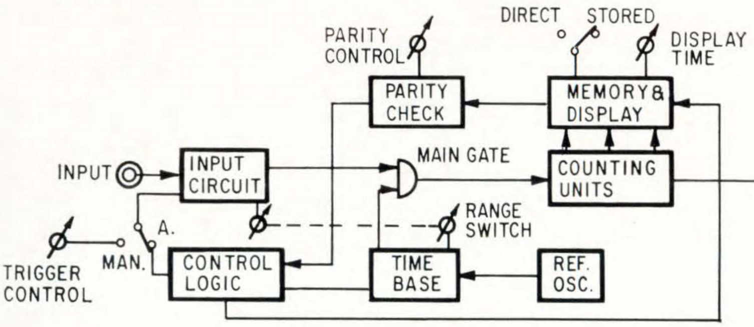
Conventional counters for the measurement of frequencies above 100 Mc usually require one of the following frequency mixing techniques: a heterodyne system must be tuned to a beat frequency that can be measured; or a transfer oscillator and a null detector where a harmonic of the oscillator is tuned to zero or constant frequency difference with the unknown. With the model 950, the manufacturer says that tuning and all ambiguities are eliminated, accuracy is improved, and calculations previously required are no longer necessary.

Some of the applications for the instrument include direct readings from, and stabilization of, high-frequency transmitters, receivers and oscillators; calibration of laboratory instruments; and high-frequency stability measurements.

The makers claim that in production testing of klystrons with the model 950 measurement time is practically zero and the answer is reliable. Drift can be monitored at specified periods. Since the instrument can be manually, remotely or automatically reset at a recycle rate of 0.2 to 15 sec, the operator need never touch the instrument for any of these tests in an automated system. With the transfer-oscillator method, if the operator selects, for example, a harmonic to measure a 4 Gc frequency when it is actually 2 Gc, a null may still be obtained and that produces a wrong answer. Also, with the transfer-oscillator method automation is not feasible.

Because the frequency range covered is so broad, the manufacturer believes this one instrument can replace a number of other frequency-measuring instruments with a limited range. The accuracy up to reference-oscillator stability is restricted only by the number of digits in the readout display, so that the 7-digit standard unit reads to 1 part in 10^7 or to the nearest 1 kc on the 6.4 Gc range. A 9-digit instrument is being planned for production at a later date.





As shown in the block diagram, additional features of the instrument aid in automatic operation and assure correct results. The model 950 circuitry contains a digital parity check in which the readings are monitored and the inconsistent ones are rejected. If a correct number does not appear, the counter displays only zeros. Thus, spurious signals caused by noise or too low an input-signal level cannot affect the reading.

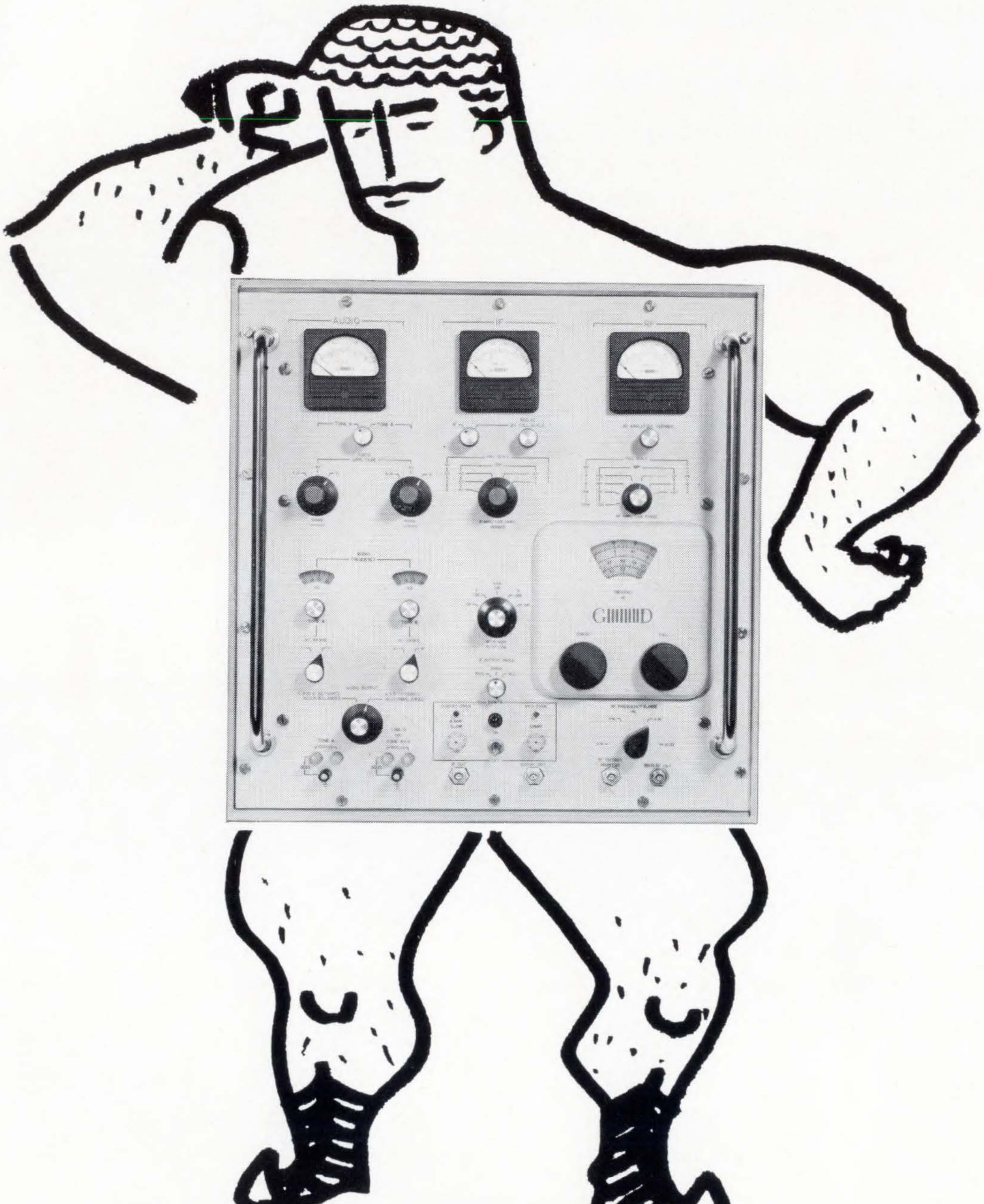
The tunnel-diode input circuitry has two modes of operation. In the automatic mode, the trigger level adjust itself to the input-signal variations. Where there are noise or other problems, a manual triggering adjustment is available. Typical input sensitivity is 50 mv; this varies slightly with frequency.

The basic unit covers from audio up through S and G microwave bands. Heterodyne frequency extenders increase the frequency capability without tuning. Model 680 more than covers X-band, 6.0 to 12.4 Gc, and model 681 covers up to the K-band, 12 to 18.4 Gc.

Solid-state circuitry is used throughout. Weight is 35 lb, and the size is 5¼ in. by 17¼ in. by 16¾ in.

The basic model 950 instrument costs $5,925 and is available in 90 days; the frequency extenders cost $1,525 each and availability is 120 days.

Eldorado Electronics, 601 Chalomar Road, Concord, Calif.
Circle **301** reader service card



Wedge-action subminiature relay

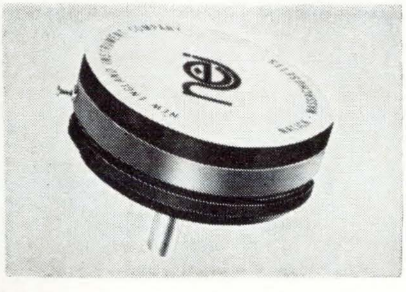
A 2pdt electromechanical relay, housed in a cylindrical case and weighing only 1½ oz, has been introduced. The wedge action design of series 400 results in extremely low contact resistance, large wiping action and high contact pressure that increases during overtravel. Essentially, wedge action employs the principle of a plunger-type solenoid to actuate the moving contacts. Each of the fully supported movable contacts is positioned between two rigidly mounted stationary contacts. Movement of the actuator, in either the energizing or de-energizing direction, is translated into a wedging action of the moving contact against the fixed contact ramp. The series 400 eliminates critical control problems in dry or power circuit applications. It meets all specifications per MIL-R-5757/8. Measuring only 0.645 in. max in diameter and $1\frac{25}{32}$ in. high over-all, the relays are hermetically sealed, operate over temperatures from $-65°C$ to $+125°C$, withstand shocks of 50 g for 11 ±1 millisec, and vibration of 15 g from 10 to 2,000 cps. Units are available in either pin or hook type base with standard 2-hole mounting flange.

Electro-Tec Corp., Relay Division, P.O. Box 667, Ormond Beach, Fla. [311]

Thin potentiometer of conductive plastic

The Waferpot is said to be the industry's slimmest conductive plastic pot. The basic single-cup unit is only 0.5 in. deep. Each additional cup adds only 0.180 in. in depth. Waferpot meets the 100-ohm noise spec now written for wirewound potentiometers. It withstands 10-day MIL-R-12934 humidity cycling tests with a resistance change of less than 2%. Temperature coefficient is ±200 parts/million/°C for most resistance values. Resolution is essentially infinite, and operating life is 10 million revolutions. The Waferpot line includes standard diameters of $1\frac{1}{16}$ in., $1\frac{7}{16}$ in. and 2 in. Resistance values from 1,000 to 20,000 ohms are standard. Special electrical and mechanical requirements can be met for virtually all parameters.

New England Instrument Co., Kendall Lane, Natick, Mass. [312]



Circular connector is subminiature

The Centi-K connector retains crimp, snap-in contacts spaced on 0.100-in. centers, in a rear-release system. The connector is designed to meet the applicable performance requirements of MIL-C-26482C (Navy). The contact design is based on the Micropin contact. The pin is a twisted cable recessed in an insulator cavity for mechanical protection. The tubular socket is

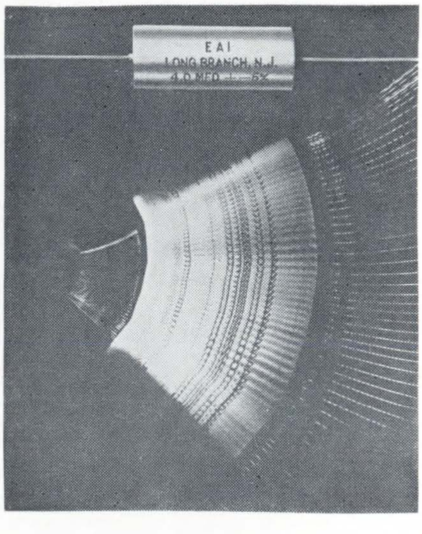
New Components

exposed, and when it enters the chamfered pin cavity, another chamfer on the socket gathers the tip of the flexible pin to assure positive alignment. The contacts accept 22-Awg wire acceptable under MIL-E-5400 and are crimped using a MS3191 crimp tool with a special locator. The contacts are inserted, and released and extracted all from the rear of the connector. To extract a contact, a simple tool is inserted in the rear of the contact cavity and releases plastic retainer cones to permit the contact and wire to be pulled out easily. The housing hardware is lightweight aluminum which, together with the 0.100 in. center-to-center spacing, comprises a connector that is 50% lighter than a MIL-C-26482 type with the same number of contacts.

ITT Cannon Electric Inc., 3208 Humboldt St., Los Angeles 31, Calif. **[313]**

Shockproof capacitors for aerospace use

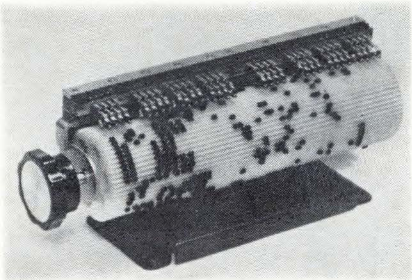
A new line of capacitors has been designed to meet the most stringent shock and vibration specifications imposed by the aerospace industry. Designated as the g-Line, and shown undergoing simulated vibration test, these capacitors are said to feature outstanding physical characteristics without the use of potting compounds or encapsulants. Optimum electrical performance is obtained since there is no



foreign material in contact with the dielectric. The shockproof line is characterized by a design which enables the center of mass to coincide with the geometric center of gravity. As a result of these features, the capacitors are nonmicrophonic even when subjected to extreme and prolonged shock and vibration. Units are available in standard tubular and rectangular configurations with either axial leads or solder lug terminals. They can also be supplied with plain or metalized plastic film dielectrics.
Electronic Associates, Inc., West Long Branch, N.J. **[314]**

Programing switches are space-savers

Significant space savings are now possible with the miniature Actan programing switches. The switches are completely field-adjustable without tools, and may be set up in either point-to-point or multiple cam modes. They are widely used for scanning, sequencing, cycling, code generation, timing and programing. Actan programing switches are available with drum positions, or discrete programs,



from 16 on a ⅝-in. diameter drum to 240 on a 9-in. diameter drum. Precise, high density contact arrays make it possible to control 17 circuits in a length under 4 in., with relative space savings in models controlling up to 51 circuits.
Sealectro Corp., Mamaroneck, N.Y. **[315]**

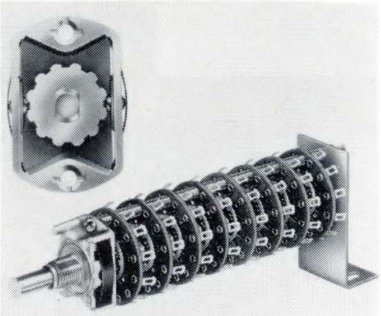
Thermistor sensors in top-hat diode cans

A series of thermistor sensor assemblies combine high power capacity and ease of installation. The

units, designated as SS14, consist of thermistor disks of 0.2 in. or 0.4 in. diameter fitted in conventional top-hat diode cans, provided with threaded mounting studs. This design permits the sensors to be quickly and easily installed and assures good thermal contact with any surface. The sensors are designed for a wide range of applications including surface temperature sensing, indication or control. Another important field of applications is temperature compensation in a wide variety of electronic and transistor circuits. The excellent thermal heat sink characteristics provided when these top-hat sensors are installed on metal surfaces extend the power range of the thermistor disks which are available with nominal resistances at 25°C of 25 ohms to 5,000 ohms.
Victory Engineering Corp., Springfield, N.J. **[316]**

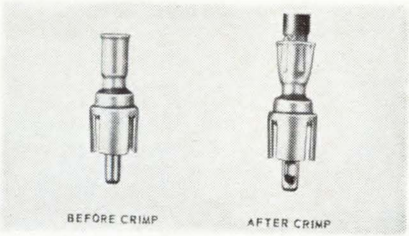
Universal index for rotary switches

A universal index, adaptable to rotary switches, has been announced. The Unidex assures consistently smooth torque (or feel) for the long life of the switch through use of a balanced dual ball and spring index system. Tests indicate it surpasses conventional indexes by many thousands of operations. In addition to durability, the Unidex is simple in design. The housing is a single casting made of a rugged zinc alloy fitted with simple, sturdy parts, which contribute to the high level of reliability of the indexing



mechanism in the unit. The housing of the mechanism largely shields it from dust and other contaminants. Unidex is immediately available in series F, JKN, and H switches. Cost for a single section switch in quantity is as low as 53 cents each.

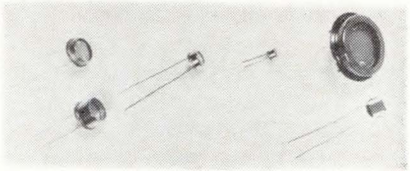
Oak Mfg. Co., division of Oak Electronetics Corp., Crystal Lake, Ill. 60014. [317]



Crimp-type phono plug

A new crimp-type phono plug has been designed especially for low-cost, high-production application. The phono plug is of one piece and is available in three sizes covering the most popular diameters of shielded cable. All three sizes are available in 9/16 in. or 31/64 in. pin lengths. The units will fit any standard phono socket. The phono plugs are priced as low as 1¾ cents each in 100,000 quantity.

Cinch Mfg. Co., 1026 South Homan Ave., Chicago, Ill. 60624 **[318]**



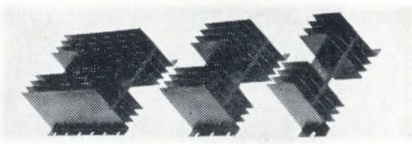
Cadmium-selenide photoconductive cells

A series of cadmium-selenide photoconductive cells is designed for application where fast response (rise and decay) and greater infrared sensitivity are required or desirable. Typical are photoelectric choppers, industrial controls, readout devices, and alarm systems. The cells are available in six sizes designated VT-100 through 600, with resistance characteristics rang-

ing from 700 ohms to 148,000 ohms at 2 footcandles. They are supplied both hermetically sealed and plastic coated. All hermetically sealed units are in a transistor-type enclosure with glass window, welded in an inert atmosphere. The plastic-coated type is a flat, thin wafer with special plastic film that provides exceptional moisture stability. The latter are intended for highly competitive commercial applications that demand low cost as well as long usable life.
Vactec, Inc., 1209-15 Olive Way, St. Louis, Mo. 63130. [319]

Industrial trimmers rated at ¼ w at 60° C

A line of ½-in. square trimmer potentiometers is offered for industrial use. The CT203 series offers a variety of mounting features, including 10-in. long, Teflon-insulated wire leads; printed circuit pins on 0.1-in. grid spacing; bare wire leads on edge, and ¼-in. bushing for panel mounting. The units are wirewound and rated at ¼ w at 60°C. They have the same machined aluminum case, all-metal slip clutch, anti-backlash screw-actuated drive, and many characteristics of the military (MIL-R-27208) version. Price is $3.33 each in lots of 500, up to 10,000 ohms.
International Resistance Co., 401 N. Broad St., Philadelphia, Pa. 19108. [320]



Heat dissipators for semiconductors

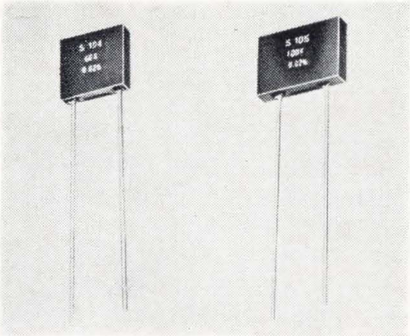
New 2½-in.-high extruded heat dissipators for power transistors and diodes have been introduced. The E-2 series, 3 in. long, has a thermal resistance rating—mounting surface to air, for units spaced 1/16 in. from chassis—of 1.39°C/w in natural convection, and 0.43°C/

w in 1,000 fpm air flow. At 40 w power dissipated, a semiconductor mounted in the E-2 in natural convection records a case temperature rise above ambient of only 70°C with the dissipator in a horizontal position. With the dissipator in vertical position, the same semiconductor recorded a case temperature rise of 63°C. Other lengths, in ½-in. increments, also are available. Standard units are supplied with black anodize finish, mounting notches, and mounting hole pattern. Unplated units with no mounting holes or notches may be ordered, as may special configurations. Also available are units with Insulube 448, the company's insulating finish that provides positive 500-v insulation.

International Electronic Research Corp., 135 W. Magnolia Blvd., Burbank, Calif. [321]

Bulk film resistors with high wattages

Higher wattages than were formerly available are said to be an important feature of two new bulk

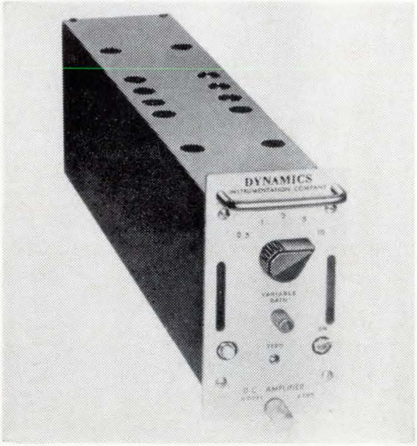


film resistors. Power rating for the new units—types S104 and S105—is 0.5 w and 0.75 w respectively, at 125°C, while temperature coefficient of resistance is 0 ± 5 ppm from −55°C to +125°C, and 0 ± 1 ppm from 0 to 60°C. Standard tolerances are from 1% to as tight as 0.01%. Type S104 is 0.56 in. by 0.53 in. by 0.16 in. and covers a range from 60 ohms to 60,000 ohms. Type S105 is 0.81 in. by 0.53 in. by 0.16 in. with a range extending from 100 ohms to 100,000 ohms. Both units are also available with an epoxy coating.

EMC Technology, Inc., 113-35 Arch St., Philadelphia, Pa. 19107. [322]

New Instruments

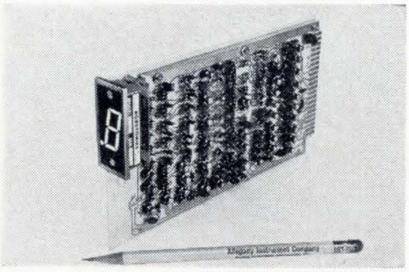
D-c amplifier with 30-kc bandwidth



A single-ended d-c amplifier has been developed for use with low-level transducers and high-frequency galvanometers. The solid-state model 6700 will drive long lines at high signal levels. Gain steps of 0.5, 1, 2, 5 and 10, coupled with a continuously variable multiplier, provide overlapping gain steps up to 25. Since no chopper is used there is no chopper intermodulation. Noise is 15 μv rms, or less, referred to the input in a 30-kc bandwidth. Input impedance is 100,000 ohms at any gain setting, and the instrument will withstand 200 v peak at the input without damage. Overload recovery is less than 1 millisec. Gain stability is ±0.1% of setting for 40 hr after a 30-minute warmup. Output is ±10 v at 100 ma. Output impedance is less than 1 ohm resistive. Capacitive loading up to 0.1 μf will not cause instability. Short circuit of the output will not damage the instrument. Each instrument has an integral power supply with less than 5 pf unguarded leakage capacitance to the power line. Each instrument module is 2⅞ in. wide, 5¼ in. high, 13½ in. deep. Operating environment is 0°C to 50°C; relative humidity, 75% or less; vibration, 0.1 in. peak-to-peak, 10 to 30 cps. Price is $340.

Dynamics Instrumentation Co., 583 Monterey Pass Road, Monterey Park, Calif. **[351]**

Decade counter adds and subtracts

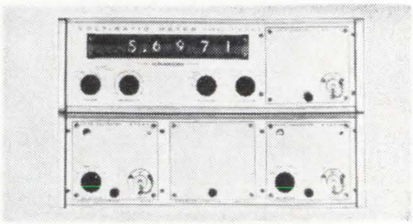


Model F113 decade counter adds and subtracts pulses at rates up to 5 Mc, displaying the difference count. It features silicon epitaxial counting circuitry, silicon controlled rectifiers for lamp control and printed-circuit construction. It is designed for operation over the temperature range from 0 to 65°C. Design provides fast mode reversal and flexible mode control. Counting is by single-line input, using two separate mode control lines. Grounding one of the mode control lines gives continuous add or subtract operation. The F113 mounts on 1-in. centers, and is designed for straight plug-in and removal. It measures 1 in. wide by 4½ in. high by 8½ in. long. Price in small quantities is $310.

Allegany Instrument Co., a division of Textron Electronics, Inc., 1091 Wills Mountain, Cumberland, Md. 21501 **[352]**

Digital system measures resistance

The 7000 series five-digit system provides resistance measurements from 10 μohms to 10 megohms with test currents from 10 ma to 1 μa. Featuring true four-wire sensing, the system may be used with a

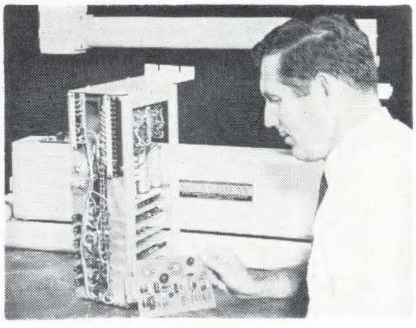


four-wire input scanner and an output recording device for data logging applications. Price range is $3,500 to $6,500.

Cimron Corp., 1152 Morena Blvd., San Diego, Calif. 92110. **[353]**

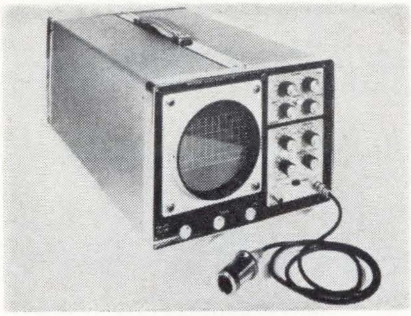
X-ray gage measures thickness of metals

A solid-state Measuray x-ray gage with modular construction measures the thickness of hot or cold metal sheet and bars while the material is moving or stationary. It is equipped with direct numerical readout of material thickness to 0.0001 in. Numerical readout or digital display indicates material thickness as easily as an automobile odometer shows the distance the car has traveled. In addition to indicating thickness, signals supplied by the Measuray gage can be fed into a Measurtrol control system to obtain fully automatic control of screwdown, mill speed and tension. The thickness signals can be used also with high-speed electronic counting, marking and sorting devices. The Measuray gage line covers a gaging range from 0.0005 to 0.5 in. in ferrous and nonferrous metals. The gage measures thickness without contact. Low-intensity x-ray pulses are flashed at the material which passes between the gage's emitter and receiver. The material absorbs x-ray energy according to thickness. The



receiver detects and amplifies the amount of x-ray energy that passes through the material and deviation from the thickness standard used to set the gage is indicated as deviation from nominal size on a meter in percent or millionths of an inch, or by digital display.

The Sheffield Corp., Dayton 1, Ohio. **[354]**



Ultrasonic instrument tests materials

An ultrasonic instrument has been developed for precision measurement of properties, thickness, and flaw detection in a variety of materials. Completely modular in construction, model M-200 incorporates features which make it adaptable to all known requirements for ultrasonic testing of materials. The nominal frequency range is 0.5 Mc to 30 Mc. Ruggedly built, the instrument has high-reliability, solid-state components for automated industrial usage, as well as for portable field application, such as inspection of welds.

Material Measurements, Inc., 7375 Greenbush Ave., North Hollywood, Calif. 91605. **[355]**

Solid-state scope with three-inch crt

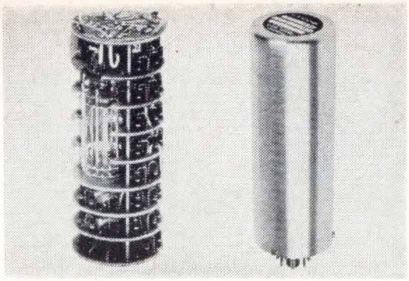
Model S-3 is a three-inch portable oscilloscope that uses 25 transistors and one Nuvistor. It features a flat-face three-inch crt with ruled graticule, d-c to 6 Mc response, calibrated sweep times from 1 millisec/division to 0.5 sec/division in 18 steps, ×5 sweep magnifier, and calibrated vertical attenuator covering from 50 mv per division to 50 v per division in 10 steps. A special feature is a new

positive lock trigger circuit. When in the triggered mode, the trigger slope selector is set, and the trigger level control turned until the trigger occurs at the desired point. There is no sweep stability control, and the sweep must trigger. When in the free run mode, the trace will not tend to synchronize. An external sync input is also provided. The unit weighs only 16 lb and uses less than 15 w of power. It is designed to operate from 120-v 60-cps power.

Imac Corp., 5744 West 77th St., Oak Lawn, Ill. **[356]**

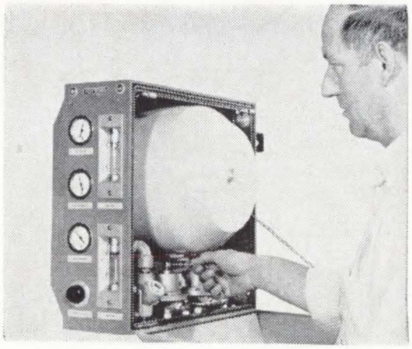
Frequency/time standard generator

A rugged frequency/time standard is announced that uses standardized circuitry to generate any specified frequency from 50 cps to 100 Mc. The ML2000 is suitable for commercial applications such as precision synchronous drives and other equipment which requires a time base for controlling or recording sequences of events. In standard frequencies of 60 cps, 400 cps, 10 kc and 100 kc, stabilities are normally ± 10 by 10^{-6} in the 20° to 50° range. Inputs are 12 or 15 v d-c with optional 6, 24, and 28 v d-c. At turn-on, square wave or sine wave, output is immediately available, eliminating output "buildup". A push-pull output is provided for synchronous drive applications. The frequency/time standard is a



round can 1¾ in. in diameter and 4⅞ in. high. Primary accuracy is set with a trimmer housed in the octal plug-in base and accessible through the center post. For additional shock and vibration resistance, units can be conformally coated.

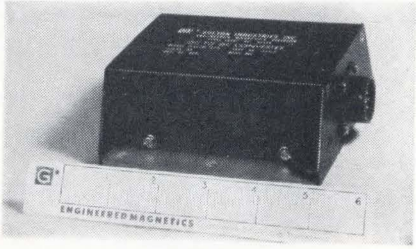
Martin Labs, Inc., 4858 Ridge Road, Cleveland, Ohio 44115. **[357]**



Analyzer measures gas hydrocarbons

A new instrument has been announced that continuously measures the total hydrocarbon content of a gas. It detects trace to percentage amounts of gases containing carbon-to-carbon, carbon-to-hydrogen, or carbon-to-halogen bonds which are present in a process stream or the atmosphere. In operation a flow of sampled gas and a flow of fuel—both carefully controlled—converge and feed into a hydrogen flame ionization detector. Supported by a fixed flow of purified air, the sample and fuel (a mixture of hydrogen and nitrogen) burn and ionization takes place. A 300-v field causes the ions to be collected from the flame jet, producing a high impedance current proportional to the amount of hydrocarbons contained in the sample. Converted by an impedance matching amplifier, the current signal is then recorded in suitable units—percent or ppm hydrocarbon. Suggested uses for the hydrocarbon analyzer are in chemical production, gas production and distribution, metals processing, petroleum refining, power, and air pollution.

The Foxboro Co., Foxboro, Mass **[358]**



High-stability power supply

Model EMCR 113B is a highly stable, airborne instrumentation power supply. The unit furnishes isolated 5 v d-c to transducers from a 24 to 32 v d-c source. The 5-v output is stable to within 5 mv for variations in input voltage, load changes of 0 to 1 amp, and temperature changes from 0° to 50°C. Output ripple is held to within 5 mv peak to peak.

Engineered Magnetics Division, Gulton Industries, Inc., 13041 Cerise Ave., Hawthorne, Calif. **[359]**

High-sensitivity portable galvanometer

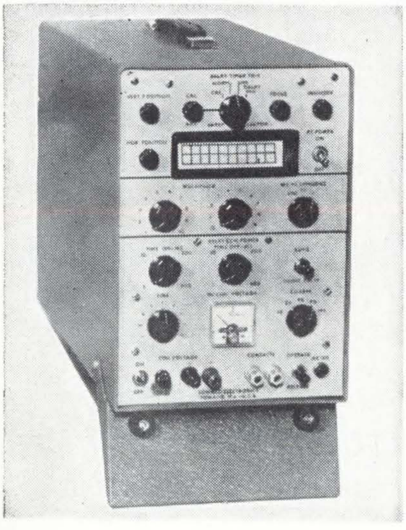
The MR4/45 portable galvanometer is housed in a rectangular metal case with removable cover permitting easy access to the internal components. A detachable screen protects the scale from extraneous light. The instrument employs an optical magnifier so that an effective scale distance of 1.5 meters is obtained in an instrument about 22 cm in length, achieving an increase in sensitivity over other types of galvanometers of equivalent size. A double light beam is used giving two separate spots on the scale. The first or main beam is passed through the magnifier and projects a well-focused spot on the scale having a clearly defined

hair-line, while the second beam is intercepted before passing through the magnifier and produces a smaller spot having approximately one-tenth of the sensitivity of the main spot. The moving coil is fitted with patent non-sticking stops adjusted so that the small spot will not deflect off the scale; this is of considerable advantage when the galvanometer is being used as a null deflection instrument, where initial readings tend to over-deflect the galvanometer. Price of the MR4/45 is $300.

North Hills Electronics, Glen Cove, L.I., N.Y. **[360]**

Relay timer includes crt display

Model TR-5 relay timer combines into a single package a relay coil supply, an automatic on-off, solid-state electronic switch for applying or interrupting the coil voltage, and a cathode-ray tube display. Relay action is shown on a 5-in. crt similar to any oscilloscope. A highly accurate sweep time generator makes possible timing measurements from 1 millisec to 1.09 sec within ±3%. An outstanding feature of the TR-5 is its ability to



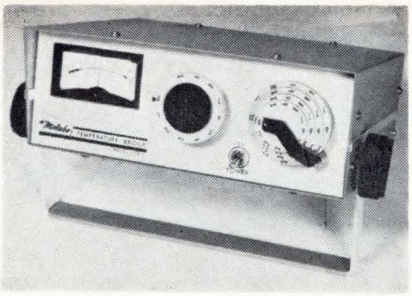
select any portion of the sweep for detailed studies of contact bounce or chatter. A built-in load regulated transistorized power supply provides voltage from 12 to 145 v d-c for the coil operation. There is provision for automatic cycling or single-shot operation.
Towaco Electronics, Pine Brook Road, Towaco, N. J. 07082. **[361]**

Frequency meter covers 20 cps to 200 kc

A solid-state frequency meter has been developed for a wide variety of research, production and quality control applications. It provides direct linear reading of frequencies from 20 cps to 200 kc in six ranges, with each individually adjustable for calibration. Features are low cost ($149.50); high accuracy (±1% from 20 cps to 100 kc, and ±2% from 100 to 200 kc); and high input impedance (100,000 ohms). An output jack, designed for use with either an oscilloscope or earphones, provides a 15-v, peak-to-peak square wave into a 50,000-ohm load. An optional strip chart recorder output provides 1 ma into a 1,400-ohm load. The unit is designed for 110 v a-c operation, consuming 4.5 w. A portable battery-powered model requires 12 v at 25 ma.
Electronic Research Co., a division of Textron Electronics, Inc., 10,000 West 75th St., Overland Park, Kansas. **[362]**

Temperature bridge in solid-state design

Model CTB-1 temperature bridge is designed for absolute and relative temperature measurements to an absolute accuracy of ±0.1°C between −200°C and +200°C.



The instrument can be used over the $+200°C$ to $+400°C$ range with an absolute accuracy of $\pm 0.2°C$. Of solid-state design, the unit is compact and simple to use for measurements in liquids, solids, and gases. Using a calibrated platinum resistance sensor, absolute readings can be made with an accuracy of $\pm 0.02°C$ when the bridge and sensor are calibrated together. The sensitivity for relative measurements ranges between $\pm 0.001°C$ and $\pm 0.005°C$, depending on the temperature range under measurement. The temperature bridge is priced at $690, the calibrated sensor (traceable to NBS) at $180. An uncalibrated sensor for users wishing to do their own calibration is available for $120.

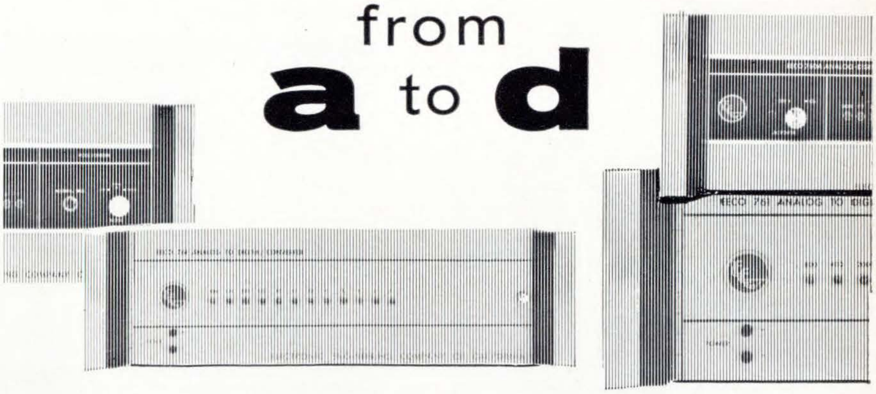
Melabs, 3300 Hillview Ave., Stanford Industrial Park, Palo Alto, Calif. **[363]**

Capacitance tester with digital readout

Three-digit, inline readout of capacitance from 0 to 1,000 μf and dissipation factor from 0 to 20% are featured in the model 5300 digital capacitance tester. This all-solid-state instrument reads true series capacitance at 120 or 1,000 cps. A built-in 0 to 200-v bias supply permits measurements at rated d-c voltage of the test capacitor, and does not add series resistance to the dissipation factor measurement. Price is $1,995.

Micro Instrument Co., 13100 Crenshaw Blvd., Gardena, Calif. **[364]**

EVERYTHING from a to d



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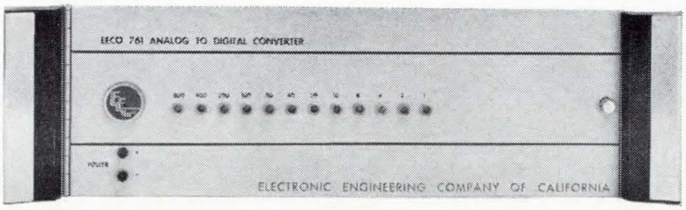
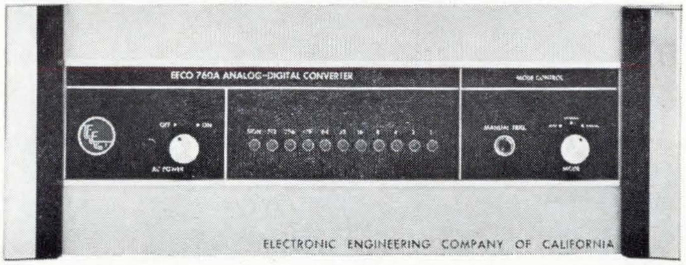


Series 761



Series 760A

Take your pick — lower cost EECO 761 models with some quality features even high priced units don't have ... or the greater speed, accuracy and sophistication of EECO 760A instruments.

Starting at $1,800, EECO 761 models provide all solid-state construction ... 15,000 to 25,000 conversions/sec ... choice of output — binary (up to 11 bits) or BCD (to 3 decimal digits and sign), parallel or serial ... automatic and external command modes ... and much more.

For higher speed systems, select an EECO 760A model with greater resolution and speeds of 44,000 to 60,000/sec ... increased accuracy.

The big news is versatility ... with selection from literally hundreds of models. By changing circuit cards or adding modules, EECO can provide exactly what you want — within your price range. With either series you can get: sample and hold with 100 nanosec aperture ... capability to measure low-level signals ... input impedence to 100 megs ... and a second output register for added buffering into your system. And, in 760A models, you can also have multiplexing or digital-to-analog conversion built right into the unit.

Want versatility and value in A-to-D converters? Look to EECO for a wide range of data handling equipment (multiplexers, converters, memories, buffers) ... timing products ... automatic programming equipment ... test instrumentation ... and complete timing and data systems.

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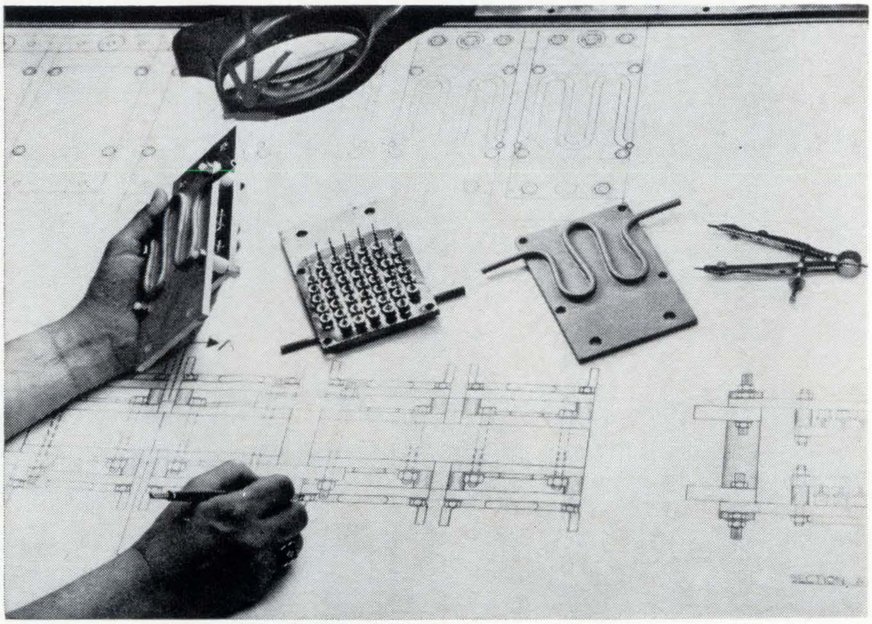
Circle 119 on reader service card



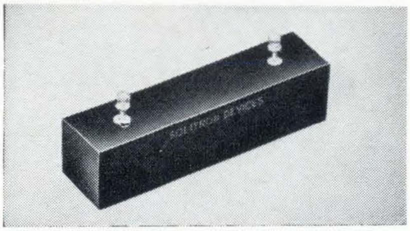
High-current silicon rectifiers

A new series of 1,000-amp silicon rectifiers are said to be the highest rated solid-state devices in the industry. The MR1290 series, eight devices with peak inverse voltage ratings of from 50 v to 400 v, features a new multiple-cell construction, extremely high surge handling capability (16,000 + amps), and a redundancy factor for added reliability. The units have solid lug terminations, and are designed for standard 4-in. bus bar mounting. The illustration shows the rectifier being designed into a bus bar assembly, one of the many device configurations that can be fabricated using the manufacturer's "universal" cell process. The 1,000-amp rectifiers are water-cooled and need no additional heat sinking. Typical applications for the devices are in welding, plating, or d-c motor power supply installations. Reverse polarities are available.

Motorola Semiconductor Products Inc., P.O. Box 955, Phoenix, Ariz., 85001. [331]

High-voltage zener diode

A temperature-compensated zener diode rated at 250 v, 8 w has been produced with a temperature coefficient of 3 parts per million over the temperature ranges of 0 to 25°C and 25°C to 75°C. The device is ideally suited for the very highly regulated power supplies used in instrument calibration work.



Solitron Devices, Inc, 256 Oak Tree Road, Tappan, N.Y. 10983. [332]

Varactor diode handles high power

This silicon, planar, varactor diode features efficiencies of 60% in tripler circuits. The H4A, with a

Now . . . a really new s-c tester

featuring digital programming and low cost

TI's Model 658 Transistor/Diode Test System has many new features to make production/inspection testing easier, faster, more economical. An out-of-the-way digital programming section uses digit-switch and rotary selectors for choosing test conditions. Both d-c and pulse tests can be performed with each module. Up to 48 plug-in modules may be mounted vertically or in slide-out drawers. Tests may be programmed in any sequence. Test duration is independently adjustable from 50 milliseconds to 5 seconds.

The 658 features digital control of test circuitry; close proximity of clamps and limiters to device under test; Kelvin connections eliminating IR drop errors; front panel lights displaying go/no-go results; memory storage permitting sorting and classification into 16 categories with an accessory sorter; swing-out card racks and plug-in assemblies for simplifed maintenance and long-term reliability. Bias and reference supplies are digitally programmable with repeatability better than ½%. Readout accuracy is ½%.

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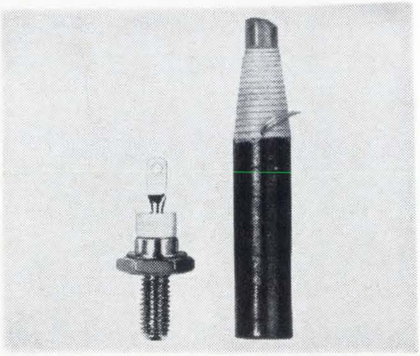
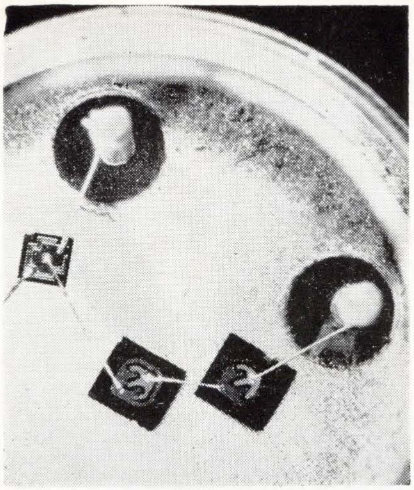
New Semiconductors



cut-off frequency of 60 Gc, offers high power handling capabilities due to its high breakdown voltage of 175 v and low series resistance. As a frequency tripler, the H4A can deliver 25 w into a 50-ohm load at 150 Mc with an efficiency of 60%, and 13 w at 450 Mc with an efficiency of 50%.
Amperex Electronic Corp., Providence Pike, Slatersville, R.I. 02876. **[333]**

High-transconductance field-effect amplifier

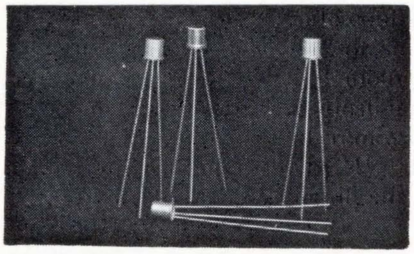
A field-effect amplifier has been developed with a transconductance greater than 1 mho and packaged entirely within a TO-5 case. Called Mho-Amp, it has a total device dissipation of 5 w and a gain of 150 db. An extremely sensitive amplifier, it has an input impedance greater than 10^{15} ohms, excluding external circuitry. It is expected to find applications as a replacement for electrometer tubes, and for instrumentation equipment and numerous military systems where very low-level signals must be amplified with minimal distortion and noise. The metal-over-oxide field effect input of the Mho-Amp gives the device a noise figure of less than 2 db at 1 kc with a generator impedance of 1 megohm. A silicon device, it is extremely temperature stable. To illustrate its operation, the Mho-Amp has been demonstrated in a typical audio amplifier circuit where it served as the only active element between a phonograph pickup and the speaker. In such a circuit the Mho-Amp delivers 1 w output with less than 5% distor-



tion at 33% efficiency. Power gain in this curcuit was 70 db.
Raytheon Co., Semiconductor Division, 350 Ellis St., Mountain View, Calif. [334]

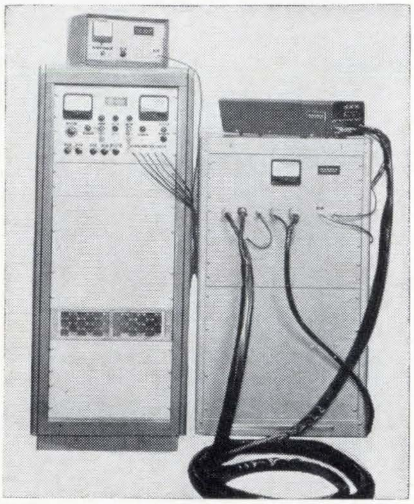
Voltage-operated switching FET's

Four new field-effect transistors are designed specifically for low-level choppers and multiplexers. The devices feature inherent zero offset voltage and maximum on-resistance of 35 ohms, together with 3 na maximum gate current and typical gate-to-drain capacitance of 10 pf. Transconductance is typically 40,000 μmhos. Typical



cut-off frequency is 300 Mc. Because these new switches are voltage-operated, no drive transformer is needed for most applications. Prices for 1 to 99 are $20 for the CM600 and CM601, and $35 for the CM602 and CM603. The devices are manufactured by the company's epitaxial junction process, which combines the advantages of alloyed, epitaxial, and planar techniques, and provides extreme ruggedness and parameter stability.
Crystalonics Inc., 147 Sherman St., Cambridge 40, Mass. [335]

High repetition laser system

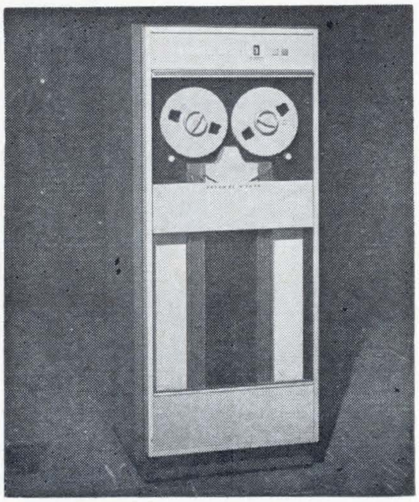


Model 1010C2 laser system is a high energy, high repetition device capable of many modes of operation varying from Q switching with an average output of 20 Mw at 1 pulse per sec to 10 joules at 4 pulses per sec. The system utilizes two 20-kw, water-cooled flash lamps. The unit is ruggedly designed for operation in the field or production type applications. It has been tested for 6-hr continuous operation at 1 pulse per sec. The unit is applicable to the areas of upper atmospheric research, welding and metal working, medical research and other fields of scientific investigations. Price of the entire system ranges from $12,000 to $15,000. It includes laser head complete with ruby and flash lamp, power supply and Q switching attachments.

Applied Lasers, Inc., 41 Montvale Ave., Stoneham, Mass., 02180. **[371]**

Magnetic tape unit for computer use

Push-button selection of three data transfer rates is one of many operator conveniences offered by the D3030 computer magnetic tape unit. The D3030 writes and reads all three density formats (800, 556 and 200 characters per in.) at 75 ips tape speed. Data transfer rates are 60,000, 41,700 and 15,000 characters per sec. The tape unit comes with either the seven-track or nine-track format. The D3030 features include vacuum column tape buffers with d-c reel torque motors and rugged disk-type reel brakes; semiautomatic tape threading; front access to all electronics (mounted on printed-circuit cards in a modular card rack); snap-in-place cover panels over drive mechanisms and electronics cards; advance-design front cover door with slide panel for fast tape load/unload. Bidirectional start and stop times are 5 millisec and 1½ millisec, respectively.

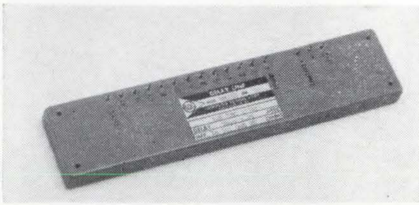


Datamec Corp., 345 Middlefield Road, Mountain View, Calif. **[372]**

Code generator for digital systems

A new group of serial digital code generators is capable of generating a pulse series of up to 32 digits at any specified pulse spacing between 0.20 and 2.0 μsec. They are particularly useful as word generators, as serial to parallel or parallel

New Subassemblies

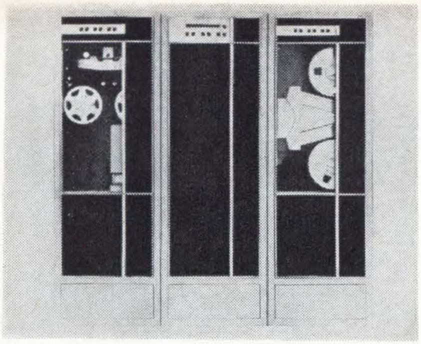


to serial converters in digital computers, or as recognition code train generators in radar systems. The generators use magnetostrictive delay lines with taps as specified. They are available either as tapped delay lines or can be supplied with the necessary solid state amplifiers and shapers for restoration of the signal to input logic level. Amplified output pulses have rise times of less than 0.05 μsec and pulse spacing is set to an accuracy of better than 0.02 μsec. The DM718 shown here was designed for use as a digital system check-out code generator and provides 12 digits spaced at 1.25 $\pm$0.02 μsec, and a total delay capability of 15.0 μsec. The unit is housed in a moisture-proof steel container with tap points convenient for p-c board mounting. It measures 1.75 by 0.5 by 8 in. Price of the DM718 alone is $185 in small quantities. Associated unity gain circuitry is an additional $150 each.

Computer Devices Corp., 6 W. 18th St., Huntington Station, N.Y. 11746. [373]

Paper to magnetic tape conversion system

The PMT-1000 system provides a means of fast input to large scale computers by quickly converting data, previously recorded on paper tape or cards, to IBM compatible magnetic tape. The new system is capable of the following conversion rates: paper tape/paper tape—110 cps; paper tape/magnetic tape—500 cps; magnetic tape/paper tape—110 cps; punch cards/magnetic tape—266 cps. The nucleus of the PMT-1000 system is the DSI-1000, a general purpose digital computer that features an operation cycle time of 3.2 μsec and a clock rate of 7.6 Mc. Other system components are the DSI-150 computer tape



punch and the DSI-700 photo reader, both with a 5 to 8 channel capacity of $\frac{11}{16}$ in., ⅞ in., or 1-in. tape; and the DSI-900 magnetic tape drive featuring IBM compatible codes and a density of 200 to 556 characters per inch. Because the DSI-1000 is a stored-program computer and is being used in the PMT-1000 system as a controllable buffer, it is therefore possible to extend greatly the capabilities of the basic paper and magnetic tape conversion systems. Some of the additional capabilities are code conversion, data packing, error recovery, and parity check or generation. Application areas for which the PMT-1000 is especially well suited include the chemical, food, petroleum, steel and pharmaceutical industries; data communication systems; and most applications involving paper to magnetic tape conversion.

Data Systems Inc., Grosse Pointe Woods, Mich. [374]

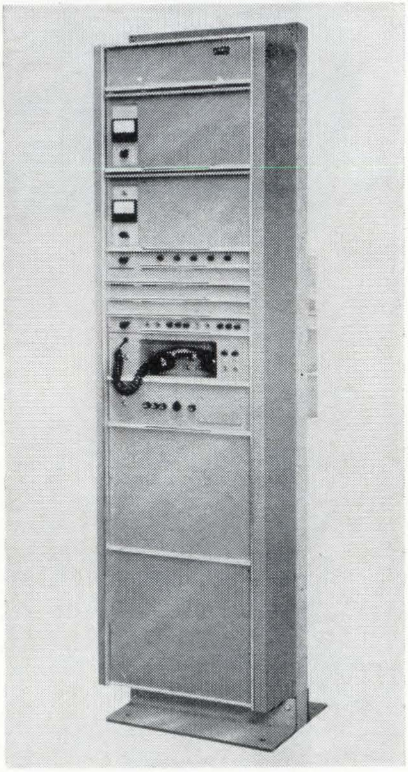
Fixed attenuators for d-c to 4-Gc

Unilateral, coaxial fixed attenuators featuring extremely low vswr, operate in the frequency range of d-c to 4 Gc. Units have a vswr of 1.04:1 or less at the input, and an excellent vswr, 1.3:1 or less, in the opposite direction. The 50-ohm units are rated at 1w dissipation. The UM-501 series considerably simplifies vswr and attenuation measurements when used to replace stub tuners, or in other applications where an attenuator or very low vswr is required. The attenuators are available in values of 10 and 20 db. Other values are available on special request.

Electro-Metrics Corp., 88 Church St., Amsterdam, N.Y. [375]

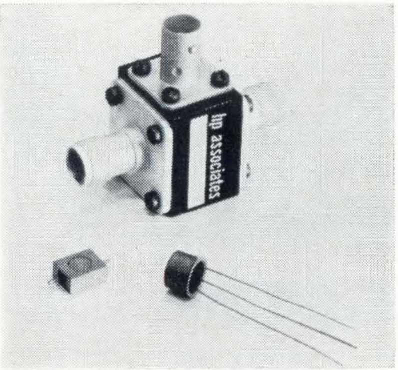
New Microwave

Rack-mounted microwave relay



Microwave relay equipment that will carry a five year warranty is being placed on the market. It will be the first such warranty in the telecommunication industry, according to the manufacturer. The KTR II rack-mounted relays can handle color or black and white tv, including both video and voice, 600 simultaneous telephone conversations or 12 million bits per sec of data traffic. All solid-state except for the final klystron output, it consumes about half the power of comparable tube models, allowing it to operate from 24 to 48 v batteries as well as 110 or 220 v a-c. The lower power consumption and accompanying reduced heat dissipation also improve reliability while cutting operating costs. New infrared production testing techniques will protect against excessive heat dissipation and insure increased equipment reliability. The new KTR's will be available during the first quarter of 1965. Price will vary with system configuration.

Raytheon Co., Communications and Data Processing Operation, Norwood, Mass. **[391]**



Microwave switch useful over wide band

A new concept in wideband microwave switches is announced. A single switch provides what is said to be a previously unattainable combination of low insertion loss, high isolation, and very wide bandwidth. The switch is hermetically sealed and designed to meet military requirements. The 3501A utilizes direct integration of p-i-n diode chips into a microwave filter structure to provide a high performance miniature switch useful over a range from 0.5 to 12.4 Gc. Embedding the uncased diode in the structure avoids parasitic reactances that accompany a discrete package. It also allows the switch to exploit fully the inherent frequency range of the diode. The 3501A is a spst switch and continuously variable attenuator providing up to 45 db isolation with less than 1 db insertion loss. It weighs less than 3.5 oz and measures 1.06 in. by 1.00 in. by 0.75 in. not including the TNC connectors for the r-f signal and the BNC connector for attenuation bias control. The picture shows the 3501A compared in size with a standard TO-5

EI digital multimeters permit checking of specifications on resistor production lines by relatively unskilled workers.

Classic Jobs of Measurement
Performed by Electro Instruments

THE EI VIEWPOINT
by Dr. Walter East
President, Electro Instruments, Inc.

The mechanics by which many types of measurements are made with electronic equipment are not generally well known. An industrial user trying to get information about a means of measuring a pressure, a temperature, a distance, or taking count of the number of items that will pass a given point in a given time, usually becomes thoroughly confused when the talk turns to volts, resistance, capacitance, frequency, etc. And well he might. Nothing in his experience equips him to immediately relate what he regards as two entirely different sets and types of measurements.


Dr. East

I am afraid that many an instrumentation engineer fails to take this into consideration when discussing electronic measuring equipment with potential users.

Grave Mistake Avoided
But I would caution industry that, outside the aerospace industry, the full potential of today's electronic measurement systems often goes unappreciated. Elsewhere on this page appears the story of a manufacturer who was prepared to make a major equipment investment—quite needlessly—on an erroneous assumption. Fortunately, he consulted an EI sales engineer and found he already had all the equipment he needed for the job he had in mind.

The moral, I think, is obvious: "Consult before you leap."

X-Y Recorder Slashes Data Reduction Time
One firm's environmental laboratory was spending 70% of its total data reduction effort in tabulation and plotting of vibration data. Methods used required eight man hours, yielded six finished graphs. Firm's engineers explored several other systems, found all inadequate. Final solution was made by EI engineers—who designed a special X-Y recorder for the job. Firm was able to make major time cuts, yet still maintain a high degree of accuracy in plotting the data required.

EI Voltmeter Adequate For Resistor Testing
Manufacturers of precision resistors must maintain tight control over the amount by which a resistor changes its values with changes in temperature. The degree of change is known as the "temperature coefficient" and knowing its value is important in a wide number of applications.

On the surface, this appears to be a resistance measuring problem. One manufacturer, viewing it as such, was prepared to make a major equipment investment in the interest of measuring resistor temperature coefficient to the precision of ½ part in 1 million.

For such a job, special equipment would have had to be designed.

Old Equipment Adequate
An EI sales engineer, called in for consultation, pointed out that the information the manufacturer was seeking could be obtained by making a simple two voltage ratio measurement; and that the EI digital voltmeter/ohmmeter which the company already possessed was completely adequate for accomplishing the job satisfactorily.

An expenditure of many thousands of dollars unnecessarily was thus avoided. Also, by being able to make the measurement involved, the manufacturer was able to effect substantial savings on its resistor production.

Electro Instruments, Inc.
8611 Balboa Avenue, San Diego, California 92112

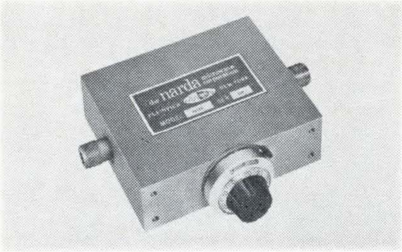
ELECTRO INTERNATIONAL, INC., ANNAPOLIS, MD. • TRANSFORMER ENGINEERS, SAN GABRIEL, CALIF.

New Microwave

transistor. Also shown is a modified version of the 3501A, the 3502, which is designed for integration into stripline systems. Price of the 3501A is $250 for 1 to 10.
HP Associates, 620 Page Mill Road, Palo Alto, Calif. 94304. **[392]**

Variable attenuators with duo-dial drive

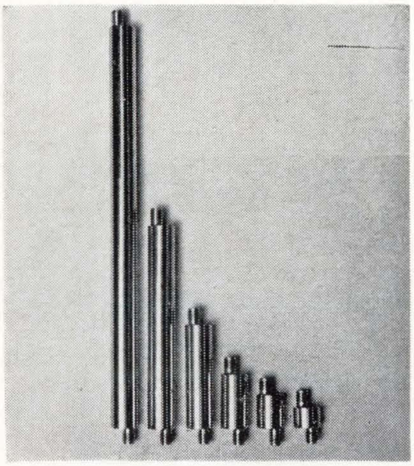
A general-purpose, 2.0 to 12.4 Gc, variable coaxial attenuator has been developed with a 0 to 40-db attenuator range. Model 791 features a max insertion loss of 0.75 db; max vswr of 1.30; power-handling capability of 10 w average, 5 kw peak; and excellent r-f shielding. The attenuators are particularly useful for power level setting or to increase



the stability of oscillators by providing isolation from load variations. They are also extremely rugged, meeting military environmental requirements. Another design highlight includes a duo-dial drive for easier resetting and positive locking. For lower frequency use—2.0 to 2.5 Gc—the attenuation range is 0 to 35 db. The attenuators are priced at $275.
Narda Microwave Corp., Plainview, L.I., N.Y. **[393]**

Bandpass filters cover 250 to 11,000 Mc

Miniature, coaxial, tubular bandpass filters cover 250 to 11,000 Mc in six bands. Nominal passband insertion loss is 1 db from 250 to 4,000 Mc; 1.5 db from 4,000 to 11,000 Mc. Nominal passband vswr is 2:1 for all models. Body length and over-all weight range from $7\frac{17}{32}$ in. and 2.7 oz for the 250 to 500 Mc models, to only $\frac{19}{32}$ in. and 0.4 oz for the 7,000 to 11,000 Mc models.

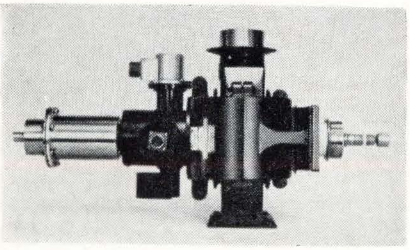


All models are ½ in. in diameter, and are available with OSM or BRM connectors. The six standard models are eight-section filters designed for Tchebycheff insertion-loss characteristics. Unit prices range from $225 at the lowest passband to $275 at the highest passband.

Sage Laboratories, Inc., 3 Huron Drive, East Natick, Mass. [394]

L-band magnetron with rotary tuning

Rotary tuning gives completely random frequency agility to a new 1.0-Mw L-band magnetron. Simplicity of design permits the QKH-1014 to replace directly fixed or manually tuned tubes in such field applications as frequency agile radars, frequency scan systems,

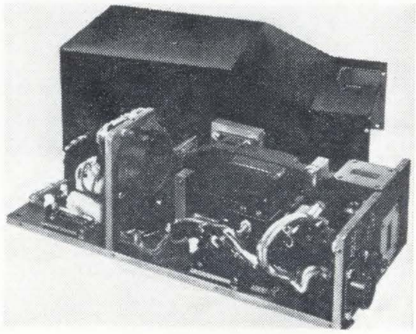


and mutual interference reduction devices. A slotted disk suspended above the anode cavities and magnetically coupled to an external, variable speed motor varies both the inductance and capacitance of

the anode and produces a frequency sweep between 1,250 and 1,350 Mc. Completely random frequency agility can be obtained by modulating the motor speed or by varying the modulator pulse rate. An integrated transducer provides receiver tracking information. The disk rotates at speeds up to 3,000 rpm. At 2,400 rpm, the full band can be tuned in 1/800 sec. Including its integral magnet, the air-cooled QKH1014 weighs 90 lb.
Raytheon Co., Microwave and Power Tube Division, Waltham, Mass. **[395]**

Parametric amplifier for airborne applications

A ruggedly packaged and environmentally stabilized, nondegenerate paramp has been developed for airborne applications. Primarily for fixed-tuned application, the X-12 may be tuned across a 200 to 300 Mc band. Bandwidth may be as much as 100 Mc. Tuning is accomplished by changes in pump frequency and diode bias. Typical center frequency is 9.375 Gc, gain is 15 db, phase stability and gain



stability are ±3°/minute and ±0.2 db/minute, respectively. Ambient temperature range is —30°C to +55°C at up to 90% humidity; radio interference conforms to MIL-I-6181D and shock performance is 15 g in all axes. The entire package is 12½ in. by 6¼ in. by 5¼ in., and weighs 8 lb. The assembly contains varactor mount, klystron pump, pump power attenuator, blower, circulator, and directional coupler for monitoring pump frequency and power.
Microwave Physics Corp., 420 Kirby St., Garland, Tex. 75040. **[396]**

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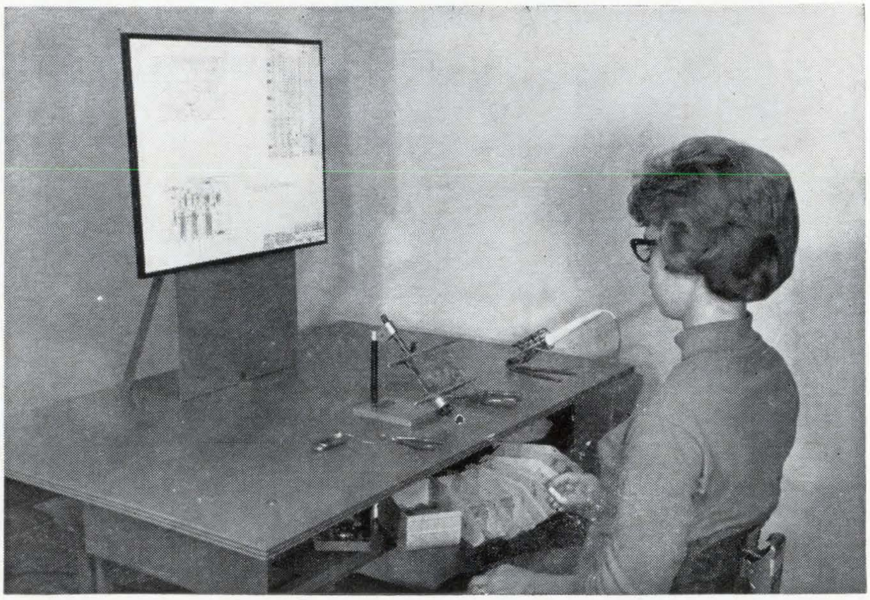


Powered bins reduce assembly errors

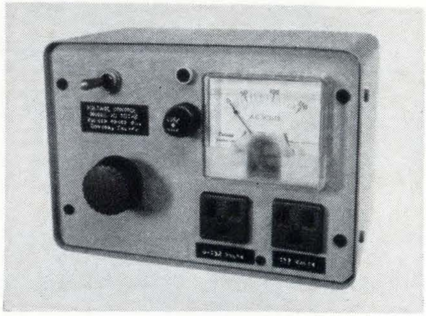
Assembly errors and rejects are reduced and reaching distances minimized with new powered bins. The assembly tool is a rotary parts bin carrier which handles any combination of users' own bins, measuring from 1¾ in. to 5¼ in. wide, up to 72 in. total. Carrier dimensions are 48 by 32 in. Simple snap-on clips are used to hold bins to the rotary carrier. Parts may be loaded in front or from the rear without interrupting production. The powered bins may be mounted on or under existing work tables or on any structural framing. On command from a foot switch, the rotary carrier indexes in sequence and delivers assembly parts to the operator-assembler at a convenient lap level pick-up point. Bins extend 6 in. beyond the front for easy access to parts. Assembly sequence is pre-established and assembler learning time is reduced. Power requirements are 117 v, 60 cycle a-c and 160 w (only while indexing), 1-amp Slo-Blo fuse.

International Research and Development Corp., 6150 Huntley Road, Worthington, Ohio. [421]

Voltage control for soldering irons

This compact voltage-control unit for soldering irons has been designed to meet the requirements of NASA assembly-line soldering. With these units in use, the operator can adjust a 100-w iron down to any desired heat, and can repeat any given operation. Soldering can be done with such accurate control, expensive components need not be destroyed by excessive heat. This also saves tips and eliminates the need for several sized irons. Model VC101-2 is conservatively rated to control up to a 100-w soldering iron and requires only 5 in. by 7 in. of bench space.

Vulcan Probe Co., 824A Dodsworth Ave., Covina, Calif. [422]



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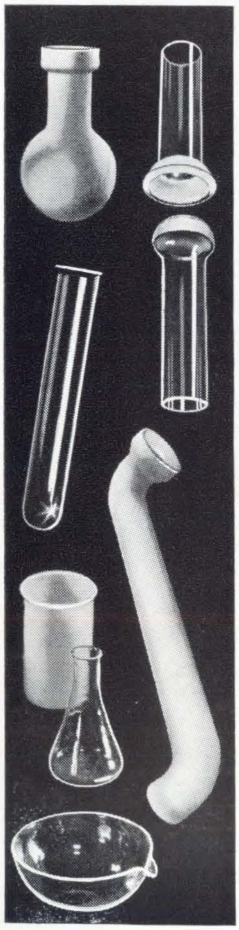

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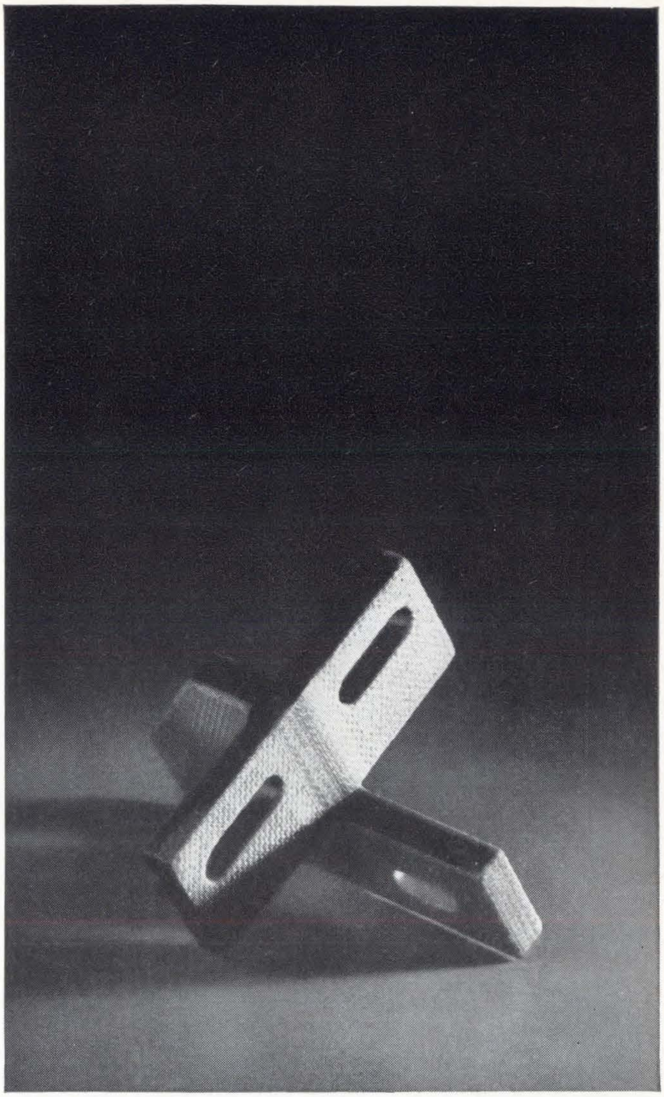

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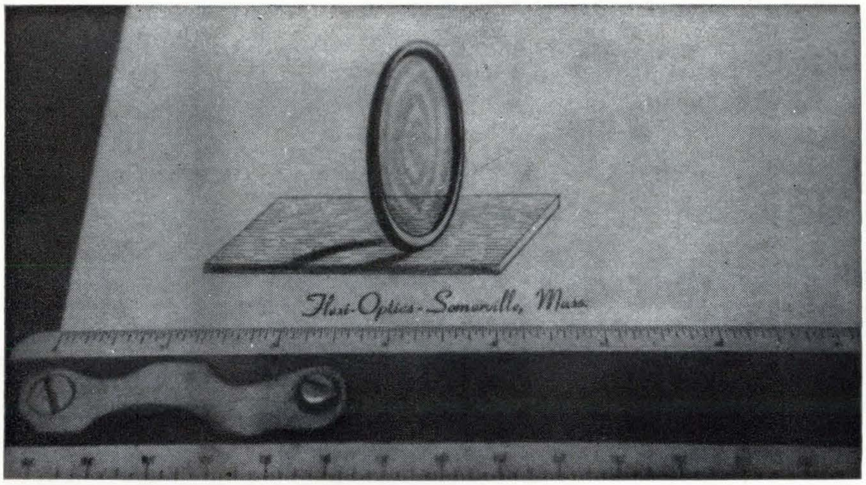
Circle 135 on reader service card



Substrateless ultrathin films

Development of unsupported ultrathin films or windows made of glass, quartz, silver chloride, silicon and germanium is announced. Scintillation, fluorescence and reaction in the presence of select radiation or light can be achieved in varying degrees depending on the material selected. The films are being manufactured as thin as 0.2 micron and up to 2 in. in diameter. They are mounted on glass or metal rings in drum head fashion or on customer-furnished mountings either as a diaphragm (where special diaphragm applications arise) or as a substrate for the deposition of other thin films. Deliquescent surfaces such as salt prisms have also been used as a substrate for the deposition of these ultrathin films. The reflected light is in the first order yellow and can even be in the gray if necessary. The relative shock-resistant quality of these ultrathin films should interest scientists and engineers. Researchers involved in the use of x-ray, electron guns, image orthicons, vidicons, detectors, masers and beam splitters are expected to benefit, according to the manufacturer.

Flexi-Optics Inc., 117 Dover St., Somerville, Mass. 02144. **[411]**

New doped glass for laser projects

A new laser glass based on ytterbium doping and one based on neodymium doping have been announced. Major attraction of the ytterbium-doped glass is its long fluorescence time constant—1200 μsec—promising to permit output in the multi-megawatt range through Q-switch operation. The ytterbium emission wavelength is 1.02 microns, as compared with the well known 1.06-micron emission of neodymium. Ytterbium energy levels are well disposed for efficiency pumping by xenon or argon arc. The glass has a borate matrix. Also offered is a 360-μsec-lifetime, silicate-based glass with neodymium doping. The manufacturer believes that beam divergence in both types of glass can be kept under 2 milliradians when used in well-designed cavities. Typical threshold for a 6 in. by ¼ in. rod of the ytterbium doping is quoted at the 250 joules. Laser action occurs below 200°K. The new neodymium-doped silicate product offers a much lower threshold and requires no refrigeration unless high repetition rates are needed. Twelve joules is considered a typical threshold for a 3 in. by ¼ in. rod.

Apparatus and Optical Division, Eastman Kodak Co., Rochester, N.Y. **[412]**

SKINNY

Yes, very. That's the idea. When you have a skinny neck you don't eat so much. And this 12″ narrow neck picture tube has been specially designed to meet the requirements of low power consumption, portable transistorised TV.

Another advantage of being skinny is, of course, the space saved. An all important factor in the design of portables. Yet another advantage is the greater deflection possible by the reduction of overall length.

Hitachi manufactures B&W picture tubes ranging from 5.5 inches to 19 inches. Naturally, only tubes of 12 inches and less are specifically suitable for portables.

And don't forget, Hitachi manufactures the complete gamut of TV tubes. Not only the narrow neck, but standard B&W and colour tubes.

Type Number	Model	Angle	Neck Dia.	Overall Length	Ef (V)	If (A)	Remarks
140DB4	5.5″	70°	0.788″	6.625″	12.6	0.05	TR'd TV
230EB4	9″	90°	0.788″	8.006″	12.6	0.05	TR'd TV
12AYP4	12″	110°	1.125″	9.313″	6.3	0.45	
12AZP4	12″	110°	1.125″	9.313″	6.3	0.6	
12BAP4	12″	110°	1.125″	9.313″	6.3	0.3	
310WB4	12″	110°	0.788″	9.331″	12.6	0.05	TR'd TV
310MB4	12″	90°	0.788″	10.551″	12.6	0.05	TR'd TV
310YB4	12″	110°	0.788″	9.331″	4.2	0.45	
16AUP4	16″	114°	1.125″	10.006″	6.3	0.6	
16BFP4	16″	114°	1.125″	10.006″	6.3	0.45	
400FB4	16″	114°	1.125″	10.006″	6.3	0.3	
16CBP22	16″	90°	1.438″	15.125″	6.3	0.9	Color TV

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New Books

Engineering systems

Dynamic Systems Analysis.
Samuel Seely
Reinhold Publishing Corp.,
1964, 514 pp., $11.

This textbook, written by a professor of electrical engineering at Case Institute of Technology, takes a novel approach to the study of lumped linear networks.

Beginning with a detailed description of the basic mechanical, electrical, fluid and thermal elements that make up systems, the author shows that these elements can be divided into three classes, depending on whether the relations between the dependent and independent variables that describe them are proportional, derivative or integral.

When such elements are combined to form a system, the connection inherently imposes constraints on the system performance. These constraints are well illustrated by network graphs.

System geometry and variables are dealt with in detail, as is the method of constructing a network graph and the basic principles of topology.

The text then describes in detail the five major methods for linear network analysis: network graphs and equations, the through-across differential equations, energy formulations and Lagrange's equations, the block diagram and the flowgraph.

The second part of the book also deals with steady-state network response in the time and general-frequency domains, and from these develops the system function and pole-and-zero methods.

The third part describes methods of dealing with transient response to system stability by the Route-Hurwitz and Nyquist criteria, analysis of singularity functions such as the unit step and unit impulse, and general systems response. The Laplace transform technique is then shown to confirm the other methods presented.

Network response to sinusoidal input functions, resonance and Q values, and conventional techniques such as the Thevenin and Norton theorems, maximum-power-transfer analysis, two and four-port equivalents, T and pi equivalent networks and reciprocity are also introduced in this part, as is a special and valuable chapter on block diagram algebra.

In the last part, the author deals with state variables and their use in formulating the state equation of a network. The resulting equation is then analyzed by matrix methods. This part also introduces the general stability theorem of Liapunov.

The text is a thoroughly up-to-date introduction to modern network theory, with an approach that prepares the reader for more advanced work in control theory. A large number of worked-out examples and exercises are included, as are many references to recent literature. The two appendices deal with the elements of matrix theory and with the Vandermonde determinant which is used to solve for exponential excitation response.

George V. Novotny
Advanced Technology Editor

Optics in electronics

Optoelectronic devices and circuits.
Edited by Samuel Weber
McGraw-Hill Book Co.,
1964, 358 pp., $15.

This is a collection of 97 articles from Electronics, dealing with optical-electronic techniques, devices and equipment.

The articles are organized by subject under 12 headings, starting with modern optoelectronic principles and continuing through lasers, optical communications and various other applications, to unconventional optoelectronic devices.

As a sampling of the considerable amount of work going on in optoelectronics, the volume serves to illustrate the wide variety of areas in which the two additional disciplines, electronics and optics, are combined to achieve entirely new devices. The manner in which the articles are organized helps to establish a continuity between them. At the end there is a collection of readers' letters with comments and corrections on some of the articles.

Circle 139 on reader service card

Technical Abstracts

Dielectric isolation

The minimization of parasitics in integrated circuits by dielectric isolation. By D.A. Maxwell, R.H. Beeson and D. F. Allison, Signetics Corp., Sunnyvale, Calif.

Up to now, active and passive elements of an integrated circuit have been isolated from each other by unsatisfactory methods involving a back-biased pn junction. Now a dielectric has been made that achieves almost total isolation with no increase in area.

The fabrication process consists of etching monocrystalline silicon to form islands. The entire surface is then covered with a dielectric material such as silicon dioxide. Polycrystalline silicon is grown on top of the oxide to a thickness of several mils. This provides the new substrate on which the circuit will ultimately be formed, along with the needed mechanical support, rigidity and dimensional stability. The coefficient of thermal expansion is very close to that of monocrystalline silicon.

The entire wafer is flipped over and the excess material removed. This leaves separate islands of monocrystalline silicon imbedded in a substrate and isolated by a dielectric.

Leakage currents are reduced to 10^{-10} amperes per square centimeter and stray capacitances to 10^{-5} picofarads per square micron. Parasitic npnp and pnpn action is eliminated, and breakdown voltage is increased by as much as 1,000 volts. Greater flexibility in design is achieved through the ability to place highly conductive "wells" where needed to obtain the benefits of epitaxial techniques, and by the ability to use devices having higher breakdown voltages.

The technique greatly enhances fabrication of npn and pnp transistors on the same substrate. The new technique has already been used to fabricate digital circuits with propagation delay times of three nanoseconds, and a video amplifier with a gain-band width product of 500 megacycles.

Presented at the Western Electronic Show and Convention (Wescon), Aug. 25-28, Los Angeles.

Multi-twt focusing

Magnetic focusing structure for a phased-array transmitter.* Helmut F. Onusseit Sylvania Electronic Systems, Waltham, Mass., a subsidiary of the General Telephone and Electronics Corp.

The application of traveling-wave-tube amplifiers in phased-array transmitters requires large and precisely controlled magnetic fields for focusing electron beams. After comparison of several focusing techniques, it was decided that permanent magnets were best for creating a straight field along the twt axis.

For minimum interception current, the electrons from the twt cathode must be directed precisely along the tube's axis. The necessity for a stable radio-frequency output with minimum phase distortion and drift also requires that the magnetic field be stable with time and free from power-supply ripple.

Several focusing techniques were investigated. One method uses an individual solenoid for each twt. This requires large amounts of regulated d-c power, highly efficient method of heat exchange, and complex control design. These result in high cost and large size.

Another technique is periodic-permanent-magnet focusing. This was found unsatisfactory because it requires tube-to-tube uniformity and stability. Permanent magnets seem unattractive at first because of their weight and inherently high stray fields. The stray fields of the individual rods, when positioned in an array, can be made to add up to a useful magnetic field with very few external components.

The magnetic design of an octagonal array can be extrapolated from a much simpler design: that of two parallel equipotential planes of infinite extent. These parallel planes automatically generate a uniform magnetic field perpendicular to their surfaces.

An infinite array consists of a forest of magnetic rods spaced in a uniform rectangular grid perpendicular to parallel pole plates. Anal-

* Presented at the National Electronics Conference, Chicago, Oct. 19 to 21.

ysis of the cross-section of such an infinite array shows a magnetic flux inside the rods that can be presumed to exist only in an area adjacent to each. Since there is no net flow of magnetic flux from one area to the other, pole plates can be made thin without affecting the uniformity of the array.

The infinite array is optimum because it leads to the simplest design equations, has no external field and generates no transverse component.

Thin-film inductors

Thin-film microelectronics inductors.*
Francis R. Gleason,
Motorola, Inc., Military Electronics Division, Scottsdale, Ariz.

Thin-film techniques have been used to synthesize miniature inductors having an inductance of 55 microhenries and a Q of 10 at one megacycle.

The first step in the synthesis of thin-film inductors is the vacuum deposition of a special pattern on a ferrite substrate at temperatures between 750° and 800°C. Reliable adhesion of the spiral to the ferrite is provided by a thin film of iron deposited under the gold film. After the spiral pattern is vacuum-deposited, it is electroplated with gold to a thickness of 0.001 inch. The unit is then fired at 950°C to remove contaminants.

The limited inductance and Q-values are results of film thickness and temperature factors. Ferrite saturation demagnetizing requires a ferrite film thickness of about 40 mils. This is too thick for standard film deposition methods such as spray hydrolysis.

And the temperature at which the ferrite film is processed is limited by the spiral coil material. High processing temperatures (about 1,300°C) are required so that a ferrite film will have the correct permeability and inductance. But this temperature is higher than the melting point of the gold coil and therefore not compatible with the present device. Low temperature produces poor permeabilities and impractical Q-value in the low megacycle frequency range.

*Presented at the National Electronics Conference, Oct. 19-21, Chicago.

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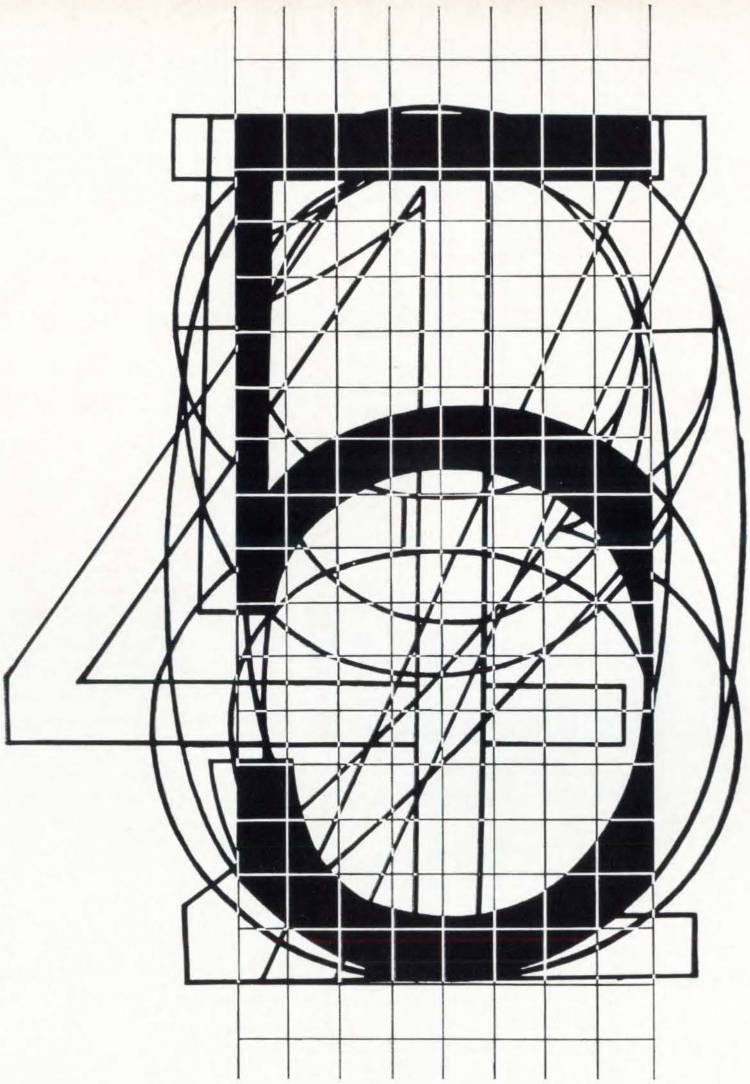

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New Literature

Electronic circuit modules. Bryant Computer Products, 850 Ladd Road, Walled Lake, Mich., offers five new data sheets describing the diode matrix 44 8040, single-shot 8055, flip-flop 8070, power control 1 8081, and power control 2 8082 electronic circuit modules. Circle **451** reader service card

Military capacitors. Sprague Electric Co. North Adams, Mass. A 28-page, quick guide to military capacitors is indexed by specification number and type designation. **[452]**

Materials and compounds. Electro-Science Laboratories, Inc., 1133 Arch St., Philadelphia, Pa. 19107. A new short-form catalog lists the firm's complete line of materials and compounds for circuit and component needs. **[453]**

Filter connectors. ITT Cannon Electric Inc., 3208 Humboldt St., Los Angeles, Calif., 90031. Significant data on a line of filter pin connectors is presented in an illustrated catalog **[454]**

Relay data. James Electronics, Inc., 4050 North Rockwell St., Chicago, Ill., 60618 offers a six-page set of data sheets covering its entire series of Micro-Scan relays for low-level, high-speed switching and sampling in industrial and military applications. **[455]**

Binary codes/terminal arrangement. Chicago Dynamic Industries, Inc., Precision Products Division, 1725 Diversey Blvd., Chicago, Ill., 60614., has published a catalog containing four pages of truth tables, grouped by switch types, for binary codes now available. **[456]**

Micromodular capacitors. JFD Electronics Corp., 15th Ave. at 62nd St., Brooklyn, N.Y., 11219. A new line of micromodular, ceramic variable capacitors is described in bulletin MT-64. **[457]**

R-f measurement instrumentation. Bird Electronic Corp., 30303 Aurora Road, Cleveland (Solon), Ohio, 44139. GC-65 is a 56-page catalog of coaxial load resistors and attenuators, absorption wattmeters, directional wattmeters, coaxial switches and r-f filters. **[458]**

Custom printed circuitry. Advanced Circuitry division of Litton Industries, P.O. Box 1046, Springfield, Mo., 65803. An eight-page, illustrated brochure deals with facilities and techniques for producing custom printed circuitry. **[459]**

Differential amplifier. Electronic Associates, Inc., West Long Branch, N.J., offers a bulletin on a low-level differential amplifier that provides high common mode rejection, high input and low output impedances, and gains of up to 1,000. **[460]**

Rfi filters. RF Interonics, Inc., 15 Neil Court, Oceanside, N.Y., has available bulletin 2610A describing its standard line of cylindrical radio-frequency-interference filters. **[461]**

All-purpose resin. Isochem Resins Co., Cook St., Lincoln, R.I., 02865. A technical data bulletin describes Isochemrez 402AP, a void-free, high-gloss electrical resin. **[462]**

Sealed-in-glass thermistors. Victory Engineering Corp., Springfield, N.J. Technical bulletin MGR061 covers a complete line of hermetically-sealed, bead-in-glass probe and bead-in-glass rod thermistors. **[463]**

Metal alloying of relay components. Alloy Surfaces Co., a division of Reeves Industries, Inc., 100 South Justison St., Wilmington, Del. A 4-page illustrated folder shows how Alphatizing, a process for forced-convection gaseous diffusion of chromium into metal, gives improved magnetic properties to relay components, and reduced production costs for relay components manufacturers. **[464]**

Microwave source. Western Microwave Labs, 1045 DiGiulio Ave., Santa Clara, Calif., has available an eight-page brochure and short form catalog describing the Solistron solid-state microwave source. **[465]**

Custom assemblies. Chicago Dynamic Industries, Inc., 1725 Diversey Blvd., Chicago, Ill. 60614., offers a two-page catalog featuring fifteen custom switches, prewired modules and panel assemblies. **[466]**

Threshold extension. Radio Engineering Laboratories, 29-01 Borden Ave., Long Island City, N.Y. 11101, has published technical notes on extending threshold in f-m receivers. **[467]**

Tubular component packaging. Niemand Bros., 45-10 94th St., Elmhurst, N.Y., offers a four-page brochure describing a variety of tubular component packages for use throughout the electronics industry. **[468]**

Snap-action switches. Cherry Electrical Products Corp., 1650 Old Deerfield Road, Highland Park, Ill. A 28-page catalog of snap-action switches contains technical data on switch characteristics, engineering drawings, and specifications. **[469]**

Linear actuator. Metal Bellows Corp., 3095 Providence Highway, Sharon, Mass., announces a four-page technical bulletin on its Compactuator linear actuators. **[470]**

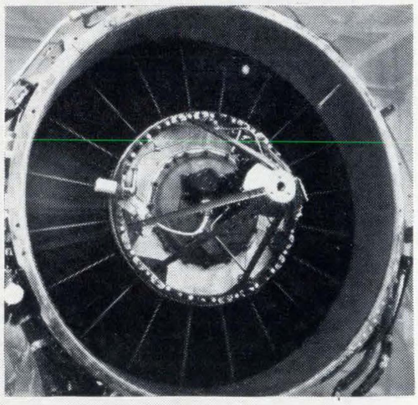
Sweeping power supply. PRD Electronics, Inc., 202 Tillary St, Brooklyn, N.Y., 11201. A two-page data sheet describes the new 816 solid-state sweeping power supply. **[471]**

Solid-State power supply. Perkin Electronics Corp., 345 Kansas St., El Segundo, Calif., has published a technical data sheet on a 50-amp silicon controlled rectifier/transistor power supply. **[472]**

Miniature monolithic capacitors. Gulton Industries, 212 Durham Ave., Metuchen, N.J. Miniature monolithic capacitors with a range to 2.0 μf are covered in bulletin H11a. **[473]**

Unregulated d-c supplies. Dressen-Barnes Electronics Corp., 250 North Vinedo Ave., Pasadena, Calif. Bulletin E-64 describes the series 221 potted, unregulated d-c power supplies. **[474]**

Where is United Air Lines using heat-shrinkable tubing of Kynar®? On the Caravelle, as a jacket over tachometer power cables. Why? Because Kynar provides excellent protection under conditions of flex, vibration, temperature (300°F). Irradiated, expanded tubing of Kynar shrinks 50%—twice as much as other thermoplastics. Its lower heat-shrink temperature (350°F) prevents damage to cabling and solder connections.



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Electronics Abroad

Volume 37
Number 31

Spain

Gain in Spain

The Madrid government seems to have chosen television as the vehicle for extending its influence in the country's remotest villages.

That trend is good news for the estimated 1.3 million set-owners in Spain, because it is accompanied by a relaxation in political control of programing on the government-run tv network.

It's also good news for foreign electronics companies, because Spain plans to spend $25 million in the next four years expanding its tv service. Foreign producers will supply most of the components for that expansion, and most of the tv sets at the receiving end.

Man behind the move. The driving force in the government's campaign is Information Minister Manuela Fraga Iribarne. Departing from the government's stated policy of rigid censorship, Fraga Iribarne says tv will be available to "anybody with something to say."

The promise of more independent programing is designed to encourage Spaniards to buy tv sets and use them. It has also resulted in cautious optimism in the board rooms of some big producers of tv equipment.

TVE, the government network, plans to open a second, ultrahigh-frequency channel in January. This channel will include five ultrahigh-frequency transmitters. It is expected to broadcast in color too, when the rest of Europe starts color tv.

Two 300-kilowatt transmitters also are planned to replace those in Madrid and Barcelona, allowing Eurovision—now sent from France to Spain—to be extended to Portugal and Morocco.

Looser reins. One of Spain's popular tv programs is a subdued version of "Meet the Press," with a handpicked group of newsmen asking relatively harmless questions of cabinet ministers.

Manuela Fraga Iribarne

And an estimated 10 million people watched Spain's soccer team defeat a Soviet squad recently for the European championship. That hardly compares with the 31 million Americans—the entire population of Spain—who are expected to watch the National Football League's championship game in the United States on Dec. 27. But Spain has only one-sixth the population of the U. S. and only about 1.3 million tv receivers compared with over 50 million in the U. S.

Both programs would have been impossible a few years ago. Now they're part of a deliberate effort to increase the country's tv audience.

Expansion. Ownership of tv receivers in Spain has increased fourfold since 1962, from 300,000 to 1.3 million. That expansion, and some economic moves by the government, spurred the creation of a tv industry in Spain.

The biggest manufacturer by far is Philips Gloeilampenfabrieken, N.V., of the Netherlands. Philips, together with Askar, a private Spanish concern, built Spain's first tv assembly plant in 1960, and now makes 35% of Spain's receivers.

Philips' chief competitor in Spain is the Philco Corp., working with Iberia, a local concern. The Philco operation accounts for about 15% of Spain's tv receivers. The biggest licensee of an American company is General Electric Espanola, an affiliate of the General Electric Co.

A 23-inch receiver costs $350 to $370 retail. About 300,000 sets are expected to be built this year, grossing $600,000 for their manufacturers. An annual 15% increase has been predicted for the next few years.

Great Britain

Sterling crisis

Suppose you're an electronics executive in Britain.

Your new government has been urging automation and other techniques to modernize industry. Now that same Labor government boosts banks' basic interest rate to 7%, the highest level in modern times, making it more expensive for your customers to buy new equipment.

Do you commit your firm to designing and manufacturing more equipment for domestic users?

Surcharge dilemma. Your government also has imposed a 15% surcharge on imports, designed to reduce the outflow of pounds sterling.

But this action has incited two strong reactions. Some European countries are considering retaliatory surcharges. And several American companies are planning to increase production at plants in Britain to avoid the surcharge.

At the end of November, the government announced that the surcharge would not apply to scientific research instruments. But there was no definitive list of instruments that would be exempted.

Your government also has granted tax credits averaging 1.5% on exports.

Decisions, decisions. Now, Mr.

Electronics Executive, how do you react to that set of facts?

Do you plan a stronger effort on the Continent—where money is cheaper but retaliatory surcharges are possible?

Do you concentrate on making scientific instruments for the domestic market, hoping the surcharge will be imposed on your foreign competitors?

If your business depends on imported equipment, do you plan to produce your own and save the surcharge?

These are some of the questions that British electronics executives must answer soon—questions involving availability of funds, attitudes of labor unions, and other factors.

Production problem. According to industry and government officials, the root of the sterling crisis is a production problem.

British industry, they say, isn't producing enough goods for domestic consumers and for customers abroad.

That's why imports in the first 10 months of this year soared 15.5% ahead of comparable 1963 period while exports rose 5.8%.

Automation would seem to be one answer. But the answer raises several new questions.

Electronic map maker

Now map making is going automatic.

The Clarendon Press plans to install a new electronic system this month. Clarendon is the cartographic department of the Oxford University Press.

The electronic map maker was developed by Clarendon and by Dobbie McInnes, Ltd., of Glasgow. It uses magnetic tapes and punched cards to produce all drawings and titles in maps.

Rand McNally & Co. is representing the equipment in the United States. Russell Voisin, Rand-McNally's vice president, cartography, estimates the system's cost at $300,000 to $400,000.

Four basic units. In conventional map making, all the data is compiled on a draft map that shows contours, coastlines, rivers and towns. This data is then redrawn accurately onto a series of plastic sheets. Place names are then preprinted and positioned, and the whole map is reproduced photographically. Scale changes or alterations in information require redrawing the map.

In the Dobbie McInnes system, four basic units make the process automatic. These units are a compilation reader, a tape-storage and editing desk, an automatic line maker and a name locator plotter.

The compiler reader abstracts data from the draft map and feeds it to the tape store. Data is extracted from the map by an operator using a stylus producing digitized X and Y coordinates for storage.

Sampling rate. The stylus position is sampled at a rate that depends on the type of line being traced. Information from the compilation unit is recorded for later identification or selection. The editor's control panel allows selection of the scale and the form of the line to be drawn. This allows a choice of thick, thin, broken, double or single lines.

Light-beam artist. The selected information is then drawn by an accurate plotting table that uses light beams from a moving projector, focused onto a photographic film. The beam diameter is controllable to generate lines 0.003 to 0.060 inch thick. Light intensity is controlled against the speed of the projector head so that the film receives constant exposure. For generating broken lines of constant length, the speed of a shutter is also linked to the projector's linear speed.

The last stage is the placing of the names and symbols on the film. These are added on a secondary plotting table. The place names are typed on a card. The location to which each name refers is automatically punched on the card at the compilation stage. The cards are then used with a phototypesetter to produce a reel of 70-millimeter film. Using the cards and film, the projector on the name plotter moves to the site for the name, then it projects the place name onto the map film.

The system handles maps up to 55 square inches.

Japan

NC turns the corner

Japan's machine-tool industry seems to have turned the corner of numerical control.

At the 1964 Japan International Machine Tool Fair that ended Nov. 20 in Tokyo, 24 NC machine tools were displayed, all by Japanese manufacturers. None were shown by exhibitors from other countries that participated—the United States, West Germany, Italy, the Soviet Union and others.

More than half of the Japanese NC tools were designed entirely for use with numerical control; they had no manual positioning devices.

Turning point. Foreign specialists compared the Tokyo fair with the 1960 machine-tool show in Chicago, which marked the turning point of numerical control in the United States. But the trade sources emphasized that Japan's tools and controls are more sophisticated than the American models of 1960.

For the first time in Japan, emphasis changed from complex contouring machines to the more simple and inexpensive positioning systems.

Last year Japan exported $11.93 million worth of machine tools. This year's exports are expected to total $16.67 million.

Importance of positioning. Fujitsu, Ltd., which dominates the numerical control field in Japan, says it expects to sell more positioning systems this year than contouring systems. It estimates 1964 sales at 31 positioning systems, exceeding the 25 total for the past five years. Next year it expects to sell 60 positioning systems.

Contouring controls, which previously comprised the major part of Fujitsu's NC business, are expected to increase more slowly. The company expects to sell 20 this year, compared with 42 in the past five years. It estimates next year's sales at 20 to 30 units.

At an average price of $28,000 for a contouring system and $7,500 for a positioning system, Fujitsu's numerical-control sales should cross the $1 million mark this year for the first time.

Dominant force. Fujitsu, a leading maker of communications equipment, has a strong patent hold on contouring controls. The company also supplies about 90% of the positioning controls now used in manufacturing, but says there are very few basic patents because the concepts of positioning control are simple.

It holds patents on the digital differential analyzer approach to contouring, in which the tool path approximates a tangent to the curve being cut. It also controls rights to an algebraic approach, in which the curve to be cut is approximated by short straight lines and segments of arcs.

Fujitsu's two big domestic competitors in numerical contouring control are Hitachi, Ltd., and the Mitsubishi Electric Corp.

Open-loop. All Fujitsu contouring systems operate on open-loop control. A pulse motor, patented in Japan and the United States, drives lead screws that control feed. Angular position of the motor shaft is directly proportional to the number of pulses fed to it; hence there's no need for feedback.

For positioning, Fujitsu makes open- and closed-loop systems. The open-loop units are based on the same pulse motors used in the contouring systems. Their use precludes any need for positioning motors, clutches or other power-train components.

The company's confidence in numerical control is shown by its use of four numerically controlled machine tools in its own plant to turn out mechanical parts for more NC systems.

Exports. The first Japanese NC machine tool exported to the United States was a Hitachi milling machine with a Fujitsu contour control, sold in 1962 to the Ace Gage Co. in Los Angeles. A similar machine was sold in Peking and another in Sweden in October.

France

Force de frappe

Any lingering doubts about President Charles de Gaulle's determination to create an independent nuclear force were dispelled late in November when the French government asked $11 billion for nuclear bombs and delivery systems by 1970.

Other military costs are included elsewhere in the budget request.

The National Assembly approved the program Nov. 27.

De Gaulle also has asked for $1.75 billion for military electronics in the five-year period.

Military electronics would rise to $225 million next year from $208 million in 1964. By 1970 the annual expenditure for military electronics would be $347 million.

More systems. In its official commentary on the proposal, the government says the electronics increase is due mainly to the development of more electronic systems. It also notes, however, the increasing complexity of the gear and the need for more specialized personnel.

The budget proposal kicked off a stormy debate in the assembly. Opponents argued that the nuclear force would slow France's industrial expansion and delay improvements in her standard of living.

President de Gaulle

Africa

Boxcar weigh-in

From South Africa comes further cause for alarm for railroad workers worried over the loss of jobs to machines.

At the Rooiwal power station, an electronic scale is weighing freight cars in 22 seconds. Previously an ordinary weighbridge was used to weigh the truck twice—first loaded, then emptied.

The new device is called an automatic tippler weighbridge. Here's how it works.

A train, filled with coal, chugs up to the siding and the engine is uncoupled. One at a time, the coal cars roll down a slight grade to the electronic scales.

Button pusher. In a control room, an operator pushes a button that starts a weighing cycle. A digital signal, representing the car's weight, is printed out on an Addox-X printer. Then the coal car is tipped on its side and emptied.

The car is righted and weighed again. The empty weight is printed out, as is the difference between the two weighings. This signal goes to an accumulator.

At the end of the day, the operator pushes another button and a computer calculates how much coal has been delivered to the Rooiwal generating station that day.

The scale can handle up to 200,000 pounds. The recording devices break this up into 50,000-pound increments.

Ahead of U. S. There are no similar systems in the United States, according to officials in the weighing field. The South African system was designed and built by W. & T. Avery, Ltd., of England.

The closest American counterpart is half electronic and half manual. Coal cars run down a section of track that is connected to strain gauges. The car's gross weight is recorded automatically. Then a man subtract the weight stenciled on the car's side, and writes down the difference.

Canadian method. Canadian National Railways has applied for patents on an electronic scale now being used in hump yards to weigh freight cars in motion.

The system uses load cells coupled to a small analog computer. As a car rolls over the scale, the load cells feed signals into the computer. The computer allows for the effects of vibration and computes the weight in digital form.

Norway

Coastal defense

Norway's 1,100-mile coastline presents enormous defense problems for a country whose width varies from 250 miles in the south to 4 miles in the frozen north. Numerous fjords increase the shorelength to 12,500 miles.

The North Atlantic Treaty Organization has spent $24 million installing a 12-station radar network for Norway, a NATO member. Each installation operates independently of the others.

Now Norway plans to connect these 12 separate stations with transmission and control links through a remote operating center. She has placed a $350,000 contract with the Silenia Telecommunications Division in Rome.

Remote center. The system will gather data from the 12 installations, combine it, scramble it and transmit it to a remote operating center. Here the signals will be unscrambled and presented to a separate display for each source station.

Error detection will be employed to prevent transmission of false control signals.

Here's how the system will work. Radar data will be transmitted with high- and low-baseband multiplexers. The high-baseband multiplexer will combine radar and identification-friend-or-foe data in a video-adding network, then combine the resultant signal with the trigger. It will use the composite video signal to amplitude-modulate a carrier frequency that is allocated in the high baseband.

The low-baseband multiplexer will convert synchro stator voltages from the antenna pedestal to phase-modulated signals of constant amplitude that are suitable for transmission on a single subcarrier. It will code the supervisory signals and will decode the signals received from the remote operating center. Remote center signals will be sent along existing telephone channels.

Two demultiplexers. The radar receiver will include high- and low-baseband demultiplexers. The high-baseband demultiplexer will select five subcarriers allocated at high-baseband frequencies. It will also detect each video signal and separate the video from the trigger.

Each subcarrier will be detected and fed to a video trigger separator. The high-baseband demultiplexer output will consist of one video signal and one trigger signal for each radar station.

The low-baseband demultiplexer will select the low-band subcarriers identifying each radar station, select the azimuth signal subcarrier, detect the various signals, recover azimuth signals and code and decode the remote alarm signals.

Correcting errors. Each radar station will be capable of transmitting 20 on-off indications to the remote center. Corresponding receivers will be installed at each remote station so that the entire system's status will be shown on monitors at the control station.

For higher reliability, the remote command equipment will include error-correction circuits.

The transmitter will scan the on-off status of 20 input circuits every 0.22 seconds and transmit the status of each in time sequence. The four basic circuits of the transmitter are the space-time converter, the programer, the signal-regenerating circuit and the telegraph channel.

The receiver will detect the signal, demultiplex it and feed the information to the output indicator circuit. The three basic circuits of the receiver are the telegraph channel, the programer and the time-space converter.

West Germany

Electronic traffic cops

Motorists usually think of radar as a foe; a police tool to help catch speeders. In Germany, where it's now helping to ease traffic congestion, radar is becoming less of a dirty word.

Hanging from a whip mast over a busy intersection in Hamburg, six antennas are measuring the number, speed and length of all vehicles passing by, with an accuracy said to exceed 97%.

The data is then sent via cable to a nearby analog computer, which selects one of six programs to determine how long the light should remain green in any direction. The computer chooses a program every five minutes.

Speed evaluated. The computer compares the flow in various traffic lanes and decides whether the traffic is moving too fast or too slow; then it selects a control program to adjust the flow.

The Hamburg device, powered by a klystron operating at 9.41 megacycles, is made by Telefunken AG in cooperation with Standard Elektrik Lorenz AG.

Enter Siemens. Electronics isn't a new weapon in Germany's war on traffic congestion. In 1954, some cities began using closed-circuit television to keep track of traffic patterns at busy intersections.

Last spring, Siemens & Halske AG, the country's biggest electronics company, put Germany's first commercial controller of traffic into use at another Hamburg intersection. This system counts cars by means of pneumatically operated contact strips in the roadbeds, then selects a control program electronically. The system is similar to several in the United States.

Now Siemens, too, is turning to all-electronic methods. At Neu-Ulm, in southern Germany, it has installed a radar setup similar to Telefunken's.

Articles, manufacturers and advertising are all cataloged in the 1964 Electronics Index

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